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DIGITAL BUILDING MODEL - TOWARD AN IMPROVED TYPOLOGY

Abstract: Computer supported design still brings confusion among AEC practitioners. Most consider the computer as an addition to the traditional design process, a tool that facilitates the work. The paper demonstrates that computer is an inseparable part of the digital design process and that it is necessary to know the types of digital models that are at the core of computer AEC applications. The paper gives an overview of model types and their roles in the digital design process.

Key words: representation, digital model, design, BIM, parametric design

DIGITALNI MODEL GRAĐEVINE – PREMA POBOLJŠANOJ TIPOLOGIJI

Rezime: Računarski podržano projektovanje i dalje unosi konfuziju u građevinskim profesijama. Većina posmatra računar kao dodatak tradicionalnom procesu dizajna, alat koji olakšava rad. Rad pokazuje da je računar nerazdvojni deo procesa digitalnog projektovanja i da je neophodno poznavati tipove digitalnih modela koji su u osnovi računarskih AEC aplikacija. Rad daje pregled tipova modela i njihovih uloga u procesu digitalnog projektovanja.

Ključne reči: reprezentacija, digitalni model, projektovanje, BIM, parametarski dizajn

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1. THE ROLE OF REPRESENTATION AND MODEL

Designing is a fundamental human activity that represents a continuation of the deep-rooted tradition that people base their survival on the change of the environment. Unlike other living beings who adapts to changes constantly taking place in the surrounding environment, man has always opposed change. At the very beginning of its existence, man used finished objects of nature to reduce impact of the environment by, for example, using the cave as an object that allows a person to not depend on changing climate conditions. Later, with the development of skills, man began to create different entities - artifacts, which allowed him to be less dependent on ubiquitous changes. In the beginning, artifacts were physical objects that had some specific use value. Over time man has developed the ability to think and create abstract artifacts such as speech and writing that allowed him to even less depend on changes in his environment. Further human history shows a constant trend towards the development of new and more complex systems, such as social organization, mathematics, science, economics, etc.

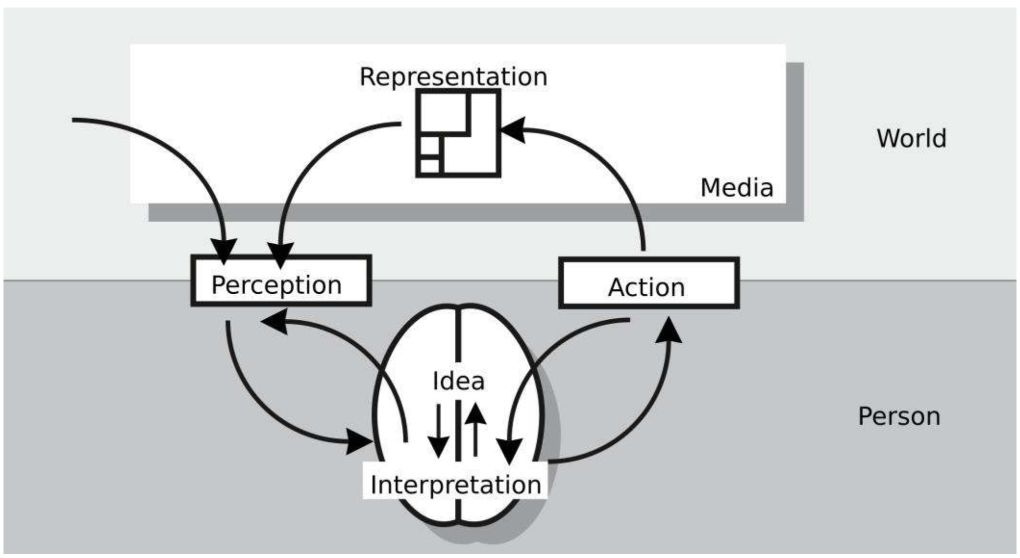

Figure 1 – The role of representation in design process

The creation of representation is the characteristic of the whole thinking [1]. Humans have a rich representational capacity. During their history people developed many artificial aids to thinking such as notation, language, models and formal systems. These 'cognitive tools' [2] or 'cognitive artifacts' [3] act both as sensory cues, and communication mediums. Human need for external structures as guides in thinking can be the consequence of the intrinsic limitation in the number of information chunks that the human mind can process in parallel [4]. Thus, external representations are artificial additions to the thinking process that overcome the limitations of our brain. Because thinking process is based on the ability to use external structures we abandon the dualistic distinction between mind and real world and treat thinking as a single process of the mind/world interaction. We can trace the evolution of this process from the perception through social interaction and participation in culture [5]. Thinking does not happen just in the person's mind, but is interactive process oriented toward representations embodied in linguistic, discursive, or expressive media. The process has a cyclical structure. The person realizes his or her ideas in some representational medium. The application of formal processes (proof, derivation, calculation, etc.) on representations yields consequences of these proposals. The consequences are also expressed in some representation. These new representations trigger concepts in the mind generating new ideas that can be further expressed using some external structure (Figure 1). Representations are a natural and irreplaceable part of the thinking process. They enable us to examine, before the action is carried out in the real world, possible alternative directions of action in virtual world, in order to avoid the potentially dangerous consequences of our actions, or, as Karl Popper [6] formulated nicely, allow our wrong ideas to die for us. The medium that is used to embody representations determines thinking style.

The connection between the creation of the external representations and the understanding of the design situation has been recognized by design practitioners and theorists. Michael Graves [7] describes design as a process in which thought guides the creation of drawings, and drawing guides thought. In his work Donald Schön [8] defines design as the interaction between designer and design situation in which the designer responds to demands and possibilities derived from the design situation that he or she created. External representations of the design situation play a crucial role in that process, enabling the designer to perceive and consider current design situation, to modify design, and to comprehend consequences of the design action.

We can identify two classes of representation: analogical and symbolic [9]. The representation in which there is some significant similarity (interpretative mapping or some isomorphism) between structure of the representation and the thing that is represented belongs to a class of the analogical representations [10]. Representations, like sketches, diagrams, 2D drawings, and 3D models, that architectural designers traditionally exploit to produce expressions of their ideas, are examples of the analogical representations. Recently, the advent of computer technologies in architectural design prompted architects to use symbolic representations to depict objects they are designing. Symbolic representation can be defined as the abstract pattern that by agreement stands for some other thing. This other thing can be some real-world object or event, some abstract concept or idea, or some other symbolic representation.

An important aspect of the symbolic representation is its ability to be combined and manipulated to make more complex, molecular, structures [11]. This enables us to create symbolic models to describe and explain phenomena. Model is a system composed of elements and their relationships, a simplified representation of an imagined reality that enable predictions to be developed and tested. The development of computer technologies has enabled the creation of numerous models which constitute the core of computer applications that are applied in AEC design.

2. TYPOLOGY OF DIGITAL BUILDING MODELS

Most architects still look at the computer as a tool that allows them to create complex geometric shapes and precise design of project documentation, but they do not want to enter into details of computer functioning. However, there is no computer program that solves all design problems. It is necessary to know the functioning of the program, and in order to achieve this, it is necessary to know the computer model that is at the base of the application.

2.1. 3D models

The construction of the geometric model of the building is traditionally at the center of the architectural design process. Because of this, 3D computer models are at the core of all AEC applications. By their nature, these models are divided into surface and solid models [12]. The first models the body by defining the surfaces (flat or curved) that surrounds it. Surfaces can be defined either as polygons defined by the spatial coordinates of its vertices or as the mathematical functions that defines surface (e.g. cylinder, sphere, Bezier surface, B-spline surface, NURBS). The solid models represent an object as a collection of geometric elements that are defined by mathematical equations which define the volume of the body. Elements of the model are either basic geometric primitives (cube, sphere, etc.) or objects derived by processes like extrusion, sweep, etc. Each element can be modified using processes like extruding, bending, etc. Elements are combined into complex objects using Boolean operations of union, difference, and intersection. The process of creating a primitive, changing it and linking it into complex forms can be displayed as a tree structure in which the nodes are geometric elements and branches represent operations performed on them. This formalism is known as Constructive Solid Geometry (CSG) and represents the most commonly used model in commercial applications.

2.2. Parametric models

Instead of using explicit values for defining a geometric body, parametric models are based on variable parameter values. Parametric models can be categorized into two kinds: Parametric Variations (PV) and Parametric Combinations (PC) models [13]. The first one enables the designer to create variety of geometrical objects by manipulating parameters that define single parametric scheme instead of using traditional modeling techniques described in previous section. The second model defines as parameters relations among objects enabling the designer to create and modify complex structures without the need to adapt the model to each change because every change to a model is automatically propagated through a chain of dependencies of the parameters enabling all model elements to adapt to the new change.

Parametric models are currently in the focus of the designers' interest either as a way to generate objects of complex geometric shapes or as the part of the Building Information Modeling (BIM) technology. In the first case, parametric design is still largely limited to the creation of 3D geometry [14]. The rules relate to the geometry of the elements and their mutual geometric relations in order to create a 3D model and belong to the class of the PV models. The particularity of this type of model is the fact that the designer does not model directly the form of the object, as in traditional 3D modelers, but program the system in which she/he defines the parameters and relations. When a system is defined, the designer can make changes to the parameter values, thus creating new forms, or letting the computer to vary the parameters and thus to generate alternative solutions. As Rivka Oxman [14] formulates: “The designer ‘designs’ the code of the parametric schema in order to design the design object.” Specific software applications are used for defining like Grasshopper, Dynamo, GenerativeComponents, etc. The fact that design actions in this type of model do not relate to the visual representation of the object but to the changes in the code leads to a new way of design thinking, the so-called parametric design thinking [14]. Although it looks as a completely new approach to architectural design, it should be kept in mind that all applications for the parametric design are based on commercially available 3D modeling systems (Grasshopper - Rhino, Dynamo - Revit, GenerativeComponents – MicroStation) that generates traditional 3D models or BIM models.

BIM model is specifically developed for the needs of AEC design. Functioning of these applications is based on the use of libraries of parametric models of elements that make up the building. In this way, the designer can quickly and easily generate the model of any building component by changing its parameters and combine them to create a model of the whole building. To facilitate the combination of elements in the whole, parametric BIM model contains information about construction elements and rules of their combinations. Depending on the particular BIM application, it is possible to achieve in greater or lesser extent the process of automatic propagation of the change in the model.

2.3. Analytical models

As stated earlier, the use value of each model lies in the fact that it allows the object to be analyzed before its implementation and the creation of new knowledge about the designed object based on the analysis. The fact that the model is a simplified representation of reality is especially evident in computer models for analysis. Calculations necessary to achieve any analysis of the building require a lot of computing resources, so that even with today's level of computer technology, these models must be maximally reduced.

Many designers consider that when they create a complex geometric model of a building or a BIM model in which they also give information about the building elements have all that is necessary for simulating the behavior of the building. However, simplified models often require completely different information. For example, surface 3D model contains only information about objects exterior, but structural analysis requires object axes. Also, the thermal efficiency analysis requires information on room volumes, while the traditional approach to create a 3D building model or a BIM model is by constructing wall and ceiling models and other closing elements. It can be concluded that digital building models, in addition to facilitating particular operations during design, also pose greater responsibility for the designer to know all types of models in order to achieve a successful design process.

2.4. Interoperability models

The existence of a large number of different types of a digital building model poses a problem of data exchange between them. If we take as an example only the simplest 3D model of the curved surface, it can be both modeled as a polygon mesh and as NURBS. In the first case, the surface information is accurate only in the polygon vertices, while in the second case it is precise in all points of the modeled surface. Also in the first case, the model is represented by the coordinates of the points in the space and the definition of surfaces through the list of vertices on its periphery, while in the second case it is defined by control points and a set of mathematical equations. Transferring data from one model to another requires a specific algorithm.

In the case of the digital building model, a very complex data model has been developed - IFC [15] as a vendor independent international standard format for data exchange in AEC industry. It is necessary to understand that the IFC represents an additional digital model of the building, not just a data exchange format. To transfer the model through the IFC format from one application to another, it is necessary first to translate the native model of the first application into the IFC model, and then the IFC model is interpreted by the second application and translated into its native format [16]. From this it can be concluded that interoperability models do not bring simplicity to the digital design process but also require additional knowledge of this type of model to achieve a successful design process.

2.5. Paradigmatic classes of models

Although the various types of digital models that are at the core of computer applications that are used in the AEC industry constantly bring designers in confusion, there are rare attempts to clarify this area. Oxman [17] identifies four paradigmatic classes of digital models: CAD, formation, generation, and performance. The first one relates to descriptive models where the designer directly creates the model and all automation is performed after that. Formation models relate to systems that support algorithms or parameterization as the method of model creation. Generation models imply the existence of a predefined generative processes that guides and controls model creation. Performance models rely on formation and generation processes, but include performance estimation (structural analysis, thermal efficiency analysis, etc.) that drives whole process.

Although it provides insight into the problem of model typology, this classification omits an important aspect of the model, the ability to predict future building behavior. Design instances enables designers to analyze models regarding their performance, aesthetic, and compliance [13]. The described classification of the models supports traditional mind-world dualism where the designer is in possession of some divine knowledge and uses media to express her/his intentions. However, as we have shown in this paper, the computer is not only a tool for expressing architectural intentions but an inseparable part of the digital design process.

3. CONCLUSION

Currently, architects have a divided relationship with computer technologies, from euphoric acceptance without reserve and praise as means of radical break with tradition [18] to reservations and returns to traditional techniques [19]. However, while designers can not find a common attitude towards computer technologies, they will be further developed. In addition, this advance tends to accelerate and designers increasingly lose contact with their profession as new developments arrive. Today, we are witnessing the development of fabrication technology, where physical objects are produced directly on the basis of the computer code, and where there are no computer models similar to those shown in this paper. If architects do not pay attention to the processes and models found at the core of computer technology for AEC design, these technologies will continue its development independently of AEC professions and designers will have to adjust their work to technologies instead of being those who inspire technology development.

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