Experimental Study of Possibilities for Developing a Building Information Model of a Laser-Scanned Physical Object

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Abstract: The methodological approach when using a scanned physical object to build a building information model (BIM) is based on laser scanning technology and aims to create technical documentation of existing buildings, most often with the status of historically significant sites. The BIM technology can be used as an integral part for the creation of the documentation in the process of construction and of the new sites, as well as their administrative and managerial control in the process of their construction and operation. The essence of the experiment is to model space in a parametric three-dimensional model (BIM) in the ArchiCAD program, using a laser-scanned physical object (point cloud). The cloud obtained from the laser scan contains detailed spatial information, which is used in the basis of creation of a construction information model (BIM) and control during the development of the model. The laser-scanned physical object (point cloud) contains the same geometric information as the construction information model (BIM), but with a much smaller amount of data, the file size is visible - point cloud - 30.41 MB, BIM - 9.83 MB). The advantages of BIM over the point cloud is to give the ability to edit the model, to study the energy behavior of the model, to create construction and technical documentation of the scanned object, as well as to disclose the ability to fill in technical data and parameters based on the map and cadastral basis. By means of the density of the point cloud (parameter of the equipment used - laser scanner) of the scanned object, information is obtained and used with sufficient detail and accuracy about the physical data of the real object and this is the basis for the full and comprehensive content of BIM. Based on the sufficient detail created in the BIM for the physical object, it is possible for its combinability and its actual use in the real environment.

1. Introduction
This article can be defined as a study of a current and significant problem - the relationship between a construction information model (BIM) and a laser-scanned physical object (point cloud). Experimental research is an attempt to analyze, systematize and summarize the problems and methodology of using point clouds in the generation of BIM on the scanned physical object.

2. Point clouds
The result of laser scanning of a real physical object is a 3D point cloud. The point cloud is a detailed array of points in 3D space. It is characterized by high accuracy (2 ÷ 10 mm), high resolution (3 ÷ 15 mm distance between points) and low noise level. Point clouds can be subjected to further processing (eg. conversion from local to another coordinate system, modeling of point clouds and transformation into 3D models). Scanned millions of points easily and accurately become surfaces by processing with
appropriate software. The spatial models prepared in this way can be converted to any of the known CAD systems for further processing. [1]

3. Building Information Model

BIM technology combines three different but interrelated concepts:

• Building Information Modelling: This is a PROCESS of creating and exchanging data about a building during its design, construction, use, maintenance and demolition, i.e. during its full life cycle. BIM allows participants in these processes to access the same information through the interaction of different technology platforms.

• Building Information Model: Is a DIGITAL DESCRIPTION of the physical and functional characteristics of a facility (building) that serves as a shared source of data and information about it. It forms a reliable basis for decision-making during its existence, from creation to destruction and.

• Building Information Management: Represents ORGANIZATION AND CONTROL of business processes using information from a digital model for the exchange of information throughout the life cycle of the product. The benefits include - centralized and visualized information, preliminary feasibility study, sustainability of solutions, effective design, integration of specialties and installations, complete construction and technical documentation, etc. [2]

Building Information Modeling (BIM) and virtual design and construction (VDC) technologies are about to become the standard in the construction industry today. Laser scanning has various applications for investment projects, ranging from new construction to renovation, and the data obtained can be useful for the entire project team, including architects and engineers, from the project concept to the project turnover. [3]

4. Experiment

An EXPERIMENT was made within the scientific project № BN-240/20 at the Research, Consultancy and Design Centre of UACEG on the topic "Study of the possibilities for creating three-dimensional geometry in CAD / BIM environment from laser scanned objects" with laser scanned physical object: auditorium 407, Rectorate, UACEG.

SUBJECT OF THE EXPERIMENT: to build a construction information model (BIM) in the ArchiCAD program because of a laser-scanned physical object.

OBJECTIVE OF THE EXPERIMENT: to model the space of the auditorium in a building information model in the ArchiCAD program using a laser-scanned physical object (point cloud).

TASKS OF THE EXPERIMENT: to parameterize the geometry of the laser-scanned physical object, to study the scenario behavior of the object in terms of energy efficiency, sunscreen, derivation of construction quantitative parameters and geographical information situation.

SCOPE OF THE EXPERIMENT: auditorium 407, Rectorate, UACEG. Initial data for the scanned physical object - the training auditorium on the 4th floor in a four-story building from the 50s of the last century.

METHODS FOR CARRYING OUT THE EXPERIMENT:

• hardware - laser scanner model Trimble TX6;
• software - for processing the scanned data Trimble RealWorks, for building a BIM on the laser scanned object - ArchiCAD.
5. Theoretical aspects

The use of BIM technology, as described above in defining the concept, has different concepts in its actual application. In the specific experiment, the priority is the PROCESS of building a construction information model (BIM), after which it can be studied in order to ORGANIZE AND CONTROL business processes, using the DIGITAL DESCRIPTION of the physical and functional characteristics of the model.

In the process of building a BIM is particularly important geographical information situation of the model. In the virtual environment, it is possible by entering the necessary information (latitude and longitude and altitude) to position the BIM at a specific location on the globe (Figure 1). This information is used to "play" different scenarios for design solutions and of the future maintenance of the new facility (building). The possible options for using BIM are:

- filling in technical data and parameters on the basis of the map and cadastral basis;
- solving the geometric facade layout;
- choice of materials for the facade layout;
- different possibilities of heating methods;
- various possibilities for shaping the surrounding environment.

![Figure 1. Geographical information situation of the model in the ArchiCAD program](image)

In the specific case with the use of a laser scanner model Trimble TX6 for scanning a real object, there is no possibility for accurate geographical information situation. Additional measurements are needed to position the point cloud at its exact location in space. This additional data is needed to automate the process of modeling and generating a BIM, both to obtain a correctly placed BIM in the space, and to obtain accurate results in the study of BIM.

Another main aspect in the building of BIM PROCESS is the accuracy in creating the model. [4] For this purpose, in software products using BIM technology there are a number of methods for precise generation and organization of BIM elements, some of these methods are:

- interception of characteristic points on the objects (figure 2);
- intelligent cursor showing additional information;
- input of precise coordinates from the keyboard;
- adhesion to surfaces of three-dimensional objects.

Accuracy in the construction of the model is required in order to be able to use the built BIM and other participants in investment design and construction. The accuracy of the built model allows the management of the BIM and the playback of different scenarios for its use, as well as for the preparation of precise quantitative accounts.
In this case, with the use of a point cloud of a laser-scanned physical object, the ability to accurately construct the model by "capturing" points is applicable. The geometry of the laser-scanned physical object is made up of an array of points in space (as the name suggests) and gives very detailed information about the real physical object, but the same geometry has a high density of the point cloud - to achieve the desired detail of the physical object, but in BIM technology this is a problem for the possibility of intercepting specific characteristic points in the construction of the "idealized" BIM. The density of the points in the cloud does not give unambiguous geometry such as surfaces, edges or vertices, the geometry with which the BIM applications work in this case the ArchiCAD program.

In the process of building a BIM, it is also important what is the degree of comprehensive detail of the model, to what new detail will be modeled the object. In the ArchiCAD program there is a level of detail (Level Of Details) of library objects, which is mainly related to the depiction of BIM elements in the drawing documentation and in particular to different degrees of detail of the elements when drawing at different scales. Other methods to BIM-plify or complicate the presentation of the model at a certain scale are: partial display of the structure of the model (Partial Structure Display) and options for detailed presentation of the model (Model View Options Combinations) (Figure 3). This technology allows seamless publication of "idealized "BIM in different scales respectively and different degree of detail, which is not feasible when using the geometry of the point cloud of the laser scanned physical object.

Figure 2. Methods for precise generation and organization of elements in the ArchiCAD program

Figure 3. Methods for BIM-plifying or complicating the presentation of the model at a certain scale in the program ArchiCAD
In the process of building a BIM should be used to separate the elements on certain grounds in a layer structure (figure 4). Using the color model of the point cloud, we can navigate the scanned elements of the physical object and easily and categorically organize their distribution, in the respective layers of the BIM. The separation of the elements of BIM gives a rich opportunity to reduce the displayed information and respectively to publish and share specific information with other participants in the investment design and construction. Flexibility and combinability when using layer organization is a powerful tool in BIM technology, which is missing in the original laser-scanned real physical object.

![Layer organization and layer combinations in the program ArchiCAD](image)

Figure 4. Layer organization and layer combinations in the program ArchiCAD

6. **Practical guidelines for building a virtual BIM in a software product ArchiCAD**

The ArchiCAD program allows you to insert a file - a cloud of dots in two formats: *.e57 and *.xyz. Both formats can be generated directly from the Trimble RealWorks program for processing laser-scanned objects. When inserting the file with a point cloud, a choice is made as to where the captured object will end up. The laser-captured physical object is transformed into a library object in the ArchiCAD program, as such it (the library object) has limited possibilities for editing (figure 5). The generated library object can be placed in the space of its original location (global coordinate system) or at any point (local coordinate system of BIM), but as it is clear from the comments above for accurate geographical information situation, additional constructions and settings for accurate binding of the level of the virtual BIM on the point cloud. Generating a plate in the three-dimensional window and subsequent floor settings - height and absolute elevation altitude (figure 6). Precise resizing of the plate in the point cloud in the window in the plan etc.
Here we encounter the second problem of scanning and the resulting point cloud. There are parasitic points from the cloud that prevent the visualization of the object in the workspace. Precise extraction of points from the overall cloud survey is required. It must be possible to reduce the scanned points (parasites to drop out), this is necessary when processing the point cloud and generating the file for information exchange between the software to the scanning device (Trimble RealWorks) and the program ArchiCAD.
object it is possible to determine the thickness of the enclosing elements, in this case there is no external scanning and the experiment is reduced to shaping the internal space of the auditorium and the wall thickness will be conditionally 25 cm (figure 7).

Several techniques are used to precisely and accurately overlap the scanned point cloud with BIM:

- generating sections through the two objects (point and model cloud);
- selecting areas with the "marking" tool and visualizing these areas in the 3D window;
- temporary cutting surfaces through the model in the three-dimensional window.

![Figure 7. Slab (parametric object) and built walls along the contour of the slab](image)

Here we encounter the third problem when working with the point cloud. The density of the points gives a precise, accurate and detailed image of the real object. But this detailed array of points is a problem when working in the ArchiCAD program and in particular with the application of the methods of accurate and precise construction of BIM, by capturing specific characteristic points of the elements [5]. By building a BIM on the point cloud, the surfaces scanned with the laser scanner are reconstructed, idealized and replaced with "correct" objects [6]. By "correct" object is meant a standard parametric object from the program in the form of a parallelepiped such as a plate, wall, column, etc. [6]

Using the layer structure of the program we generate parametric objects - walls, slabs (floor, ceiling), columns, beams and other structural elements and organize them in layers with the necessary attributes (name, priorities) (figures 8 and 9). We reduce the information displayed on the screen and work only with the point cloud and the specific category of elements. We create and use combinations of layers (visibility or not, editing or not).
**Figure 8.** Example of work in the three-dimensional window of the program with the possibility of precise placement in the space of windows (upper side lighting)

**Figure 9.** Final result precisely placed windows and beams
7. Conclusion

From the experiment made on the creation of BIM using a laser-scanned physical object, the following advantageous conclusions can be listed for practical use:

- The laser scanned physical object (point cloud) contains the same geometric information as the construction information model (BIM), but with a much bigger amount of data the file size is visible - point cloud - 30.41 MB, BIM - 9.83 MB);
- The laser scanned physical object does not allow editing, unlike the rich possibilities for editing and research of the generated BIM;
- The laser scanned physical object does not allow the reduction of information, in fact it is a library object, unlike the BIM which allows different variants of publishing;
- The laser scanned physical object does not allow the publication of drawing information, unlike BIM which allows different options for publishing additional drawing information (figure 10) - sections, facades, interior unfolding, etc.

Despite the above conclusions in favor of the practical application of BIM, it does not follow that the point cloud has no place in the preparation of drawing documentation, on the contrary it is an important and integral part of its accuracy and detail of the methodology of BIM on existing sites, especially those with the status of historically significant sites.

Figure 10. Final result with additionally generated drawing information - distribution, section, unfolding and perspective
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