EXPERIMENT, SIMULATION – DESIGN TECHNIQUES AND EDUCATIONAL CHALLENGES

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Following the trends in the development of modern schools of architecture, it is difficult to resist the impression that they tend towards greatly expanding the range of issues to be considered. Creating our curricula we draw upon the environment: social, geographical, engineering and programming. We use the digital medium to acquire and process information. When organizing classes we follow effective solutions, of which we have knowledge owing to global networks.

When we were preparing a new MA program at the Faculty of Architecture of the Warsaw University of Technology titled Architecture for Society of Knowledge[1], we realized that among the classes devoted to design we need something open, a class devoted to intensifying methods of reasoning and developing tools to support creativity. Thus was born the concept of experimental projects – workshop courses based on the utilization of modern technology. The students work in teams, constructing prototypes and models of spatial solutions, which they then test. The objective is not to find clear-cut solutions but to gain knowledge through carefully planned experiments. Trying to achieve a teaching formula using the natural sciences, we wondered to what extent such a method could be trusted. Today, I will again begin with a question: does architecture know how to experiment? Is architecture like chemistry?

The ancients did not trust experimental sources of knowledge. The development of strict methods of reasoning, mainly logic and mathematics, opened the way to fascinating, previously unavailable tools of epistemology. Architects, who have a genetic tendency to idealize, fell in love with the structure of Platonic reasoning. Rather than an analytical description of perception/observation, they preferred to operate on models which were both a simplification and a synthesis. The discipline which provided the most universal models was geometry. As Plato wrote: "We will pursue astronomy as we pursue geometry, but we will leave things in heaven alone if we are to cultivate true astronomy"

Respect for geometry and for the two Platonic ideal forms, the line and circle, were transplanted to architecture by Vitruvius[2]. Everything that an architect deals with is shapes which can be drawn using a ruler and compasses. After adding the component of commensurate proportionality, Pythagorean harmony, he arrived at the definition of the canon – the basic instrument of classic architecture. Canons are still with us. We change their formula and ideological bases, still *believing* more in established forms than truly *testing* the perceptual consequences of their spatial actions.

The choice of representing techniques based on geometric models leads architecture towards idealism and arbitrariness. While from the same Platonic source comes Robert de Grosseteste's optics, which is in fact the prototype of descriptive geometry, an advanced geometry of the ruler and compass, considered the basic component of the Chartre school of knowledge. From Grosseteste is only a step to the work of Francis Bacon, which forms the foundation of the modern natural sciences. His *Novum Organum* with its praise of inductive reasoning and criticism of syllogism opens the way to empiricism. Thanks to Bacon we gained the basis for defining an experiment as a technique serving to eliminate the illusions of perception. To this should be added the conceptual apparatus and practical sense of John Locke, prescribing the use of observations to verify a complex theory to, finally, using Hume's ideas, to put in order the picture of cognition, taking into account both the theoretical elements (mathematics, logic) and the empirical (the natural and social sciences). Equipped with the tools to control the four channels of information (stimuli, feelings,

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[1] Architecture for Society of Knowledge [ASK]; English language MA at the Faculty of Architecture of the Warsaw University of Technology; the curriculum includes issues related to the development of the knowledge society, developing awareness of digital tools which make possible integration of knowledge and interdisciplinary cooperation, as well as formalization of theoretical inquiries.

[2] Witruwiusz, *O architekturze ksiąg dziesięć*, Warszawa 1956, p. 15.

memory, imagination), we are ready to build scientifically an image of the world.

The experiment, in terms of a methodology that can be transferred to architecture, means an ordered set of actions aiming at verifying a hypothesis. An experiment is always planned. Bacon writes that when experience comes *en passant* – it is solely chance, and only when we search for it can it be considered an experiment. An important consequence of this is that when experimenting we expect results the detailed analysis of which will bring knowledge. Galileo measured the time of free fall; Lavoisier measured the mass and volume of substances. Today, in aerodynamic tunnels we analyze airflow dynamics and from the radiation spectra of stars we draw conclusions about their chemical make-up. An effective experiment is only one whose course we fully control, or know the exact boundaries of. It is best if laboratory conditions allow us to limit the analysis to two variables of the process. One is adjusted in accordance with the plan of the experiment while the other is measured, allowing us to determine correlations and, if need be, to check the results in a series of repetitions. To formulate a definition of an experiment in empirical terms, we must use four criteria:

– cognitive goal (verification of hypothesis)
– intention and planning
– placing in a controlled situation (laboratory)
– effectiveness (the possibility of obtaining interpretable results)

Adding the term *experimental* facilitates interpreting unconventional architectural works. Whereas the definition of an experiment, at least in the context of modern methodological tradition, seems to be fairly clear, we succumb to the temptation of calling experimental every activity exceeding the threshold of perception or the abilities of the descriptive apparatus. First and foremost, utopias are referred to as experimental: ideal cities of the Renaissance, Boullée's monuments, the visions of Garnier, the constructivists, and Archigram, superstructures, transarchitecture and, of course, the worlds of virtual forms. We can easily stick the experimental label onto innovative designs, though they are implemented because the authors are convinced they are right and not because they needed to check anything by experimenting. Such were most of the works of modernism, structuralism, the heritage of HiTech and contemporary optimization trends.

Truly experimental architecture would have to create laboratories adapted to tests related to the building process, use, aging of buildings. People would have to participate in the tests, knowingly sentenced to experiencing borderline situations which would make it possible to ultimately decide about the usefulness of a given solution. That is why experimental architecture does not exist. Or, if it does, then only in a totalitarian system, with the cooperation of unethical architects. There exist only fragmentary experiments placed in an architectural context.

The fascinating buildings of the Munich Olympic complex arose owing to precisely prepared tests conducted by Frei Otto's team. It was not possible to determine the influence of wind on huge hanging structures using computational techniques so the team worked out a method of testing models in an aerodynamic tunnel. The detailed descriptions of materials used to build the models, procedures of flow loading, measuring reactions, averaging results and verifying data in series of trials still fascinate today.

The design for the kitchen in the "Marseille unit" was supported by ergonomic studies which Le Corbusier was already conducting in the period between the wars. But again, it is difficult to call them proper experiments. No one was forced to perform long-lasting repetitive actions. Mapping of technological movements was based on real situations but excluding disturbance variables – for instance through modularization. If we respect people's freedom and privacy, the architectural experiment must be restricted.

Always?

In order to free our experiment from ethical encumbrances which effectively restrain our freedom, we must replace real architecture with a representative copy. Structural models are an excellent example of this method. The model prepared by Brunelleschi for the Florentine council of the Opera del Duomo can hardly be called completely isomorphic. It was to illustrate the process of raising and static work of the two-layer shell wrongly called a dome. If a hypothesis needs checking at an early stage of creation, one can use a model which allows for a large degree of freedom to modify. Gaudi worked liked that when he created the never finished vault of the church in Santa Coloma de Cervello. Sandbags played the role of control variable and the web of strings formed the registered image of a lattice as a function of load and the degree of freedom of points.

A representative model reflects simultaneously many characteristics of the original. It guarantees not only adequacy of form and detail but can imitate interactive processes taking place in time, depending on external parameters. Such a model is hard to make from cardboard and plaster. A much more plastic material is needed – pure information is best. The digital model of a building seems to have crept into the architect's workshop incidentally. William Mitchell compares it to the unplanned and inevitable effect that popularization of CAD software had[3]. Initial improvements in drafting provided growing amounts of information. It was organized in data bases representing traditional technical documentation. When drawings acquired a third dimension, it turned out that database records correspond not only to abstract addresses. They could be assigned to a position in a three-axis coordinate system, in other words – to architectural locations. That is how the technique used to construct complex, multiform sets of information about a building, now known as BIM (Building Information Modeling), was born.

Architectural experiments using information models surpass all others because the digital medium provides the means of simulating processes with unprecedented fidelity. Numerical representation, modularity, automation, variability and the ability to transcode[4] are the main features distinguishing the new media. Owing to them, architectural experiments encompass the sphere of generative creation, simulation, optimization, telepresence – all this taking into account the interaction between human being/user and information model.

Although adaptation to the conditions in the natural environment may be considered a natural tendency of architecture, the process could never be strictly formalized. While complicated physical, geological or meteorological phenomena are difficult to model, it is even more difficult to determine the conditions for an experiment at the meeting point of architecture and the natural environment. This changes when we use much more efficient computational techniques and when we replace the traditional model with the digital one.

Today, digital simulation techniques serve to test solutions which end up at the construction site. Gaussian curve analysis allowed Frank Gehry to control the technical conditions when building the museum in Bilbao. An algorithm was prepared allowing the titanium cladding to be divided into panels of production format. The aesthetic decisions of the architect, expressed in the language of a digital model (CATIA), formed a set of input data. The result was a map of optimal, difficult and impossible situations (a greater curve means greater technological difficulties and higher costs). This was the basis on which the team introduced corrections of the external form and examined successive versions.

When Norman Foster designed the office building at 30 St Mary Axe, he used a digital laboratory which allowed him to do experiments in various areas. The controlled variables were the height of the building, projection parameters resulting from the limited space available and sufficient capacity to guarantee return on the investment. As the planned design was to utilize natural ventilation mechanisms, architectural-spatial solutions were generated and checked in terms of static, aerodynamic and aesthetic quality. The interactive process of designing and visualization made it possible to produce any number of trials – virtual models. As a result, a form was achieved that was not only aesthetically satisfactory but also tested in terms of the technical and economic effects.

In the world of real buildings, the ability to test prototypes and foresee consequences is a condition of success for the undertaking. Academic works, produced to improve technique and develop talent, rarely take into consideration all the realization conditions. Nevertheless, the experimental workshop supported by digital modeling play an important role in the process of shaping architecture. They teach the student proper evaluation of different solutions. Competencies which were hitherto reserved for architects with a large experience can now be, at least partly, built on the basis of simulated experience.

Research conducted at the Department of Computer-Aided Architectural Design includes simulations. Simple theoretical experiments are accompanied by experiments based on complex models of spatial sit-

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[3] W. Mitchell, *Antitectonics: The Poetics of Virtuality*, [in:] *The Virtual Dimension: Architecture, Representation and Crash Culture*, (ed.) J. Beckmann, New York 1998, p. 203.

[4] Typologia wg L. Manovich, *Język nowych mediów*, Warszawa 2006, p. 13.

uations. They add to the teaching process, including experimental design, i.e. designing by testing solutions. Modeling of spatial processes, an essential component of the architectural laboratory, needed appropriate tools. Initially, these were development environments of editors and pure programming languages, that is instruments with naturally limited universality and versatility of application. Freedom to construct test environments greatly increased when the CAD workstation expanded to include parametric modeling techniques using pseudocode. With software which made it possible to create decision diagrams expressed as geometric objects[5] architects acquired the possibility of building conditional models which, by introducing variables, various logical operators and feedback, relaxed the unambiguity of the design. The architectural model instead of being a one-time reproduction of a form became a definition of its possible variables.

The master's thesis prepared by Piotr Kuś shows how parametric modeling can be used to create a laboratory for architectural experiments which comply with test criteria. The aim of the project was rebuild the tenement house at 14 Waliców Street, designed by Wacław Heppen (Fig. 1). Devastated during the Warsaw Uprising, it has survived to the present day in fragments, with only the back building still standing. The author wanted to recreate the front building, not so much by imitating the original form as in a manner analogous to historical precedent. The laboratory situation was created by the digital representation of a sun knife. In different seasons of the year, much more precisely than demanded by building rules, the line of the ray of light cut out the shape of the building, introducing light to the courtyard of the tenement. Apart from the position of the sun, the external measurements of the building, its height, number of floors and the height of the floors were controlled in the laboratory. The target variable was the usable floor area in the front wing, the economic effect of the undertaking. As a result of optimation, the author obtained a complex, multi-curved surface which he then simplified using Gaussian analysis and triangulation, division into areas appropriate for covering with a curtain. The funnel shaped north wall of the well-like inner courtyard did not resemble the historic south wall, though the assumptions were similar. The contemporary façade, like the historic enclosure of the courtyard, tried to provide the interior maximum light while, at the same time, achieving sufficient capacity to be economically profitable. The result was achieved not by recessed windows, as in Berlin, but through a shape which was experimentally checked and unique to the location.

An architect's research perspective is closely connected with the prospect of construction. Irrespective of ideological assumptions, the building must ensure safety and comfortable use, which result from an optimally designed construction. When the static system becomes complicated, it is difficult to intuitively foresee the load of all elements. The accepted practice is for the architect and construction engineer to cooperate on periodically improving successive proposals. The architectural concept transformed into a static model, then subjected to computational treatment, tells us only about the possibilities of realization or lack thereof.

In his diploma work on shaping spatial structures, Marcin Brzeski, when creating a dynamic model tried to simplify the circulation of information. For this purpose he prepared a simulation tool which visualized the effects of his design activities. The research concerned a small connector which joined the main building of the Faculty of Architecture of the Warsaw University of technology with its rear building (Fig. 2). The tubular structure of rods forming a network of triangles was constructed using parametric image editing software. By moving the defining curves, it was possible to freely form the body of the connector, which underwent surface triangulation according to posed criteria[6]. Apart from external dimensions and definitions dividing into segments, the digital lab made it possible to adjust permanent and variable loads acting on the structure. The experiment measured the static effects of the connector working. The program, connected with editing software, on the basis of the displacement of the nodes analyzed the forces in the rods. The results came out as data sheets, continuously updating the values characterizing the various elements of the structure. To make the work of the

[5] Such as Grasshopper for Rhinoceros.

[6] The form of the network was kept within the boundaries of the definition designated by the maximum length of the rods, number of rods in a node and the permissible minimal angle of neighbouring rods.

architect who is looking for the optimal form even more intuitive, the program visualized the forces using a color code. Rods in optimal state turned green, overloaded – red, borderline – yellow. The program implemented all the functions reactively, in real time, so that the consequences of architectural decisions were monitored at the moment when they were made.

It is also worth noting that Anglo-Saxon empiricism, effecting an important breakthrough in the modeling of spatial forms, did not stop with the natural sciences. Already according to the Scottish philosopher David Hume, human relationships and the behavior of individuals were assigned to the sphere susceptible to empirical evidence. The ASKtheBOX Pavilion, built for one of the courses in experimental design, checks the usefulness of digital modeling methods for analyzing perception of the environment (Fig. 3). The organically shaped interior was designed in such a way as to evoke a feeling of detachment from the context. To shape the mechanism of interaction, the authors used feedback between the shadow cast by the user, his image transmitted to the computer and the sound generated, which, emitted in the interior, again reached the user. A picture of the laboratory situation could be legibly followed on the control screen of the pavilion. The shape of the matrix, degree of simplification of the shadow image and the algorithm generating the musical communication were the controlled variables of the process. The active spheres of the pavilion were regulated. By moving and changing the contours of the colored areas, it was possible to guide the reactions of the instalation. At the same time, by watching the behavior of users, it was possible to check which parametric configurations building the pavilion intensified its impact and which were not accepted (Fig. 4).

Architectural experiments realized using computers, in the information technology milieu sometimes raise concerns. We ask whether parameterization does not mean loss of control over the details of a design. William Mitchell was already suggesting the opposite scenario in the 1990s and stressing the opportunities resulting from the greater elasticity of the design tools available to architects. He wrote "digitally fabricated and electronically visualized versions are simply successive realizations of a single architectural work which has been defined by a set of drawings or a computer model – just like performances realized by successive interpreters on different instruments" [7].

Making use of the multi-version character of the new medium and computer technology, we now have the opportunity of experimenting in a discipline which, for a long time, lacked such possibilities. Obviously, this does not solve all problems of architectural design but it certainly brings us closer to the desired effect. When penetrating the deceptive territory of attractive roads of architectural creation, it is worth keeping to the rules whose ancestry reaches much further back than the method gained. The rectitude of the experimenter demands that we adopt the principles left to us by the great achievements of empiricism, as they are binding today both in the natural sciences and in the area of shaping space.

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[7] W. Mitchell, op. cit.