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The usage of the openBIM idea in architectural design on the example of Blender and BlenderBIM add-on

Introduction

Nowadays, the concept of BIM (building information modeling) is considered as a standard, which combines information about the geometry of a building and its parts and also data describing the geometry, e.g., how an object is used or its physical features. The advantages of using the BIM concept in design have been described in many scientific publications [1], [2]. The BIM concept is complemented by the openBIM idea defined by the buildingSMART organization [3], which constitutes a universal approach to the digital design process, openness of information flow between entities constituting its parts, as well as the building management.

The direct method of implementing the openBIM postulates is the standard of data recording and exchange – Industry Foundation Classes (IFC). This standard is a clearly defined scheme for recording information about the building, infrastructure elements, etc., in the assumption that it is to enable the exchange of data, regardless of what program the participant of the design process uses [3]. IFC, as an open, ISO certified (ISO 16739-1:2018) standard provides a set of definitions (so-called classes) for buildings and building elements. It also provides the structure of classes notation for unlimited reading by various computer applications. However, the IFC is only a standard that does not have to be fully implemented. The basic problem with the use of the IFC standard results from the fact that it is not treated as a native way of recording data created by specific BIM applications. Thus, the data exchange forces the conversion of the BIM model to the .ifc format. Therefore, cooperation very often causes data loss, errors in the geometry of the model

itself and other problems [4]. The IFC standard itself is also constantly developed and there is no final version, which means that it may not support some geometric elements or objects available in programs such as Archicad or Revit.

According to the idea of openBIM, designing in this standard should be open and enable cooperation at the highest possible level [5]. Therefore, it should be noted that from the designer's point of view, not only data exchange is important, but also the ability to work together on the BIM model. Due to the way BIM applications are organized, the above demand cannot be met. The IFC standard applies only to data exchange and reading, not editing. BIM design programs themselves do not provide the tools to work together on one model in different programs either. The offered solutions are limited to a simplified conversion without the .ifc format. The Graphisoft Archicad Connection [6] add-on can serve as an example.

Another important aspect related to cooperation on a project created in a digital standard, including the BIM standard, is access to software and materials. One of the biggest problems with the adoption of BIM design software is the cost of the software itself and other related additional costs [7]. The above problem very often leads to a situation where some co-designers work in BIM software, and some still use software for editing two-dimensional drawings. A possibility of solving the above problem situation is the use of open-source software [8]. Reducing the cost of purchasing software to zero would certainly expand the group of designers working in the BIM workflow.

Objectives

Undoubtedly, designing in the BIM standard and implementing the postulates of the openBIM idea cannot take place without a specific tool – BIM software. The

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modern IT industry provides designers with many possibilities to choose applications with very different characteristics [9]. The aim of this article is to present the Blender program and the BlenderBIM add-on in terms of the openBIM postulates implementation, in particular the postulates about the openness of the designing process and extending the possibilities of cooperation between co-designers.

Blender and BlenderBIM

Blender is a software developed by the Blender Foundation and made available on an open-source basis (the GNU GPL license) [10]. It is a very powerful tool that enables direct and parametric 3D modeling, it also has tools for digital sculpting. Thanks to the built-in Cycles and Eevee rendering engines and the Grease Pencil function, it allows you to create static renderings as well as 2D and 3D animations. An additional functionality of the program is the editing of raster graphics and movies, which extends the program's usefulness to the post-production stage [11]. There is also a very strong software development community. Thanks to making the program available on an open-source basis, many add-ons have been created that enable, for example, lighting analyzes (Ladybug) or libraries of fully parameterized architectural elements (Archipack). Despite a very wide range of functions, this program was rather associated with the CGI (Computer Generated Images), VFX (Visual Effects) and computer games industries. The literature review did not reveal any publication devoted to the use of Blender in architectural design.

In October 2019, the BlenderBIM add-on was released. It is an open-source extension to Blender, created by volunteers from the ifcOpenShell project [12]. This add-on allows you to read and write design files in the open IFC standard, which allows you to design using Blender in the BIM standard and to cooperate with other designers operating in the BIM workflow (regardless of the program used). The BlenderBIM extension is completely integrated with Blender and adds extra functionality to its interface.

Designing in the BIM standard using Blender and the BlenderBIM add-on looks different in comparison with other BIM applications. Programs such as Archicad and Revit represent an object-oriented approach to modeling. The user has a specialized tool at his disposal, suitable for modeling specific elements, such as walls, ceilings or stairs. Blender does not have any such object-oriented tools as it is rather a traditional 3D modeler. The designer, using the Blender functions, has to create the geometry of the given object, and only at the second stage, using the BlenderBIM add-on, adds the information layer to the geometry. Such a solution treats geometry and information separately, and creating the connection between these two elements is the role of the designer. This is a very different approach than other programs, however it undoubtedly provides great control over the geometry itself and the information assigned to it.

Therefore, in the author's opinion, Blender and BlenderBIM can be considered as a full-fledged tool for

architectural design in the BIM standard. However, it should be noted that the BlenderBIM add-on is an open project, constantly updated and is not a finished version. Therefore, some functions may not work as intended, and the software itself may be buggy.

Methods

In the conducted research, the author focused on the capabilities of the Blender program and the BlenderBIM add-on, compared to other BIM software, in the context of the openBIM idea. The author's analyses relate to the following issues:

1) the way and scope of integration of the Blender environment and the BlenderBIM plugin with the IFC standard,

2) possibilities of cooperation on the project in the BIM standard offered by the Blender program and the BlenderBIM add-on in terms of editing projects saved in the IFC standard,

3) adapting the software to the various needs of the designer,

4) access to the software.

Blender version 2.92 for MacOS and BlenderBIM version 0.0.201025 were analyzed. To the best of the author's knowledge, the Blender program with the BlenderBIM add-on has not been the subject of any scientific publication, nor have these programs been analyzed in the context of the openBIM idea.

Integration with the iFC standard

The key element for the analysis of Blender and the BlenderBIM add-on in terms of the level of integration with the IFC standard is the method of recording the information layer of the model. As already mentioned, Blender and BlenderBIM add-on, unlike other programs (such as Archicad or Revit), do not use object-oriented modeling tools. The role of the designer is to create geometry using Blender tools and supplement it with an information layer using the BlenderBIM add-on. This plugin uses only the IFC standard to describe the geometry. The classification of the modeled elements of the building geometry is carried out in three stages [13]. First, the object should be placed in the appropriate folder, thanks to which it will be assigned to, e.g., a suitable building and floor. The folder structure, compliant with the IFC standard, can be generated automatically by the BlenderBIM add-on, however, it is possible to create and edit it manually. The next step is to give the object an appropriate IFC class, thanks to which it will be correctly recognized, e.g., as a wall or a window (regardless of the shape of the geometry itself). The IFC class should be assigned to an object by selecting a definition from the context menu presenting all available classes. The final step is to define the object's attributes, i.e., its specific features (such as physical features or wall function). The set of attributes depends on the assigned IFC class. Each of these three stages is directly based on the definitions of the IFC standard, thus treating the discussed standard as a way of

recording data not only at the stage of data exchange, but also at the time of their creation [13]. Due to the above, the IFC standard is treated by BlenderBIM as a native way of recording information about the model. A very similar approach is represented by FreeCAD which, like Blender, is not a BIM software by default, but a standard CAD modeler. However, a special overlay allows to describe objects in accordance with the IFC standard. The implementation of the IFC standard in the case of solutions presented by Blender and FreeCAD is much simpler than in the case of other BIM programs. Support for the IFC standard, despite the short history of BlenderBIM, for example compared to Autodesk Revit, is much wider [14]. It does not require creating new tools in the program or objects, but it comes down to introducing new IFC classes. At the same time, it should be noted that the discussed software still requires the project to be converted to the .ifc format, however, in this case it is only related to the translation of data into and from the Blender language. Therefore, the traditional problems related to the conversion to the .ifc format [4] should not occur, although their occurrence cannot be ruled out.

Possibilities of cooperation

Due to the differences resulting from a different approach to 3D modeling (and from other peculiarities that each software has), there is often a need to use several applications. Unfortunately, the flow of a BIM model between programs in order to edit it is basically impossible. BIM applications allow the import of .ifc files, however, they consider them only as a reference. Blender and BlenderBIM can solve this problem by treating a file saved in the .ifc format not as a reference, but as data that can be imported and edited. For verification, the author modeled a simple, single-layer wall in Autodesk Revit, which was then exported to an .ifc file and imported to Blender. After importing the .ifc file, BlenderBIM added access to the model information. The wall is classified as ifcWall, which means that the object is a wall according to the IFC standard. It also had the ifcGlobalId (individual object identification number), ifcPredefinedType (predefined wall type) and ifcMaterial (wall material) attributes. However, the very geometry of a rectangular, imported object symbolizing a wall has lost the possibility of parametric editing. Changes could only be made directly. Accordingly, the problem can only be considered partially resolved. However, it should be noted that this is due not so much to the limitations of the Blender and the BlenderBIM add-on, but to the limitations of the IFC standard itself, as well as the solutions used by manufacturers of other BIM software. Objects modeled in BIM applications become non-parametric already at the time of conversion to the .ifc format, which is related to two issues. Firstly, each program has its own source code, which may additionally use a different programming language. Thus, different applications define the same objects differently, and the layer of classes and attributes of the IFC standard is somehow overwritten with the object only at the time of conversion. Secondly, most BIM applica-

tions save geometry as Nurbs, i.e., surfaces described by mathematical functions. Such a record of spatial information allows for a high level of parameterization of the model and does not introduce any limitations in the event of a possible re-edition [15]. However, the IFC standard uses 3D mesh geometry, which is based on a set of points, edges and planes. In the case of planar elements, the difference is purely conventional, but in the case of more complex surfaces or solids not composed of planes, the difference is very clear. An example can be a sphere which, written as Nurbs geometry, will be an ideal mathematical sphere, and as a 3D mesh it will consist of triangles or other planar polygons. A graphical comparison of a sphere written as Nurbs and 3D mesh is shown in Figure 1. The IFC standard uses 3D mesh geometry for optimization reasons, and also because of the objectivity of interpretation (independent of the computer program used) of geometry recorded in the Cartesian coordinate system. However, conversion of Nurbs geometry to 3D mesh during the conversion of a BIM project to the IFC standard causes many problems that make it difficult to edit even using direct tools. If the edition is not a complex interference, for example is limited to moving an opening in the wall or changing its dimensions, the problem will not be encountered. Clear complications appear when edition means, for example, adding new holes in the wall or removing previously modeled ones. In such a situation, the surface should be detriangulated in the first stage, which consists in combining triangles with parallel directions of normal vectors into polygons (ngons). However, there is a clear limitation in the case of 3D mesh geometry, which does not allow for full detriangulation of surfaces with cut openings, because 3D mesh geometry can only consist of triangles (tris), quads and polygons (ngons). Accordingly, a rectangular face with one rectangular opening cut after conversion from Nurbs geometry to 3D mesh and subjected to detriangulation will consist of two polygons. Figure 2 shows the object before and after detriangulation. The geometry transformed in this way can be subjected to, for example, a Boolean operation, which will allow for cutting an additional hole in a given place. However, the 3D mesh geometry consisting

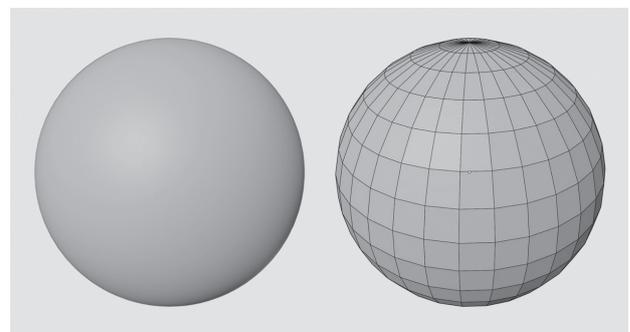


Fig. 1. Graphical representation of a sphere modeled as a B-Rep (left side) and a 3D mesh (right side) (elaborated by M. Malewczyk)

Il. 1. Graficzna reprezentacja kuli zamodelowanej jako B-Rep (lewa strona) oraz 3D mesh (prawa strona) (oprac. M. Malewczyk)

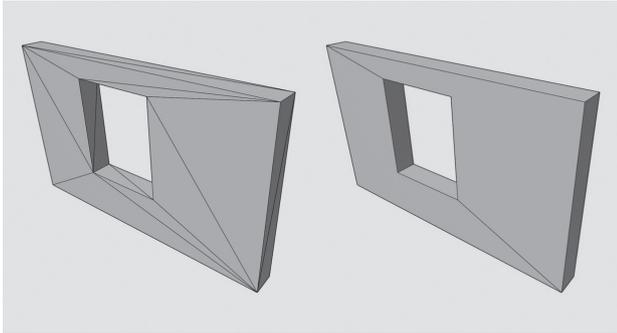


Fig. 2. Wall converted from a Nurbs to a 3D mesh (left side) and after detriangulation (right side) (elaborated by M. Malewczyk)

Il. 2. Ściana po konwersji Nurbs 3D mesh (lewa strona) oraz po detriangulacji (prawa strona) (oprac. M. Malewczyk)

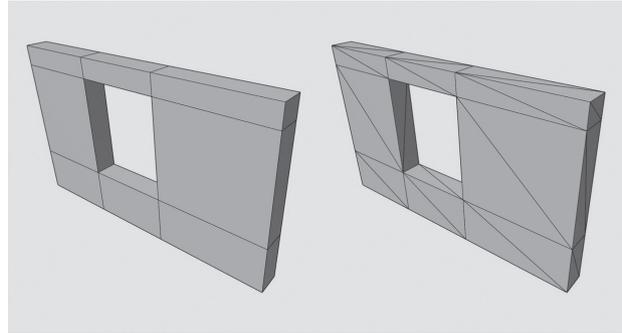


Fig. 3. Wall modeled as a 3D mesh, composed of quads, before (left side) and after triangulation (elaborated by M. Malewczyk)

Il. 3. Ściana zamodelowana jako 3D mesh, składająca się z czworokątów, przed triangulacją (lewa strona) oraz po triangulacji (prawa strona) (oprac. M. Malewczyk)

only of quads is much easier to edit and also fits well with the nature of most architectural objects. Composing 3D mesh geometry from quadrilaterals also allows for relatively safe data exchange between various 3D modeling programs. Each quadrilateral can be divided into triangles only in two different ways, in the case of polygons there are many more possibilities. Such a method is therefore definitely more geometrically unambiguous, and after possible triangulation and detriangulation in another program, the geometry is always saved in accordance with the will of its creator. An example of a face composed of quadrilaterals before and after triangulation is shown in Figure 3. Apart from the editing difficulties associated with the conversion of Nurbs geometry to 3D mesh, there are also frequent problems resulting from the conversion itself, which fact has already been described in the literature [4]. Blender and BlenderBIM provide, therefore, the possibility of cooperation on a BIM project created in various programs, but for many reasons it is difficult. First of all, it is not possible to use the parametric model editing capabilities offered by other programs, it also requires modeling only using 3D mesh geometry. An additional difficulty limiting the possibilities of cooperation is the need to work with .ifc files, which can be further edited only in niche applications such as FreeCAD or usBIM. viewer +.

Blender and BlenderBIM in the context of the diverse needs of designers

Undoubtedly, each architectural object is a complex structure of individually designed elements, but also typical catalog objects. In addition, the design process itself somehow forces the designers to approach each project individually. Accordingly, the needs of designers for a BIM design program are very diverse. These needs relate primarily to the modeling methods. Blender offers several possibilities in this regard.

The basic modeling method offered by Blender is direct modeling. The user has a morphing method and

a curve method at his disposal. The morphing method involves editing basic objects such as a cube, cylinder or sphere, and this method is not available in programs such as Archicad because it is characteristic of traditional 3D modelers, not CAD programs. The functionality of Blender can be compared in this respect to programs such as 3DSmax, Cinema4D or Maya. At the editing stage, the user has access to several hundred tools that allow for extruding, cutting geometry or sculpting with digital brushes. It is a great way to model small architectural forms (e.g., benches, lamps) or details (e.g., drainage gullies, roof hatches). The curves method is based on creating three-dimensional geometry on the basis of curves moved along other curves or combining a series of curves into surfaces (the curves in this case are the sections of the generated surface). This type of modeling allows you to quickly create the geometry of balustrades or topographic surfaces or coatings, and the functionality of the Blender program is similar in this respect to both CAD and BIM programs, as well as traditional 3D modelers.

Blender also has a lot of tools that allow you to parameterize elements created directly. In this scope, the user has the option of imposing constraints on the model (for example, connecting windows with the external wall, in effect moving one triggers an action on the other) or creating parameters [16] (global or object-oriented, which allows for editing, for example, the height of all stories of the building or specific window width). It is also possible to add parametric modifiers (for example, dynamically copying repetitive elements such as stairs and columns). Since the user can also create their own scripts in this area using the Python – open programming language, the possibilities of the program in this area are almost unlimited. It should be noted, however, that creating all parameters and assigning them to objects is done manually, which requires a lot of experience with the software.

The application also provides solutions that enable fully parametric design using graphical programming, similar to, for example, the Grasshopper add-on implemented in the Rhinoceros modeler or Dynamo built into the Autodesk Revit program. One such solution is availa-

ble in Blender from version 2.92 (geometric nodes), and there is also an add-on called Sverchok, which is open-access. Despite the lack of publications comparing the functionality of the solutions offered by Blender with other available solutions, those offered by Blender are much shorter developed. Therefore, it can be presumed that their usefulness is lower.

Because thanks to the BlenderBIM add-on, Blender supports the .ifc format, the user also has the option of employing ready-made models available, for example, on the manufacturers' websites. The use of these types of objects does not require additional work related to assigning classes and attributes to the IFC standard, as these objects already have such information. In addition, it is also possible to use ready-made 3D models that are not, by definition, objects to be used in designing in the BIM standard. However, information about the IFC class and attributes should be completed individually for such a model. An additional advantage of the analyzed software in terms of the use of ready-made libraries is the possibility of creating references to external files, therefore there is no need to nest models in the main file. This solution significantly improves the speed of work on the project and allows you to reduce the size of files.

In addition to the design itself, an important element of the designer's work is the preparation of documentation. The Blender program and the BlenderBIM add-on offer very limited possibilities in this regard, which are only in the initial stage of development. The user has only the tools to export the cross-sections created with flat viewports and very limited possibilities of drawing description. The analyzed programs do not have tools for creating lists or intelligent dimensioning tools present in other leading BIM programs.

Therefore, Blender and BlenderBIM are software with very different functionalities, giving access to many different modeling methods not available in other BIM applications. Nevertheless, due to the initial phase of BlenderBIM development and other types of Blender starting purpose, they do not give access to other, highly specialized tools implemented in other BIM applications. First of all, they make it almost impossible to create full, professional project documentation.

Open-source

A clear extension of the openBIM idea is the open-source concept, according to which the Blender software and the BlenderBIM add-on are made available, as well as the IFC standard itself. In the same way, the previously mentioned FreeCAD program is made available. Free access to software in the context of the openBIM idea allows you to use the discussed applications without any restrictions in order to analyze ready-made projects written in the openBIM standard, but also for the design itself. In line with the third freedom, as defined by the definition of free software [17], making a program available on an open-source basis also enables more advanced participation of the developers themselves in the process of creating the tool. Thanks to this, the designer can be more asso-

ciated with the tool. Naturally, the concept of making all BIM design software open-source is utopian. Moreover, it should be mentioned that the concepts of open and closed-source complement and support each other, as Lerner and Schankerman wrote about (after: [8]).

Conclusions

The idea of openBIM in its basic assumption is to allow an unlimited flow of information between entities participating in the design process. The actual form of implementing this idea is the IFC standard, which allows the BIM model to be read by software from different manufacturers. However, there are many problems with the actual use of this standard in practice. The necessity to convert and the fragmented handling of IFC classes (different in different programs) very often causes various types of errors in the information about the model or in the geometry itself. The current state of development of most BIM modeling programs also does not allow for the joint editing of model geometry using different applications.

Despite the very advanced method of implementing the openBIM idea (as evidenced by the award granted to the team creating BlenderBIM in 2020 by the buildingSMART organization) and the editing capabilities of .ifc files, Blender and BlenderBIM have many features that make their use in everyday design difficult. These difficulties are mainly due to the level of development of these tools and the structure of the BIM modeling software market. Undoubtedly, the implementation of some of the solutions that Blender and BlenderBIM offer to the majority of BIM programs would significantly facilitate cooperation on the project. The key element seems to be a solution treating the IFC standard as a native way of recording information about the BIM model and covering most of this standard with support. The development of support for 3D Mesh geometry also seems to be important in the process of implementing the openBIM idea. According to the example of the Blender program (in which the geometry is initially saved as 3D mesh, not as Nurbs), there is no need to convert the geometry, which reduces the risk of errors when writing data and reading them in other software, and also significantly increases the editing possibilities of the geometry in other 3D modeling programs.

Despite the obvious benefits of using computer tools in design, there are also many limitations connected with them. Modern programs in most cases constitute closed, heterogeneous environments, which significantly hinders cooperation between participants in the design process. Taking into account financial factors and design needs mostly results in a significant reduction of the pool of applications to choose from. Extending the idea of openBIM is an undoubted chance for designers to work better, more efficiently, but also for the architectural form itself, potentially less limited by the program that was used to design it.

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Abstract

The usage of the openBIM idea in architectural design on the example of Blender and BlenderBIM add-on

The aim of the article is an analysis of the method and advancement of the openBIM idea implementation, clearly defined by the buildingSMART organization. The conducted analyses are limited to the Blender program and the BlenderBIM add-on and were embedded in the context of the work of an architect and other IT solutions. The article presents four aspects of the openBIM concept implementation. The first approach relates to a process of data exchanging between different computer applications using the open IFC standard. Another two focus on the method of creating and coding the three-dimensional geometry itself, through the prism of cooperation between various entities and further editing possibilities. The last aspect deals with the extension of the openBIM concept by combining it with the open-source idea. The author bases his considerations on the existing, analyzed scientific material, as well as on his own experience in the everyday reality of a designer and a teacher.

Key words: openBIM, Blender, BlenderBIM, IFC, buildingSMART

Streszczenie

Zastosowanie idei openBIM w projektowaniu architektonicznym na przykładzie programu Blender oraz dodatku BlenderBIM

Tematem niniejszego artykułu jest analiza sposobu oraz zaawansowania realizacji idei openBIM, jasno zdefiniowanej przez organizację buildingSMART. Przeprowadzone badania ograniczają się do przykładu programu Blender oraz dodatku BlenderBIM i zostały osadzone w kontekście pracy projektanta, architekta oraz innych rozwiązań informatycznych. W artykule zostały przybliżone cztery aspekty realizacji koncepcji openBIM. Pierwsze ujęcie odnosi się do sposobu wymiany danych pomiędzy różnymi aplikacjami komputerowymi za pomocą otwartego standardu IFC. Drugi oraz trzeci wymiar skupia się na sposobie tworzenia oraz zapisu samej geometrii trójwymiarowej, przez pryzmat współpracy różnych podmiotów i dalszych możliwości edycyjnych. Ostatni aspekt dotyczy rozszerzenia idei openBIM poprzez jej połączenie z koncepcją open-source. Autor swoje rozważania opiera na istniejącym, przeanalizowanym materiale naukowym, a także na własnych doświadczeniach w codzienności projektowej oraz dydaktycznej.

Słowa kluczowe: openBIM, Blender, BlenderBIM, IFC, buildingSMART