# INFORMATION IN ARCHITECTURE

## 1. INTRODUCTION

Design is a process of creation based on specific conditions and guidelines to solve a particular design problem. It often requires proposing a number of different variants and comparing them, in order to achieve the optimal form [5]. In case of architectural concepts, the design process is preceded by analyses of natural site conditions, requirements of the function, construction, implementation, financial and legal-normative aspects as well as aesthetic-compositional needs [16]. These conditions appear as parameters in the form of physical units (such as the site area or the height of the planned building) and numerical values as well as verbal descriptions. Based on this, a building program concept has been developed, the aim of which is to describe the design possibilities in the context of a particular investment [16]. The data, as a starting point, has a direct impact both on the final effect of the architect's work and on the overall design process.

Information is the knowledge transferred from the source to the recipient. Its nature is potential, which means that the recipient can react to the message or ignore it. Information is also relative, so it may have a different value for its individual recipients [15]. In modern architectural design, the vast number of guidelines and conditions makes it practically impossible to remember them by a single architect and, therefore, to use them all in the project [16]. Another issue is the detection of missing or incomplete information, and the exclusion of false or outdated data. Errors slow down the design process and may contribute to the decision about abandoning an established solution and returning to an earlier stage of design.

The aim of this paper is to draw attention to the form taken by information in architectural design and the consequences of changing the way the information flows thanks to the use of new technologies[1].

## 2. TECHNOLOGICAL PROGRESS AND ARCHITECTURE

Architecture as a profession has existed in the ancient times, but as time went by, form and the nature of the occupation has been changing. Despite that, the fixed elements that remained are the existence of an investor, a purpose and resources available to achieve the goal. Prior to the introduction of digital tools, the architectural design was made in paper form. Drawing and duplicating the project would take a long time, and each change in the project would require revisions on many pages, which additionally could lead to incompatibilities [17]. It was difficult to distribute the documentation to people who

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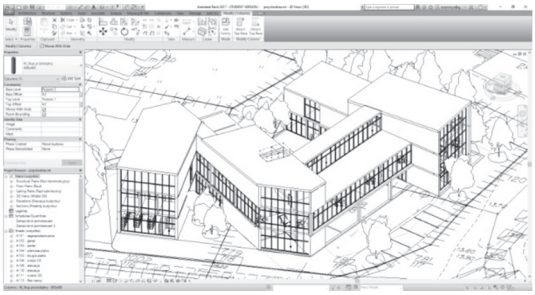

Fig. 1. Creating a model of a building In Autodesk Revit software (source: own study)

needed it at a given time. As time went by, more and more information available about the project became increasingly more difficult to comprehend.

The need to use a variety of design calculations is another fixed component in the architect's work. In the 18th and 19th century, architects were equipped with a device called pascaline, which was used to add and subtract numbers [8]. Mathematical tables also had been available by that time. The tables included the results of basic calculations. Since 1960s, computers have started to become a new tool in architect's work. As a result, mathematical models and algorithms were implemented into architecture in order to aid in the creation of building projects. Notable architects of beginning of computerization in Poland are Adam Szymski and Stanisław Latour, who described the concept of system design (Polish: projektowanie systemowe) in their works. System design focuses on the problem analysis and specification of the goal and design task [8].

In the 1960s, the first computer aided design (CAD) software was introduced, but only after thirty more years the number of software licenses sold has increased [17]. The introduction of 3D modeling has completely changed the process of architectural design. A totally different approach to creation has been introduced by BIM (Building Information Modeling) software (Fig. 1). Based on the virtual model of the building, all the data and properties of the individual components, as well as their placement and anticipated means of use, are included in the project. This facilitates cooperation between many designers and gives new opportunities for project presentation. BIM is also considered a creative process [17].

Thanks to computer-aided design, it has become possible to create architectural forms that are much more flexible than ever before [8]. CAD and BIM software have been equipped with the option to use the designer's own programming scripts, resulting in more unusual forms being created [17]. The presentation of the project has also changed. The documentation is currently usually available in digital format, and moreover, the information about future investments is often presented in the form of graphical boards and even animations. Scalable building models can be made quickly and precisely based on three-dimensional model files [6].



Technological progress was also reflected in the way the building was erected. With the development of industry, standard components have been introduced, with standardized sizes and dimensions reflected in modules [16]. Currently, once the exact virtual building model has been created, all dimensions and geometric coordinates can be passed directly to CAM (Computer-Aided Manufacturing) programs to produce individual components or – before that – to CAE (Computer-Aided Engineering) software to validate the model. In

addition to improving production, greater control over material consumption and therefore more economical administration is achieved [17].

Creation of an accurate building model also influences the construction process. Designated geometric coordinates can be passed to automated devices that calculate the placement of items or even place them in a specific location [7]. After the building has been put into operation, information about it is constantly being forwarded and analyzed. This is performed by FM (Facility Management) software that helps with coordinating and maintaining the building.

## 3. PARAMETRIC DESIGN

As mentioned above, architectural design meets many limitations. This information can become parameters shaping the body of the building [5]. By selecting the output data, for example, the placement of windows in an object or the size of a facade, and using an appropriate algorithm (Fig. 2), a new shape of the building can be generated. Furthermore it can be easily modified and changed with adjustments to other building elements or external conditions. Elements of the facade of the building are proportions, divisions, holes, carving, accent placement and color [16]. By representing these data parametrically, one can easily modify them separately or make one dependent on another. Parametric architecture features round forms and coatings, as they allow for more efficient constructions and avoiding material losses. It also lets the architect create multiple versions of the form in order to acquire the most effective and desired structure [14].

An unquestionable advantage of creating projects using algorithms is their geometric order [5]. Owing to parametric architecture it is possible to divide irregular curvilinear surfaces into elements that are easy to manufacture and use on site [5]. A great benefit of choosing parametric design is the wide scope of optimization for acoustical, thermal, lighting, etc. conditions, without having to re-draw the design or to make changes to many of its components [5]. The process of reaching the optimal shape of a building becomes more important than its final form [9].

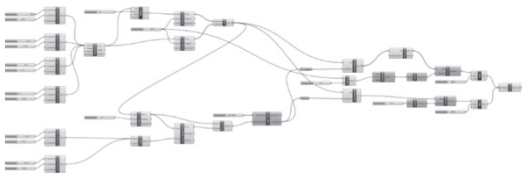

Fig. 2. A simple algorithm created by the visual programming method in the Grasshopper extension for the Rhinoceros 3D modeling software. By using ready-made components, combined in a specific way, the program generates a volume with a form defined by the designer (source: own study)

Thanks to the ability to quickly generate multiple versions of a building model, it is necessary to define a method of selecting the final option. Parametric design involves high risk. Improperly selected input may lead to the creation of a non-functional building or an object impossible to erect. Uncertainty is expressed by, among others, UNStudio architects, who emphasize the importance of the pre-planning process and the preparation of methods of checking that the project meets all specified requirements [10].

Parametric architecture often uses generative systems. One of them is the voronoi diagram, which divides the surface into areas in a specific way. Another is the L-System, imitating the process of organism development using strings, object sequences and cellular automata, creating a variety of geometric patterns [9]. Oblique forms, which are characteristic for parametric architecture, can also be simplified. Curved surfaces are much more difficult and more expensive to manufacture than flat ones, so tessellation is used to convert a curved mold into a mosaic or flat mesh [6].

Algorithmically-generated architecture has its name – Parametricism. It was coined by Patrick Schumacher, the chief architect of Zaha Hadid Architects and architectural theorist. Later, however, he distinguished Parametricism 2.0, describing architecture focusing on social and ecological issues.

## 4. EVOLUTIONARY ARCHITECTURE

Although, in past epochs architecture has repeatedly tried to reference nature in form, nowadays this association is made by using other methods. Decorative elements and the visual expression in finishes and details that imitate shapes of plants or animals are approaches have been used by architects since the ancient times. Today, thanks to the use of new technologies, it is possible to simulate the evolutionary processes characteristic to the natural world [10].

With the introduction of a computer, it became possible to create virtual objects changing in time. This requires programming a simulation of the development of a virtual organism that the building design in a way becomes. This process, in contrast to the evolution in nature, requires much less time, which is directly dependent on the computer performance. Individual versions of each model can mutate. It is important, however, to create an appropriate method for selecting features of the generated model. In this situation, it is not the architect who chooses the final version of the building but the selection is made by the algorithm that he or she created. Such architecture can become more natural and less subjective [10]. Nevertheless, algorithm-generated architecture does not always meet the aesthetic requirements as those cannot be expressed in the program as parameters. For this reason, the shape of the building should not be chosen based on construction effectiveness or economically efficiecy, but rather based on architectural qualities [5].

Lidia Klein, a Polish art historian specializing in contemporary architecture, devoted to this subject her PhD thesis "Living Architectures. Biological Analogies in Architecture of the End of the 20th Century" (pl. "Żywe architektury. Analogia biologiczna w architekturze końca XX wieku"), published in 2014 by the Fundacja Kultura Miejska (ang. Municipal Culture Foundation). In that thesis there can be found numerous references to works of architects such as John Frazer, Dennis Dollens or Greg Lynn (Fig. 3). The last one of those creators focuses on folding in architecture and animation. He sees the link between curved architectural elements and the development of CAD tools that have enabled the use of higher mathematical algorithms. Computer-based design is not, therefore, merely a digitalization of paper-based architectural processes, but it begins to rely on the careful data entry that starts the process of model generation [10]. The created building thus becomes "materialized information," and is the result of input

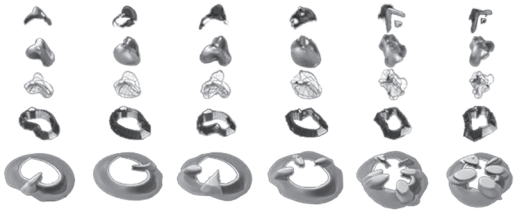

Fig. 3. Embryological House, Greg Lynn – a computer-generated geometry, based on control points that change location, which allows to create almost an unlimited number of versions in the form of animation (source: http://glform.com)

parameters. This information becomes the genetic code of the building [10]. Around the information a living architecture springs out, based on changes in parameters, including those that take place over time.

## 5. INTELLIGENT BUILDINGS

In the 1970s, newly built objects started to be equipped with various automation and telecommunication solutions. In the next decade, the concept of an intelligent building, that is, a building which responds to the needs of users or regulates the cost of living in a premeditated way, was established. Intelligent buildings may include modern installations and mechanical devices and a building management system [2]. Thanks to the monitoring of building conditions (sensors), it has become possible to automatically control the heating, air conditioning and ventilation systems. The installation of intelligent systems also has a huge impact on building safety and evacuation conditions.

Smart buildings design is also associated with the modern concept of sustainable development, expressed in the reduction of energy consumption and better resource management [13]. For this purpose, data on energy consumption are collected and processed to provide users with analyses and comparisons between particular periods. Intelligent buildings can also become elements of intelligent energy management grids and transfer resources between individual units depending on the demand [12]. Considering the amount of energy consumed by buildings in the world, the introduction of intelligent technologies can contribute to significant changes in global energy consumption [12]. Because of the use of renewable energy sources, it is important to manage them appropriately according to the difference in consumption between peak hours and the rest of the day. Intelligent systems can reduce these differences by adjusting the indoor conditions of the building [12].

Architecture can change, respond to the environment or its users and it can stimulate them to act or learn. Such object ceases to be static or placed in a particular form, and begins to communicate and react.

## 6. NEW MATERIALS AND INFORMATION

Advanced technologies require careful selection of the right materials. The choice of material solutions should take place during the creation of a virtual building model. Due to the constant technological advancement in materials, it is impossible for a single architect to fully understand all of its aspects - there is an exchange of information between the professionals representing the manufacturers of individual materials and the designers of the building [16]. Individual materials have known parameters that can also be taken into account during design process. In addition to the physical and chemical properties, there is also

the structure of the material [9]. That knowledge makes it possible to simulate the effects of the exposure of the building to atmospheric factors, loads and time.

An example of contemporary technology is cold bent glass used for curved glazed surfaces. Its shape depends on the frame, without which its surface would be completely flat [3]. The shape of the curvature of the glass surface is formed by a properly designed frame or mounting points. Cold bent glass was applied in a project of a vault above one of the platforms in the 's-Hertogenbosch railway station in the Netherlands. This example demonstrates that using a smaller film thickness in comparison with the case with hot bent glass appeared to be an appropriate and economical solution [4].

Currently, composite materials are widely used in architecture. Advanced composite materials are composite materials that have been manufactured using nanotechnology to achieve much greater strength and smaller weight [3]. An example of the use of composite materials is Cocoon_FS Pavilion designed by Pohl Architekten in 2010 (Fig. 4). The body of the building consists of a cocooned shell, created on the basis of a Voronoi diagram made of thin-fiber-reinforced polymer panels.

Polymeric films are used in coatings and cushions of building facades, thanks to their high strength combined with lightness. ETFE cushions can be seen on the facade of the Media-ICT building, designed by Cloud-9 architects in Barcelona in 2007. To improve the performance of the building, the cushions are being filled with air depending on the sun. Each of them is controlled individually by devices that measure the temperature and humidity inside the building [3]. This transfer of information occurs between building elements without the active participation of its users.

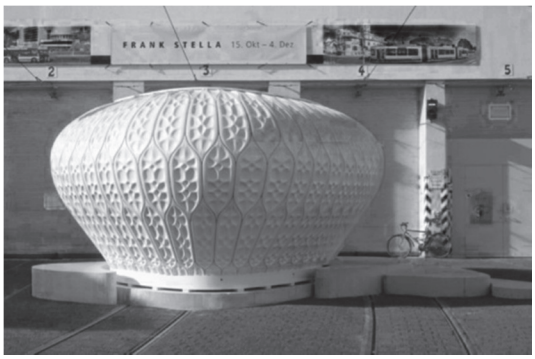

Fig. 4. Cocoon_FS Pavilion (source: photo by Lidija Grozdanic / http://www.evolo.us)

Apart from new materials, the manufacturing process has also changed. Nowadays, 3D printing, also known as spatial printing, is gaining popularity. It allows an architect to achieve much more freedom in the form of a designed building. Initially, 3D printers were limited in size, reducing the elements they produced to pieces intended for later assembly. Currently the size of printed items is only constrained by the budget. Also, the range of materials used for 3D printing has grown from plastics to a variety of blends. Elements created in this way are characterized by greater freedom, so that the erected building can feature a completely new aesthetic form. The future of 3D printing is not only related to enlargement in scale, but also to the development of nanoscale micro-structures [18].

## 7. NEW FUNCTIONS OF ARCHITECTURE

When erecting a building, information is passed between not only construction workers but also through devices which can relieve the workers from the hardest jobs or replace them at more complex tasks. Thanks to appropriately designed robots, it is possible, for example, to accurately place elements (eg bricks) in a specific way, which can be impossible to achieve by a human. Examples include The Programmed Wall project by Fabio Gramazio and Matthias Kohler, professors at the Zurich Institute of Technology. Using a prepared script, the bricks were placed in the right places, with the right offset and twist to create a smooth transition in shape. In this way a unique artistic expression has been achieved.

What is noteworthy is the change in the purpose of architectural design. More and more frequently designed buildings do not leave the memory of a computer. This is not because of their too complicated form, difficulty or inefficiency, but because of new methods of project presentation. Building models are created for research or visionary purposes. Examples of unrealized designs are Frazer and Lynn's projects, which, despite their only existing in the virtual space, have influenced the development of contemporary architecture [10].

There are also non-architecture-related branches of culture, such as the computer games industry. Developing virtual reality in the virtual space requires placing precise and precisely executed architectural elements there.

## 8. CONTEMPORARY CHALLENGES OF ARCHITECTURE

An aspect that cannot be overlooked is how to use the building appearance to suggest the purpose of the object. A fine example is the building of The Netherlands Institute for Sound and Vision in Hilversum. Designed in 2006 by Neutelings Riedijk Architects, the object features with all its four façades that it is occupied by museum and magazine for the cultural heritage of the Netherlands. The building is in the shape of an ideal cube with its sides 50 meters long and is located in part underground. It has a lightweight steel construction filled with multicolored glass panels. On their surface were recreated selected famous stills from Dutch television. The panels are not fully translucent, so that one can see what is happening inside the building through façades [3]. The information on the elements of the façade is mixed with the current life inside the building.

Due to social changes and technological progress, buildings often change their function. This involves very high costs. Also while the building is performing one function, it can be frequently modified by its users. Thanks to the use of appropriate algorithms, it is possible to analyze and customize the building according to such changes [1].

Nowadays, it is also possible to model the behavior of a future building's users. Crowd simulation can influence the optimization of the flow of people in designed building and can therefore affect the required communication space [14]. Up until now, the intended user of the building has been represented by a numeric information value, static in time. Nowadays, with scripts that give virtual users a variety of behavior patterns, it has become possible to predict which building spaces will be more frequented. It may be necessary to inform the future users of the building how to use its facilities. Such message may be included the

manual of a building, presented in various ways, integral to the architecture. Information provided to the user of the building is its function and arrangement of the rooms.

Three levels of communication can be distinguished: 1) basic information provided by selected graphical signs, schemes and short slogans, addressed to the people passing by; 2) further data, intended for interested passersby, displayed on information marks placed in niches; 3) precise information for people related to the subject, also available in digital form on the internet [11].

## 9. CONCLUSIONS

Modern technologies can relieve the architect in designing and significantly improve the whole process of creating a building. Nevertheless, together with its development, a few doubts can arise. One of which is whether or not the architect's role can be reduced in architectural design by using a computer, and in particular in algorithmically-generated designs. The designer, formerly used to shape the form of the building as a whole, took over a function of a controller of the processes taking place in a virtual reality [9]. Moreover, the appearance of CAD and BIM software made the design process more accessible. The role of the architect changes along with the progress in technological development, although he or she is still the key figure in architectural development. John Frazer wrote that if we replace the drawing with writing on a computer, we will not achieve anything [14].

Another problem is the development of artificial intelligence and learning systems. Is a computer able to generate the most efficient architectural solution? This is currently impossible due to the problem of selecting a small enough number of parameters and of finding the criteria for selecting the final version of the model. Optimization also involves very complex computational processes. Finding the largest possible building area and the largest possible biologically active area at the same time requires a decision about which is more important. Even though artificial intelligence may in the future take over many professions currently performed by human, in the case of architecture this can be greatly hampered.

Computer aid, however, has widely influenced the form and aesthetics of buildings, allowed to exclude many errors and contributed to the reduction of materials usage. Thanks to modern software and architects' own scripts, computer becomes a tool that does not limit but expand the creative freedom of the designer.

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## INFORMATION IN ARCHITECTURE

**SUMMARY:** Architecture has always been created as a result of the connection of the between vision of the architect, the investor's guidelines and external conditions - the possibilities of the site and legal regulations. That information has evolved over time from unwritten agreements to specific parameters, often defined by physical quantities or numerical units. A building design can be created in the form of a virtual model, based on information about individual elements. The architecture generated by algorithms is growing more and more rapidly, which allows designers to simulate multiple versions in order to select the most effective one. The use of appropriate software has introduced new possibilities for the architect, while influencing the whole creative process. The effects of this design are reflected in the new forms of information about the future building – not only a digital recording of drawings, but first above all, a much more applicable model. With these changes, computer-aided architecture offers a whole new artistic expression.

**Key words:** CAD, BIM, parametric architecture, new material