Modeling of non-standard geometry of energy-efficient building facades

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Abstract. This article describes the approach of parametric modeling using modern software. This decision should help to change the already established rules for building BIM models. This approach became the basis of the idea of using parametric modeling for two main groups in the modern modeling of construction projects: modeling of the architectural appearance of the building and structures. This method can significantly reduce labor costs, and it also can be used to implement non-standard solutions in the design energy-efficient building facades.

1 Introduction

The topic of this article is of interest, because BIM modeling have been known to many modern architects and builders for a long time. M. Hamma-adama and T. Koider describe the experience of using BIM in Nigeria in their work [1], Rizal S., R. Olivadese and M. Arnesano, A. Gralka in [2] describe the experience of using BIM technology in Europe describe. In Russia A. Lyapina and S. Borodin described the use of BIM, in particular in the construction, in their work [3]. It can be stated that BIM has almost completely replaced standard and outdated construction methods around the world. At the same time, not everyone knows about special modeling methods, technologies are developing rapidly and BIM is already used in VR [4]. This article will be especially relevant for those who want to combine a kind of programming (writing scripts) and computer modeling. According to M. Stavric [5], the construction of city buildings up to the 18th century was like the creation of "shelters", but now more and more old approaches of construction are changing to the new ones, typical city buildings are replaced by unique works of art. Many companies have been using various software systems from Autodesk and Graphisoft for design automation and softwares for calculations such as Lira, Tekla, and many other variations of BIM solutions. Although the ”new" creation of the building model appeared about ten years ago, this is just mentioned by R.Rushel [6] , who describes the introduction of BIM in the construction of Brazilian projectsin her article. The author claims that initially the construction companies may not have willingly responded to these innovations, but it definitely found its application it is in design. Nevertheless, many approaches to modeling can be called outdated, but the development of architectural solutions never stands still, this is evidenced by the article [7] Tiago Cardoso de Oliveira. This article is about the beginning of the development of modern architecture in Portugal, various

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architectural styles are transformed and added more non – standard forms in facades, windows, walls of non-standard geometry, all this is the future of modern architecture. Because of all of these innovations it is quite complex to create a roof or facade of a non-standard form . Using standard tools of the ArchiCAD will take a lot of time, a lot of trials and errors. There is a risk that that this design and does not be perceived by other programs because of the many parameters. That is when parametric modeling comes to the rescue.

The method of parametric modeling is to try to describe the complex geometric shapes of the model through the primitives, the form and the connection of which is given by various parameters, such as the coordinates of the points, the division of the line into individual segments, the length of the segments, the number of splines, the radius of circles and many others. When you specify individual parameters, relations between them are established, they are called constraints. To make it clearer, the constraints in standard construction methods are, for example, two parallel lines, those lines that must not intersect, or two circles can be called the same, if their radiuses are equal. When a set of primitives and restrictions is specified, a sketch of the model can be built on them. That is, the contour of the future object is built. Because of this, the engineer does not need to specify the coordinates for each object, he only need to specify the geometric relationships between the objects, and the rest of the calculations of the resulting coordinates of each object will be performed by the geometric constraint solver. These main features of this approach distinguish it from the others. This method is already used in in different spheres [8] it can be seen in the research of L. Duan and other about how the parametric modeling can be used in the field of mechanical engineering, In their work [9], the parametric modeling for the study of the surfaces of the helium in descriptive geometry is described by F. Teixeira Régio Pierre da Silva and tânia Luisa Koltermann da Silva.

2 Goals and Objectives

It is necessary to come up with and implement the idea of non-standard facadeof the building based on four conventional steps:

1. Concept
2. Software choice
3. Sketch
4. Implementation

3 Materials and Methods

The implementation of this approach can be easily demonstrated by the interaction of three hardware systems: Rhinoceros 3D, a module for this complex Grasshopper and the transfer of the finished model to ArchiCAD 22 [10] using the Grasshopper-ArchiCAD Live Connection module. The use of this module describes M. Aydin in his work [11]. Graphisoft's product was chosen specifically. The affordability and versatility of this hardware complex has been confirmed in an article [12] by J. Crippa, which aims to present a structure that integrates BIM and life cycle assessment (LCA), which are useful for architecture, engineer and AEC. The topic of AEC is considered by students of the University of Nottingham, Ningbo Campus Chao Chen and Llewllyn Tang in their study [13]. It states that in China, due to numerous AEC projects that start and fail each year, the traditional workflow-based drawing can no longer meet the growing requirements of the digitization project, and it loses total control of project management. That is why modern construction is no longer possible without the use of a variety of BIM solutions. This is

important also because the BIM model must be non-standard, embodied, and sustainable in real life.

First, let's give a brief description of what we are dealing with. Rhinoceros 3D is a 3D modeling software. This sotware is mainly used in architecture, in the creation of design solutions, in the design of machines, ships and complex mechanisms, and even in the creation of jewelry. For example, J. Dźwierzyńska in their work [14] describes the development and effective formation of a curved rod of stainless steel is based on the surface of enneper. This program was chosen because Graphisoft (ArchiCAD creators) actively cooperate with Rhinoceros developers Robert McNeel & Associates. In addition, Rhinoceros has a very high accuracy in setting parameters and calculations, which is why the resulting models have high accuracy and good detail. Due to this cooperation appeared such a module for Rhinoceros as Grasshopper.

Grasshopper is not a separate program, it is a plugin for writing scripts inside Rhinoceros. This plugin is used in various fields. The idea of implementing the original facades came to me after reading the article “Façade 2018 – Adaptive!”[15].

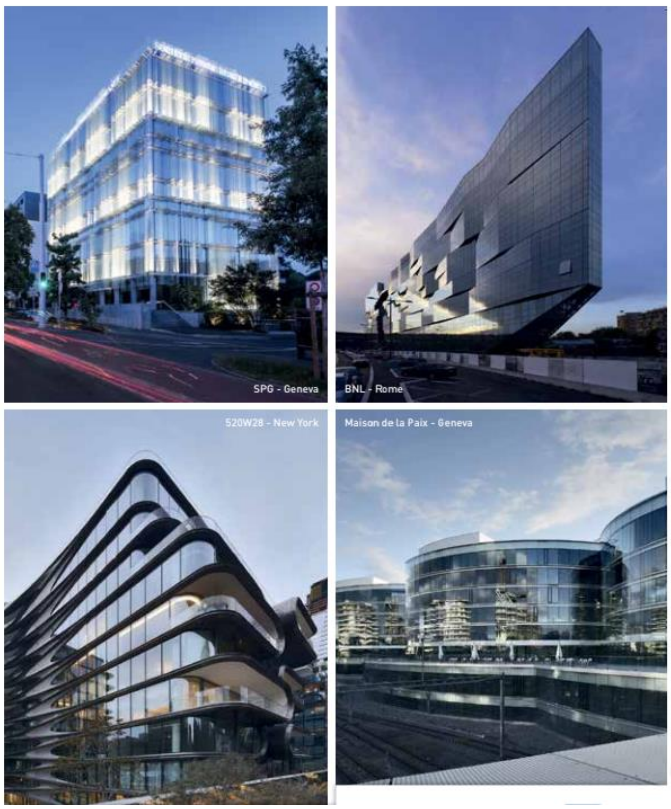

Fig. 1. Facade ideas.

The working method of Grasshopper is simple. The engineer need to specify the parameters and the relationships between them, and according to the relationship coordinates are calculated and build the model objects, whose parameters were specified. Grasshopper is a node-based editor. This means that the parameters are passed from one object to another through the "connecting" wires, thus creating a relationship between all the objects within the script written in Grasshopper, model inside Rhinoceros is created on the basis of this. This is how it looks like:

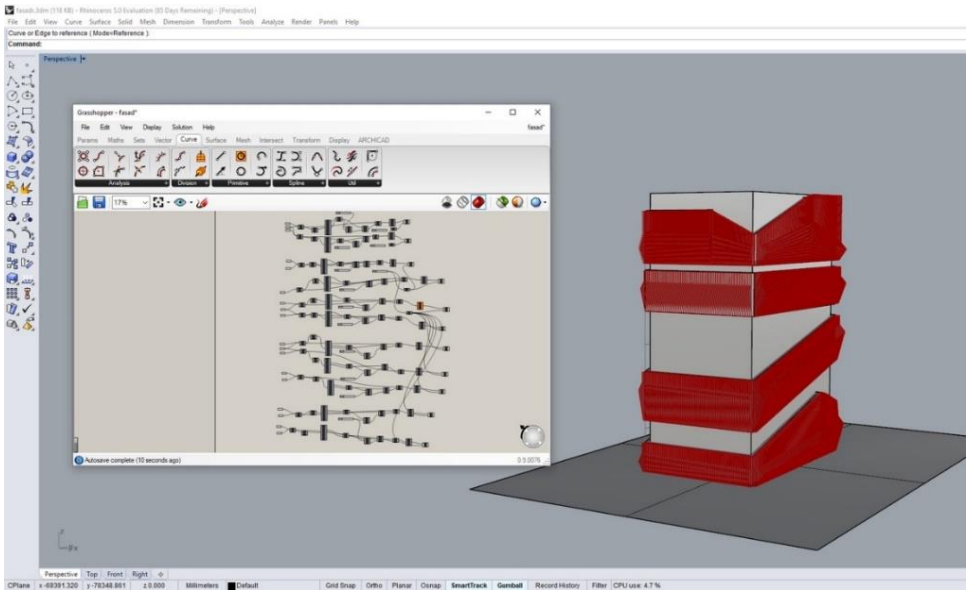

Fig. 2. Script in Grasshopper to create facade slabs in Rhinoceros 3D.

On the left is a script for creating facade panels and walls of the object. This non-standard facade was made specifically for transferint to ArchiCAD 22. The originality of these panels is that it is not a whole object, each panel consists of many objects (in this case, the components of the panel are from the tree).

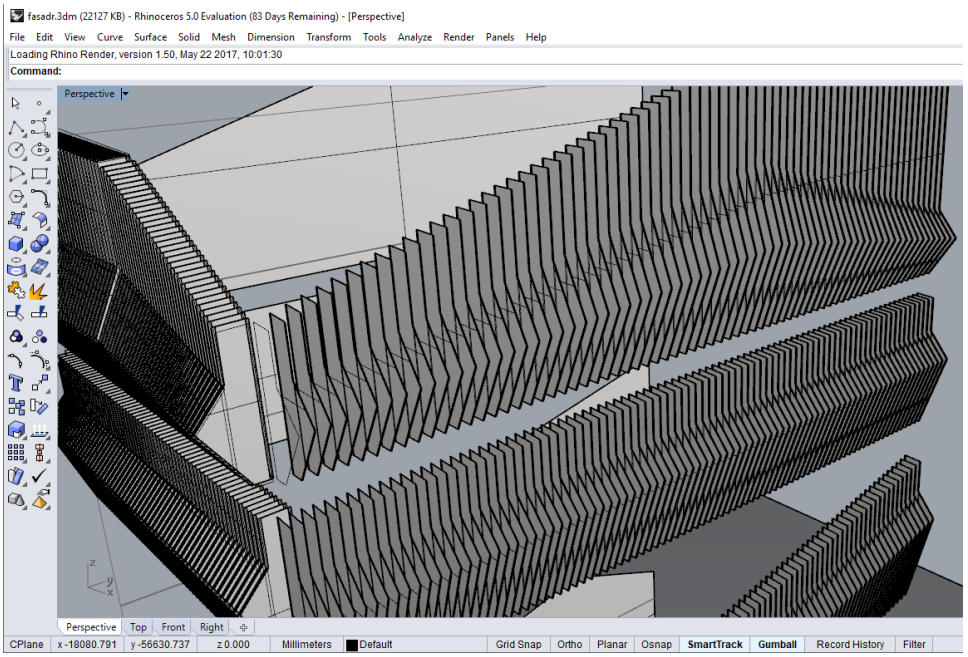

Fig. 3. Final models of front plates after rendering, ready for export to ArchiCAD 22.

After the final inspection and preparation of the model in Rhinoceros 3D, you can transfer this model in ArchiCAD22. This transfer is carried out using the tool(plugin) Grasshopper-ARCHICAD Live Connection, designed specifically for communication of all

three programs. The main feature of this approach is that the transfer of the model from one hardware complex to another takes place in real time, which allows, if necessary, to correct errors and defects, to make amendments immediately to Grasshopper and see the changes in ArchiCAD.

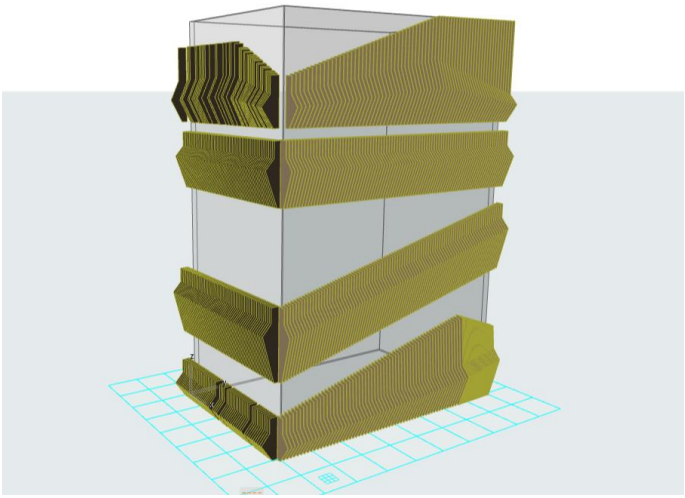

Fig. 4. This screenshot shows the model transferred from Rhinoceros 3D to ArchiCAD 22 using Grasshopper-ARCHICAD Live Connection.

3 Results

So, the idea described in the paragraph goals and objectives came true. All three hardware complexes were used. It all started with the creation of a sketch on a sheet of paper, the idea was transferred to Rhinoceros 3D, it was embodied using Grasshopper, and when implemented in ArchiCAD 22. It also received an actual appointment in the BIM model of a modern building. The knowledge that is necessary for the implementation of new, more complex concepts was obtained due to this experience of using these hardware complexes.

4 Conclusion

In conclusion, I would like to note once again that all actions take place in real time, which means that if the developer notices an error or inconsistency, he can immediately eliminate them. If we evaluate this method on a global scale it should noted that the script can be used at any time and on any PC. If you need to develop a typical construction project, you can create the first floor in the usual BIM solutions like ArchiCAD and Revit, and then make copies of it on as many floors as you need according to the drawings. But let's suppose that this building will need to be done again, and the developer will have to make the first floor again. But if you write a script for creating the first floor immediately when you receive a job, you can run it and in a few seconds the first floor would be ready, and then copy it already as much as necessary, or amend the script to use the copy immediately, and if necessary, just to amend the number of floors of the building that is necessary for the new construction project. Also, this method can be used to create similar buildings, making changes in the number of floors or a change in the architecture. It all depends on your approach to solving the problem.

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