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3D COMPUTER MODELLING OF ARCHITECTURAL DETAILS BASED ON THE MODERN BIM INVENTORY SYSTEMS

MODELOWANIE KOMPUTEROWE 3D DETALI ARCHITEKTONICZNYCH W OPARCIU O NOWOCZESNE SYSTEMY INWENTARYZACYJNE BIM

Abstract

The article presents the 3D computer modelling of architectural details based on the modern BIM inventory systems. It discusses the methodology of architectural inventory, which employs laser measurements in the ArchiCad programme interconnected with the FlexiJet system. The use of this method allows one to create elements of a virtual building (BIM model) with great precision, thanks to its very high measurement accuracy and appropriate software. The application of this system is exemplified by the specified elevation detail of the Royal Palace in Łobzów, currently housing the Faculty of Architecture of Cracow University of Technology.

Keywords: Flexijet inventory, 3D modelling, architectural detail, ArchiCAD

Streszczenie

Artykuł prezentuje modelowanie komputerowe 3D detali architektonicznych w oparciu o nowoczesne systemy inwentaryzacyjne BIM. Przedstawiono metodę inwentaryzacji architektonicznej wykorzystującej pomiary laserowe w sprzężonym z programem ArchiCAD systemie FlexiJet. Zastosowanie tego sposobu inwentaryzacji umożliwia tworzenie z niezwykłą precyzją elementów wirtualnego budynku (model BIM) dzięki bardzo dużej dokładności pomiarowej i odpowiedniemu oprogramowaniu. Zaprezentowano działanie tego systemu na przykładzie wybranego detalu z elewacji dawnego Pałacu Królewskiego w Łobzowie, obecnie mieszczącego Wydział Architektury Politechniki Krakowskiej.

Słowa kluczowe: inwentaryzacja Flexijet, modelowanie 3D, detal architektoniczny, ArchiCAD

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1. Introduction

The article presents 3D computer modelling of architectural details based on modern BIM inventory systems. For this purpose, laser measurements in ArchiCAD-connected Flexijet system have been used. The details on the facade of the former Royal Palace in Łobzów (currently housing the Faculty of Architecture of Cracow University of Technology) have been chosen as an example.

The article presents particular stages of work: from the operating functions of the Flexijet system, through measuring stage, until final modelling of architectural detail in ArchiCAD. The methodology of creating particular elements enabled the authors to examine the most common problems encountered in the virtual renditions of details. The article also discusses various ways of adding up the measured details using certain advanced functions of ArchiCAD. Particular focus has been given to options which compress the files being created which directly influences the speed of working on the model and time required for visualization. The comparison of certain functions of ArchiCAD allows for making optimal choices in the process of modelling.

The concept of creating inventory systems in BIM technology has to begin with the analysis of computer assisted designing. The ways of creating inventory of buildings have been evolving in parallel with the constantly-improving tools needed for this process. In the past, the two dominant solutions used by designers and architects were hand-drawn sketches and perspective drawings as well as Monge's perspectives – plans, facades and cross-sections. Nowadays, drawings are predominantly made with the help of digital technology, the knowledge of which may directly influence the methods being used and the ultimate quality of the produced architectural designs.

More and more often architectural designing is based on working with virtual objects. In order for the graphics editor to generate the required two-dimensional drawings, it is enough to request the appropriate method of projecting the 3D model. The graphics editor will create floor plans, facades, cross-sections, perspectives and axonometric projections, all in accordance with the rules of descriptive geometry [2].

In computer aided designing, three main methods of defining space can be distinguished:

- digital form definition,
- computerized form finding,
- computational form generation [13].

The article discusses the issues related to digital form definition based on CAD (Computer Aided Design) and BIM software. A great deal of publications dealing with these problems has already come out. They present the optimal methods of using computer aided designing software, creating technical drawings and modelling virtual reality [12] together with methods of visualization.

Introduction to BIM technology can be found in the following: BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors by Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston [8] as well as in BIM Content Development: Standards, Strategies, and Best Practices by Robert Weygant [25].

The usage guidelines for the program are provided, among others, in the following publications: ArchiCAD by Jesse Russell and Ronald Cohn [21], Начали! ArchiCAD by Andrej Orlov [18] as well as ArchiCAD 17 – Grundkurs by Bernhard Binde [3], and

ArchiCAD 17: Praxiseinstieg by Detlef Ridde [20]. The notion of BIM has been discussed in the following publications: ArchiCAD.Wprowadzenie do projektowania BIM by Rafał Ślęk [23], ArchiCAD 17 BIM Modelling und Dokumentation by Bernhardt Binde [4], Building Information Modeling for Construction Using ArchiCAD by MohdShiratuddin, Shane Germany, Tulio Sulbaran [22], as well as in Основы BIM Введение в информационное моделирование зданий by Vladimir Talapov [24].

2. BIM Technology

Digital form definition dates back to mid-1970s. It was then that technical drawings were beginning to be created with the help of vector graphics software. In the late-1990s, applications based on creating virtual buildings were introduced [8]. Such model constitutes the base on which later 2D drawings are made. This method is represented in such computer programs as: AutoCAD Architecture by Autodesk, Revit by Charles River Software (later Revit Technology Corporation), ArchiCAD by Graphisoft [6], ArCADia-Architektura by Polish company INTERsoft [7], Bentley Architecture by Bentley, or IDEA Architecture by 4M Software. The increasing popularity of designing in BIM technology was connected with the introduction of IFC format (Industry Foundation Classes) [6], which constituted the platform for exchanging data between BIM-class computer software and various participants of the designing process. IFC, being an independent format of files, is compatible with most BIM applications.

Design in BIM technology involves building a 3D model, which is the ‘preliminary realization’ of the object. The system relies on 3D elements which are defined by means of parameters. It enables registering all the necessary data required by all participants of the prospective building process. The digital form of the object reflects its physical and functional characteristics. All data stored in BIM format is internally consistent – particular parts of documentation contain interrelated information. Any changes made to the BIM model are automatically visible in all drawings, perspectives, facades or cross-sections [23].

3. ArchiCAD Software

ArchiCAD application, developed by the Hungarian company Graphisoft, is the program which implemented the very idea of BIM right from the start. It was the year 1982/1983 when the first version 1.0 appeared. It was based on creating structures in 3D geometry, on the basis of which 2D drawings were generated – floor plans, facades, cross-sections etc. The ‘Virtual Building’ concept, which to a large extent realized the BIM idea, was introduced in the program as early as in 1987 [6]. The distinctive feature of this application is the way of creating 3D model, similar to the architectural approach to designing and constructing buildings. The idea of the program is based on drawing in the system which is close to WYSIWYG (What You See Is What You Get), so whatever appears on the screen, will closely correspond to what is printed out. Modelling begins with the selection of floor plans in which the designer defines geometrical and material parameters of walls, window and door frames, openings etc., on the basis of which the program is able to produce expenditure estimates. This process may be called ‘preliminary construction’ because the model of the future building is being created

from the objects which correspond to real construction elements (walls, ceilings, beams, etc). Any changes made to the virtual building are transferred to floor plans and vice versa [1]. All the technical and designing documentation has been prepared in this way starting from the 9.0 version of the program. Before, it had to be prepared in a separate program called PlotMaker. Moreover, ArchiCAD application allows storing data in the format of IFC files, which makes it compatible with other computer software involved in the designing and construction process [9].

4. Flexijet – conducting inventory of historical buildings in BIM system

Flexijet system consists of two elements: hardware (tripod, laser distance meter, touch sensor and rotatable device (Ill. 2–4)) and software which manages the measurement process (Ill. 1). Currently, it is compatible with the following programs: ArchiCAD, Rhino, Compass CAD10, Scala, PaletteCAD, PythaCAD [9].

In the area of inventory systems for buildings, Flexijet works best with the ArchiCAD application. It conducts laser measurements and simultaneously creates standard ArchiCAD elements in BIM technology. The resultant model may contain complete detailed data of the building undergoing inventory thanks to very precise coordinates. The accuracy of measurements is 2 mm, which guarantees a very faithful rendering of the object. Understandably, it is especially crucial with historical buildings and their technical documentation. During the measuring stage, such complex elements as windows, doors, stairs, balustrades, etc., may be created. As they are parametric objects, their models constitute ideal basis for planned modernisation. It is a very important aspect of the Flexijet system especially in Poland, where adaptations, rebuilding and building extensions account for over half of all building activities conducted in urban areas. The information stored in the BIM model may also serve for various simulations and analyses [10].

Standard range-finders provide us with a set of points that are defined spatially. Creating inventory requires a rather time-consuming process of linking these points and their interpretation. The Flexijet system allows for instant modelling of particular elements of the virtual building (Ill. 6). Therefore, the first step in conducting measurements is choosing which part of the building will be measured and recreated in ArchiCAD program. Flexijet laser range-finder is positioned on a point by hand or with the help of a touchpad. We get the reading of the range and, on the basis of three points in space (at least 3 in case of a wall), a BIM model of an element is created. Further measurements enable us to model particular interiors. Measuring elements invisible for the range-finder is executed by metering and indicating 3 base points that are visible from both positions in which the Flexijet device was installed. Next, the device needs to be repositioned and the previously established reference points must be located, which enables us to continue conducting measuring operations and create the virtual model [15–17].

5. Modelling details

When modelling architectural details in ArchiCAD assisted by Flexijet, one should get acquainted with possibilities of obtaining data and possible applications. Flexijet measuring system can provide very important information about a given structure. Having this data

before the start of actual modelling effectively saves time and facilitates adding details later on. The output data can be divided into the following categories:

- photographic documentation of the building, particular details, ledges, etc.,
- spot metering with the use of Flexijet system and ArchiCAD program executed on the views of the facades, cross-sections and in 3D view mode,
- measurements defined by lines, polygons, arches and circles using Flexijet and ArchiCAD in facade and cross-section views.

Although laser distance-measuring is very precise, it cannot provide all the necessary information. It has to be remembered that, during the inventory, very complicated shapes may not be possible to be modelled straight away. Reconstruction works should be preceded by photographic documentation since multiple elements must be created during a separate stage in the studio. Thanks to the photographs, we get comparative material and there is no need to come back to the place of inventory. The next step is spot metering executed with the help of a Flexijet device. It begins with establishing fixed marking spots, which define the position of the object irrespective of the position of the distance measuring device. The coordinates obtained in this way are very precise. In this way, it is possible to measure a particular detail, establish points defining its length and width as well as characteristic elements. Another possibility is using the tool which allows for drawing straight and curved lines. It is possible to define essential divisions of a detail, axes and geometry of a particular element. In order to do this, one needs to open the view mode of appropriate facades or cross-sections in ArchiCAD and start drawing in them. It is done by the means of spot metering with Flexijet the first and last point of a straight line, or three points in the case of a curved line, circle or a rectangle. If an object has an axis of symmetry, it is not necessary to contour all its elements, only the ones which will be replicated by its mirror image (Ill. 7).

This very method was used for measuring and defining the front facade of the former Royal Palace in Łódź. The team of architects, including Farid Nassery, Szymon Filipowski and Rafał Zieliński, prepared documentation together with a virtual model and details. (Ill. 9–13). One thing which is especially worth mentioning here is the modelling of portals on the basis of the obtained data. The first and fundamental step was modelling profiles of walls and balustrades. The greater the density of the metering spots, the more precise profiles geometry will be. The same effect can be obtained using lines and arches. After entering the profile into the ArchiCAD library, it is possible to draw a balustrade with the ‘wall’ tool. The 3D image created in this way will display all the details and ledges which have been measured earlier. A clear advantage of this method is its precision and the possibility to define the geometry from a large distance with no need to use scaffoldings (Ill. 7).

The same element may be created with the help of the ‘Morph’ panel, which was further developed in ArchiCAD 16. Apart from building morph objects from scratch, it is possible to transform the already-existing elements. For this purpose, one needs to draw the contour and trace with the ‘Fill’ tool, and change into the morph element with the help of the so-called “magic wand” (pressing and holding the spacebar). After rotating it in appropriate position, the ‘tube command’ may be used, which may be a straight line, a curve or a polygon (Ill. 8).

The next stage is refining the details. Depending on the scale of a building, additional measurements may be required. Before starting the inventory, it is worth establishing how detailed it should be and what exactly constitutes the focus of our interest. Laser measuring with Flexijet enables us to obtain a huge amount of data, including the curvature of the walls, vertical deflections, or small changes in the profiles of the analysed elements. Hence the need

for establishing the level of detail refinement of our inventory measurements as well as the amount of time we want to devote to it.

In the case of the balustrade of the portal in the Łobzów Palace, profile, metering, and division measurements were conducted with the accuracy of 5 mm. However, the details, such as roses and pilasters, were defined only by marking their main geometry. Modelling of these elements was based on the 'Morph' tool and its additional functions thanks to which various morph elements can be joined into one or removed. It has to be remembered, though, that in case of using such operations on morph elements, their result is permanent. It means that such operations cannot be 'undone' at a later stage, and returning to the original shapes is not possible. Such option exists only with 'Wall' type elements. Additionally, The 'Morph' tool has the option of 'Smooth & Merge Faces', texturizing separate each face and 'Modify Segmentation'.

During the process of modelling, it is crucial to remember about the following:

- checking the correctness of the morph elements – many elements may contain mistakes which are invisible on the screen and, consequently, the program is unable to 'close' the morph element. Such an object is empty and will have no cross-sectional filling. It may also result in the incorrect edition of polygons it is made up of in some other computer programs as well as during the attempt of visualization of a given element. If possible, the morph element should be checked after each operational step. In order to do that, one needs to choose DESIGN > MODIFY MORPH > CHECK SOLIDITY,
- switching off layers which are not being used at a given moment – with very complicated objects, it is advisable to only leave the layers which are being worked upon at a given moment visible, since it speeds up working in the 3D view,
- editing layers in the 3D window in 'wireframe' view – this option is useful when using functions for solids; editing objects in such situation does not overload the scene, which enhances considerably the process of modelling.

6. Conclusions

Digital tools developed for inventory systems in BIM technology can be used extensively in architectural research and conservation works. The precision of measurements and modelling results in a better description of both the state an object is in as well as a possible range of required renovation works or modernisation. Unlike most 3D scanners, the systems like Flexijet are not based only on a point cloud, which needs to be reinterpreted and converted in order to get 2D images. A project executed in BIM technology resembles building a detailed virtual 3D model, together with simultaneous preparation of designing documentation. The result of such inventory is a 3D model of the whole building or its part, which can be freely edited with all changes made to floor plans, facades and cross-sections remaining consistent throughout. Thanks to the ArchiCAD interface, BIM allows preparation of very accurate cost estimates on the basis of obtained data and, consequently, facilitating scientific research as well as influencing possible future renovation decisions. Therefore, it is an extremely useful tool in reducing costs of the renovation or conversion of a building. Moreover, 3D models of architectural details may constitute the basis for detailed comparative analyses, and possibly the basis for recreating them with the use of 3D printers. Constantly advanced computer techniques result in innovations and improvements of inventory systems, designing and renovation methods, contributing to their greater accuracy and widening the scope of applications.

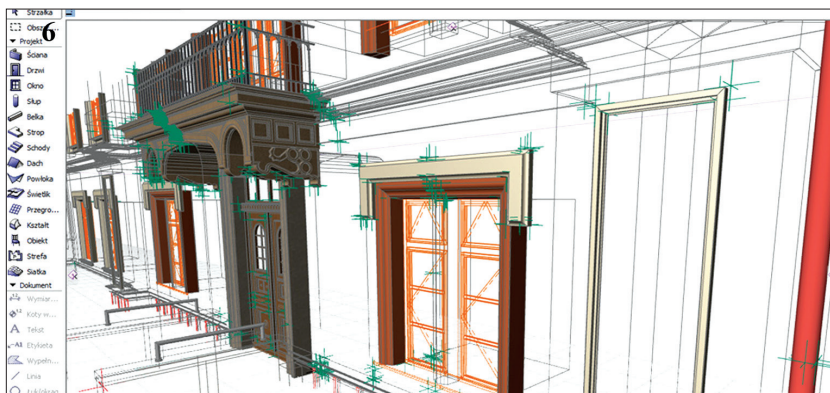
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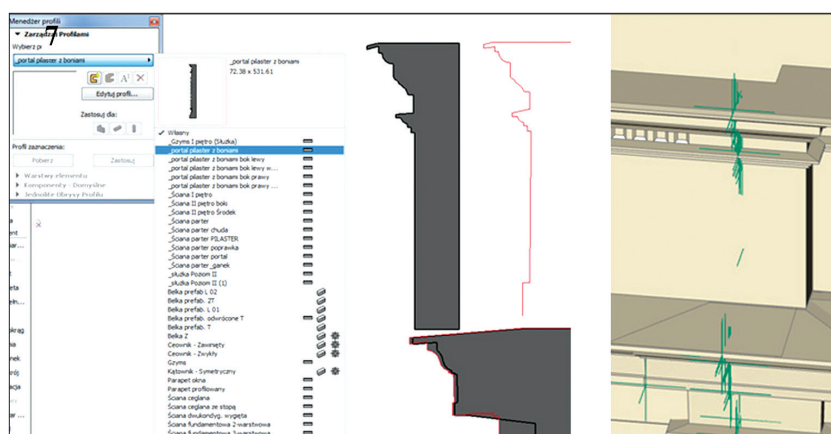
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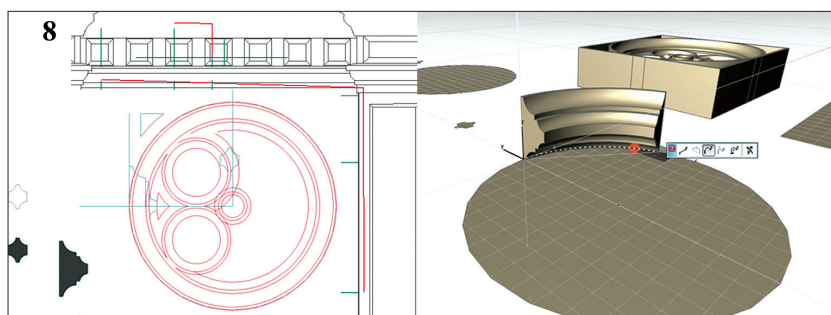
Ill. 1–5. Flexijet device (photos by Rafał Zieliński, 2015)



III. 6. The measurement of the Royal Palace in Łobzów which employs FlexiJet system (photo by Rafał Zieliński, 2015)



III. 7. The example of profile measurement and their use in FlexiJet system (photo by Rafał Zieliński, 2015)



III. 8. The example of detail measurement and their use for 3d modelling (photo by Rafał Zieliński, 2015)



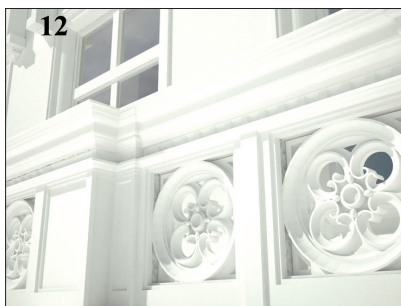
III. 9. 3D visualization of the Royal Palace in Łobzów (photo by Rafał Zieliński, 2015)



III. 10. 3D visualization of the Royal Palace balcony in Łobzów (photo by Rafał Zieliński, 2015)



III. 11. 3D visualization of the Royal Palace archway in Łobzów (photo by Rafał Zieliński, 2015)



III. 12. 3D visualization of the Royal Palace balcony rose detail in Łobzów (photo by Rafał Zieliński, 2015)



III. 13. 3D visualization of the Royal Palace detail in Łobzów (photo by Rafał Zieliński, 2015)