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UNIVERSITY OF NOVI SAD
FACULTY OF TECHNICAL SCIENCES
DEPARTMENT OF CIVIL ENGINEERING
AND GEODESY
DEPARTMENT OF ARCHITECTURE AND URBAN
PLANNING
IN COOPERATION WITH
ASSOCIATION OF STRUCTURAL ENGINEERS OF
SERBIA

13 iNDiS 2015

PLANNING, DESIGN, CONSTRUCTION AND RENEWAL IN THE CIVIL ENGINEERING

International Scientific Conference

PROCEEDINGS
Novi Sad, Serbia 25 - 27 November 2015

EDITORS
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TOWARD MODEL INFORMED ENERGY EFFICIENCY DESIGN

Abstract: Lately, a merger of the BIM and energy simulation software was seen as the solution for the energy efficiency design. The idea was based on the assumption that BIM software can produce general building model that can provide all necessary information for the energy simulation software. Unfortunately, the current level of technology development does not support streamlined energy efficiency design process. The paper discusses main obstacles in the current technology that postpone their application in everyday design process, and concludes with the proposal for further research and software development toward computer assisted design process where information model plays central role and enables designer to better understand energy requirements of the building.

Key words: BIM, energy simulation, energy efficiency design, information model

PREMA ENERGETSKI EFIKASNOM PROJEKTOVANJU ZASNOVANOM NA MODELU

Rezime: U poslednje vreme BIM i softver za energetsku simulaciju su viđeni kao rešenje za energetski efikasno projektovanje. Ideja je bazirana na pretpostavci da BIM softver proizvodi opšti model građevine koji pruža sve neophodne informacije programima za energetsku simulaciju. Na žalost, trenutni razvoj tehnologija ne omogućava kontinualni proces energetski efikasnog projektovanja. Rad razmatra glavne prepreke u postojećoj tehnologiji koje usporavaju njihovu primenu u svakodnevnom projektovanju i daje predlog za dalje istraživanje i razvoj softvera prema računarski podržanom projektovanju gde informacioni model igra centralnu ulogu i omogućava projektantu da bolje razume energetske zahteve građevine.

Ključne reči: BIM, energetska simulacija, energetski efikasno projektovanje, informacioni model

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1. INTRODUCTION

Most today programs for building energy consumption simulation appeared in the late 1970s, and were refined during 1980s. With the expansion of PC computers in 1990s these applications became available to wider audience. At that time, their widespread adoption in everyday practice was suppressed because applications required 3D computer models of the building. However, architectural practice was based on paper documentation, and 2D drafting programs where considered as the state of the art technologies. Lately, with the advent of the Building Information Modeling (BIM) technology that enables creation of the building models composed from components that mimic real physical building elements, containing not only 3D geometrical information, but also information about materials, their properties, and rules describing constraints and relations among objects, the merger of BIM with existing energy consumption simulation programs was seen as the solution for the energy efficiency design.

The paper discusses three main obstacles in the current technology that prevent seamless integration of technologies: 1) current BIM applications do not construct general building model, instead each application uses different modeling concepts making their models incompatible, 2) interoperability formats like IFC and gbXML provides just data structures for information interchange between applications, but do not prescribe which information is necessary for each particular energy simulation application, and 3) the information flows in one direction from BIM applications toward energy simulation applications. The paper concludes with the proposal for further research and software development toward computer assisted design process where information model plays central role and enables designer to better understand energy requirements of the building she/he designs, and to develop more efficient solutions.

2. BUILDING MODEL

At first glance, the BIM applications like ArchiCAD and Revit exhibit similar functionality. The user chooses among different building components (like wall, ceiling, roof, window, door, plumbing, etc.), then in appropriate dialog box specifies values of the parameters to define specific building component that is part of her/his design. When all necessary parameters are defined, the designer chooses location of the component in the building model. Finally, the application launches its core mechanism and updates the model according to defined parameters and inherent composition rules.

It comes as no surprise that each BIM application applies specific core mechanism. But in BIM this difference is fundamental and impacts on the way the technology is applied in the actual design practice. In the paper we are discussing differences among two BIM applications that are most prevalent in the Serbian market – ArchiCAD and Revit.

Starting with building components, the designer will quickly recognize that both applications does not share the same basic set of components. Also same components in different applications exhibit diverse composition behavior. Soon, the designer will discover that she/he can download from the internet missing or enhanced components, that each application requires different file format, and that if the component is not available for your application there is no general substitution.

This brings us to the core mechanisms that ArchiCAD and Revit use to construct their models.

The ArchiCAD uses Geometry Description Language (GDL) to describe all application components. It is a BASIC like programming language that defines parameters, object geometry, user interface display, behavior, and other necessary information. The language is flexible and enables definition of any geometry, inclusion of custom parameters, and even creation of custom user interface. The designer's experience when using ArchiCAD resembles virtual construction or mock-up making. The designer first shapes building component that she/he is going to include in model by defining appropriate parameters. While doing, she/he can constantly monitor parameter's effect on component by watching 3D preview. After the component is located, the system applies rules and includes component in the model. If the component does not fit appropriately in the model, the designer can make further modifications to achieve perfect fit. Some real building logic is included in the system, for example windows and doors become part of the wall in which they are located and when wall is moved, windows and doors move together with the wall. Also, when two walls are connected the system takes care about appropriate trimmings and connects together same materials in two walls. But, if one wall is moved, established connection breaks apart, and designer has to make all necessary modifications. In large models manual update of revisions becomes tedious and time consuming task.

The Revit is an application designed from the beginning to achieve effective revision update. Its name is invented to imply for "revise instantly". To achieve that goal, designers devised core mechanism that is based on relations among elements that enables quick propagation of modifications from one component to all related components. Since the relationships between elements represent piece of the core mechanism, the components that are part of the application library are predefined as the families. If the designer wants to create custom building component she/he chooses family that suits her/his needs and adapts it to achieve desired results. This kind of "machine like" behavior is apparent during modeling process. When the designer defines parameters he can not see how they influence component that she/he is shaping. After the designer chooses location for the new component the system checks relations between all components and reports to the user about all found inconsistencies that have to be resolved before component is included in the model. The system does not allow small user's adaptations after the element has become part of the model. Contrary to the ArchiCAD, all relations once established (like connection between two walls) will apply during all further model revisions. If, for example, designer moves one wall, all walls already connected to it will automatically change their dimensions to preserve connections.

The ArchiCAD and Revit use two significantly different core mechanisms to accomplish similar task. Differences are such that some instructors even prevent their disciples to think of components in one application in terms of other application. It is obvious that different core mechanisms and resulting diverse models prevent development of unified BIM design method, and as the consequence it is impossible to treat BIM as the general solution for the computer assisted green building design.

The building models created with ArchiCAD and Revit are rich models containing both detailed information about geometry and information about building materials, spaces and zones in the building, their occupancy type and daily schedules. Unfortunately, these models are too detailed for the current building energy consumption simulation applications. At the time when most energy simulation algorithms were developed 3D building models were scarcity, and computers did not had enough power to accomplish complex calculations. For that reason computer applications were based on simplified models. In the meantime, algorithms were refined and achieved level of good prediction so at the moment nobody sees no need to change the model on which energy consumption simulation applications are based. Instead, these simplified models coupled with the related results acquired status of Building Energy Models (BEM). The process of transforming BIM model to a BEM model is not straightforward and requires many specific operations depending on the BIM application and target energy consumption simulation application [6].

3. INTEROPERABILITY FORMATS

The field of computer assisted building design was confronted with diverse applications having proprietary data formats from its beginning and diverse interoperability formats, primarily geometry oriented, were devised. In 1994 Autodesk started initiative on defining set of classes that could support development of AEC (architecture, engineering, and construction) software. This initiative led to formation of industry consortium that devised Industry Foundation Classes (IFC) standard [2]. It is a neutral and open object oriented data model developed to attain highest level of interoperability in AEC. The standard defines classes necessary to represent all concepts related to building during its lifecycle and is registered as the ISO 16739:2013 standard [4]. The standard is anticipated to provide data interchange without information loss among all AEC applications and unified model-based description of all building components.

Initially, it was thought that IFC can function as the neutral and open building model. But soon, it was recognized that incompatibilities between BIM applications, caused by their core mechanisms, make such an idea impossible. Additionally, richness and flexibility of IFC standard intended to enable data transfer among all AEC applications and to provide space for future new products and techniques has led to confusion in the data exchange. This led to the development of strict definitions what information is necessary in particular data exchange and clear specification of what data structures are used. The result that is now introduced in majority BIM applications is the IFC 2x3 Coordination View 2.0 [3].

Despite all efforts, data exchange using IFC format is not a seamless process. When one application exports data as IFC it translates its internal building model to IFC format according to IFC 2x3 Coordination View 2.0. Since the specification is not intended to transfer all information, data specific to one particular BIM application will not become part of IFC file. On import side the problem is increased since every BIM application interprets building blocks in IFC file and tries to reconstruct how to create this component using native mechanism. The IFC file contains only information on current state of particular component and importing application needs to reconstruct how this particular state can be achieved using application's core mechanism. In this process many specific information not shared between all applications will be lost, like for example information about relations that is specific only to Revit application. When we come to the problem of exporting BIM model for the use in energy simulation software the situation is even worse. The IFC 2x3 Coordination View 2.0 covers only coordination between the architectural, mechanical and structural engineering tasks during the design phase. No official model view definitions exist for the use of IFC format in the energy simulation. So the process is based on try-and-error method and that is the reason why only one commercial energy simulation application uses IFC format to import building model for further analysis.

The Green Building XML schema – gbXML [1] is the format based on the Extensible markup language (XML) developed to facilitate data exchange between digital building models and the energy simulation applications. Its geometric requirements deal only with spatial volumes and thermal zones with simple boundary surfaces. BIM application that supports must export its complex model information in a simplified form. This process is not regulated in any particular way, so every application performs that task in a way that developers believed to be best. And only when the designer tries to import such file to particular energy simulation application that she/he finds errors. And sometimes energy simulation application simply proclaims the file to be invalid and leaves the designer without any answer how to establish connection between two applications [6]. Different simulation programs may have different software architectures, different algorithms to model building and energy systems, and require different user inputs even to describe the same building envelope or HVAC system component. The existence of the gbXML provides only standard data structure for information transfer and the task of preparation appropriate data depends on the detailed knowledge of each particular energy simulation application.

4. INFORMATION FLOW

The information flow between BIM and BEM is unidirectional from BIM applications toward energy simulation applications. The designer creates her/his model in the BIM application and when she/he wants to analyze how the design performs regarding the energy efficiency she/he prepares the model for the export. The exported model is imported in energy simulation application, missing data is added to create valid BEM model. After the required calculations are performed the results remain connected to the BEM model. Even if energy simulation application provides mapping of the results on the building model, that mapping is performed against simplified BEM model.

The designer who wishes to design energy efficient building is forced to base her/his decisions on the interpretation of the BEM model. If designer tries to do that by himself, she/he he falls into the trap of false understanding of results. Result obtained with different applications or with different version of the same application shows considerable variation [5]. The understanding of the results requires detailed knowledge of particular energy simulation application that only proper expert can have. Unfortunately, these people are specialized in their field and they can give excellent recommendation how to improve BEM model to achieve better results, or how to improve BIM model to get more accurate BEM model. The designer does not receive any feedback from BEM model how to improve her/his design to achieve more energy efficient building. He can not get any information how to improve building’s form, how to select more appropriate building components or how to design efficient building systems. All these decisions are still based on designer’s experience and intuition.

5. MODEL INFORMED ENERGY EFFICIENCY DESIGN

We can conclude that at the current level of technology development applications are using models to achieve final results like consistent building plans, coordinated technical documentation, effective rendering or precise simulation of building energy consumption. The model *per se* is not treated as an important component of the whole process. This fact is confusing in the time when majority of engineering branches embrace model as the essential building block of their profession. Perhaps the reason lies in the fact that in the AEC, especially in architecture, the model is identified with the mock-up.

In the initial stage of popularization of BIM technology computer generated building model was seen as the core around which all applications gather and every one believed that interoperability formats will provide the appropriate support. But reality denied that initial optimism. On the other hand, as the paper shows, greater reliance on computer model of the building is necessary if we want to achieve better energy efficiency design.

The first step toward model informed energy efficiency design is change of designer’s habits. Greater effort must be invested in the education of designers and a better understanding of the term “model” should be achieved. The computer based building model should be regarded as an essential source of information which underlies all design decisions. We don’t need to develop some new overarching theoretical construct that will again led to overoptimistic expectations, instead we should use existing information resources and technologies and enhance its value by creating better interconnection. Also, the list of useful applications should be expanded to include programs like SketchUp and other light BIM applications. Attention should also be paid to the so-called BIM explorers or viewers, like BIMx, Tekla BIMsight, DDS-CAD Viewer, etc.

The first step toward model informed energy efficiency design is thorough analysis how each design application interacts with each energy simulation application, and special attention should be paid to free energy simulation software that often offers excellent simulation algorithms but lack in compatibility with other programs. This should led to better understanding of what information is needed by energy simulation applications, how is that information handled by existing interoperability formats, and finally, how that information is incorporated in components that design applications (BIM or light BIM) uses to construct their models.

Once detailed understanding of information needs is achieved the next step will be the development of software tools that that connect various files and applications and inform the designer to how achieve optimal connectivity. The technology most suited for that task has already been developed as the part of the semantic net project [7]. It compromises of the layers of standardized technologies that allow addition of the meaning to basic information. Using this technology it will be possible to develop a knowledge bases that will improve the use of BIM tools and provide feedback that will help the designer to develop more efficient solutions. Also, new developments in the field of building information interoperability, like IFC4 Design Transfer View will add increase the efficiency of data exchange between applications and lead to even simple creation and use of computer based building model.

6. CONCLUSION

Computer software like BIM applications coupled with energy simulation applications have great potential to improve energy efficient design despite current problems. The existing technology already has potential to achieve that goal, what is now required is greater involvement of designers in that endeavor that will led to better understanding of technologies and more informed requirements toward technology improvements that will persuade software developers to enhance their products.

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