Possibilities of Using Modern Technologies and Creation of the Current Project Documentation Leading to the Optimal Management of the Building for Sustainable Development

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Abstract. Nowadays, we use many of the modern technologies to make the optimal design of new buildings. Building Information Modeling Technology offers state-of-the-art solutions that allow the design of a building to create in many variants a realistically time-consuming development process and, by virtue of an almost fully automatic assessment of the variants, choose the most appropriate one according to the required criteria. Such a design of the building assumes its optimal behavior according to the criteria required by the investor, the user and other stakeholders, but also helps to keep the construction towards the sustainable development goals. There are many existing buildings that have obsolete properties. The management and durability of such buildings is very costly. Such buildings should be refurbished to meet the properties and imitations of new building behavior. 3D scanning technology goes hand in hand with the building sector digitization and outputs from 3D scanning technology serves as a useful basis for further working with data using BIM technology. This paper outlines the possibilities of creation of basics for current documentation with graphical information of these buildings and how it may serve for evaluation of possible options for repairs and reconstructions through the whole building lifecycle and further use in facility management.

1. Introduction
The BIM Technology is mostly linked with design of a new building and new approach to make a project documentation and construction. But the most significance use, from the aspect of costs, lies in the operation phase of building lifecycle and facility management [1].

1.1. BIM
This paper is dealing with existing buildings and advantages of its conversion into BIM project documentation. “Knowledge of objects, their behavior, and other characteristics has high impact on whole building life cycle. Other structured and unstructured knowledge is rightfully added (e.g. historically based experience, needs and requirements of users, investors, needs for project and objects revisions) Grasping of all attributes into system for collection, managing and time control of knowledge.”, Nývlt wrote (2017) [2].
1.2. Building Lifecycle
As Nývlt (2016) wrote: “First steps of Building-Life-Cycle are of major importance of effective and efficient building sustainability. All decisions made would always rely on good, timely, and correct data. Usage of BIM models in terms of Building Information Management can support all decision through data gathering, sharing, and using across all disciplines and all Life Cycle steps. It particularly significantly improves possibilities and level of life cycle costing. Experience and knowledge stored in data models of BIM, describing user requirements, best practices derived from other projects and/or research outputs will help to understand sustainability in its complexity and wholeness.” [3].

2. Necessity of current project documentation
BIM technology and project documentation created with BIM is not just an issue of new buildings. BIM Technology has many advantages, which are connected to well enhanced process of design, but also with other phases of building lifecycle. The cost of building operation is 48%, and the maintenance and repair costs are 23% of the total lifecycle cost of the building [4]. This suggest that it is very convenient to create a BIM project for existing buildings and use it to reduce costs and simplify the facility management of the building during its use.

Former project documentation usually consists of drawings and text attachments stored in paper form. It is definitely not an exception, that documentation doesn’t correspond to current form of the building. This may complicate many situations such as planning of reconstruction, new type of building use, rentability of space, but also in emergency situations, such as firefighting, when rescuers rely on mystifying information, which may lead to loss of life.

The current documentation with reliable information is very reliable product, that BIM technology offers. Also, the information model of the building serves as a platform for design of reconstruction and its evaluation by simulations. When creating the information building model, input information is the basis. There are several ways how to gain the input information. It can be provided by manpower with laser meter, recording of measured distances and creating new drawings or recording new changes in to former documentation. A slightly more accurate and faster way of gaining information about the construction can be 3D scanning methods, which this paper is concerning about.

3. 3D scanning as a method for creation of existing building BIM model
We have a choice of several ways to create a BIM model of existing building. Examined state-of-art technology is the use of a 3D scanning device that allows to produce the most accurate building model for the shortest period of time on the basis of measurement of building properties which are graphical information such as dimensions, shapes, material indentation and material structure, etc. High demands on computer performance and high demands on workers knowledge of geodesy and 3D scanners may be the negative.

The main feature of laser 3D scanning is the short measurement time in relation to geodetic methods or classical laser meter. Data processing is, however, significantly longer, as is the case with photogrammetric focusing. It is precisely photogrammetry that 3D scanners should eliminate from technologies used for measurement and modelling of existing objects. However, after performing a marked amount of comparison, it was found that both methods suitably complement each other [5].

4. Measurement and data processing procedure
This paper reveals the research of effective process of 3D scanning of building objects (Figure 1). The process is determined on the basics of authors’ experiences in the field of gaining data representing object shape, dimensions and dimensions of single elements. The process is described according to Business Process Model and Notation version 2.0.1. as specified in [6].

4.1. Reconnaissance of measurement object (A. 1.)
When reconnaising object / terrain, it is appropriate to adjust the angles of scanning beams impact to the particular shape and surface of the object. In addition, it is necessary to plan the layout of the puncture
points and scanning standpoint, taking into account the features and capabilities of the scanner used, especially whether the scanner is panoramic or laser, as well as scanning density and scanning range.

4.2. Measurement and settings of parameters of scanner control software
The acquisition of spatial information about the scanned object is called measurement [7]. This information is the coordinates of the points lying on the surface of the measured object, and at the same time, the intensity of the returned beam used to measure the distances. Measurement also includes the photographic focus of the subject, either separately from the digital camera that is part of some 3D scanners.

The scanning process itself is primarily the setting of the parameters appropriate to the object (D.1.) to the scanner control software (A.2., A.3.). The selected parameters then determine the density (D.2.), accuracy (D.3.), and scanning area (D.4.).

4.3. Division the object into single areas, scanning execution and merging single scans
There is now way to scan an object – a building – by single scanning process. It is necessary to scan the object partially. In order to gain one model, the cloud of points representing whole object, it is necessary to plan whole process of scanning and divide the process into scanning of single areas. From this plan, we get the plan of scanned areas (D.4). Subsequently, after the scanning execution of single areas, these scans have to be merged depending on the method used.

When scanning large objects, in our case buildings, we get dozens of scans (clouds of points) that need to be merged into one homogenous cloud. Modern laser scanners are integrated into the total station. This allows us to scan both in the general coordinate system of the scanner and in the global coordinate system. Talking about buildings, the total coordinates of building are important. Total station is used to measure just several defined points and assigning the global coordinates to them. The phase of whole scanning process and points’ definition depends on used method of scanning procedure.

4.4. Two methods of scanning procedures depending on the method of merging single scans
There are two possible ways how to scan an object and gain a model representing the object. Choosing proper method is depending on the shape, structure and surface of scanned object.

4.4.1. Method for scanning execution and merging scans using puncture points. A very important part of scanning is puncture points definition (A.4.) that affects the accuracy of the merging of individual scans (point clouds). The individual positions of the points must allow the points to be transformed with the control. For this reason, they must be targeted and stabilized with maximum accuracy. There is also a possibility to scan without a puncture points, for example, if the scan object has precisely identifiable signalling points such as sharp edges or non-repetitive shape changes. The other option is to scan the whole object from one standpoint. This method performs lower accuracy and, in some cases, failing to merge scans.

Most scanning systems use a specific type of signal to stabilize the pointers, which the scanning system can automatically search for, in some cases, focus with higher resolution and therefore precision over detailed points. It is also possible to select as the measured points or the points derived from the measured ones, such as the use of spherical or semi-circular signals to scatter the ball after scans, and its calculated center to be determined geodetically [7].

It is important to provide the list of puncture points (D.5.), which are placed on the scanned object. These points will serve for merging of single scans. In order to assign the model, the cloud of points representing object, global coordinates, it is necessary to measure global coordinates (A.5.) of listed puncture points (D.5.) by total station.

Next (Figure 2), the execution of single scans (A.6.2.) follows according to the plan of scanning areas (A.6.). In order to provide scanner settings (A.6.1.) for each defined area containing some of defined puncture points, we define the starting and ending zenith angle as well as the starting and ending
horizontal directions. The most important parameter is the scan density, which affects the detail of the cloud of points, which results in the total measurement time and the amount of data obtained. Outputs of this scanning is scan, cloud of points (D.6.), of scanned area containing puncture points. All of planned area are scanned.

These scans (D.7.) are subsequently merged (A.7.). For merging of scans using method of puncture points, we use so-called transformation. This transformation is executed in space, an ICP (Iterative Closest Point) algorithm is used for the calculation. It works with two sets of points: P and Q, where P contains points pi for i = 1 .. np, and Q contains points qj for j = 1 .. nq, where P is to be transformed to Q. Points are given by x, y, z coordinates [7].

After merging scans, there is homogeneous cloud of points (D.8.) of merged single scans containing puncture points with assigned global coordinates. Due to these puncture points, global coordinates are assigned (A.8.) to all points from this cloud (D.8.) representing the building and its position in global coordinates.

4.4.2. Method for scanning execution and merging scans using scans overlays. The second method of merging a large number of scans into on homogeneous cloud of points is a link base on the partial overlapping of individual points. These points can be linked different ways in accordance of object shape intricacy.

Scanning areas must contain points common to multiple areas. These points form an overlapping (A.9.). Defined overlapping (D.9.) will be lately used for merging single scans. Scanning of single areas (Figure 3) is done in the same way as in the previous method (A.10.). Difference is in the method of merging.

Object shape intricacy (A.11.) causes divergence of merging ways. Automatic merging scans (A.12.) using scans overlapping can be executed on object (part of object) of high shape intricacy. When object (part of object) is of low shape intricacy, manual merging scans (A.13.) using scan overlapping has to be chosen. Manual merging consists in linking selected points. In practice, a combination of automatic and manual merging (A.14.) takes place so that the dimensional accuracy of the model is as accurate as possible.

Merged scans contain a homogeneous cloud of points (D.12.) which doesn’t contain global coordinates. In order to set the model, the cloud of points, into the global coordination system, selected appropriate distinctive points are defined. Global coordinates are assigned to these points (D.13.) by total station measurement (A.15.). In accordance of distinctive points global coordinates (D.12.), global coordinates are assigned (A.16.) to all points from the cloud.

4.5. Cloud of points cleansing (A.17.)

After merging the scans into one homogeneous cloud of points, we can make further adjustments to achieve a precise model. These include, in particular, the removal of redundant points, the reduction of point noise and the assignment of actual colours according to photographs.

Excess points we think especially of the points that were created due to the partial overlapping of individual scans. This will duplicate these points and removing just these points will reduce the amount of data being processed. Most projects contain tens and hundreds of thousands of points; for this reason, it is good to consider whether it is inappropriate to work with the data to divide the model into smaller logical units and to process it in parts (eg: individual floors of the building).

The accuracy of data obtained from 3D scanning is affected by a number of factors that cause errors in cloud points. These errors are manifested by inaccurate positioning of individual points in the selected coordinate system. This reduces the quality of the resulting model.

Measured clouds of points are colourless, but in software, they have assigned colour according to the intensity of the returned signal. The colour to create a BIM model is not important. But for people with a worse spatial conception, the colour and material structure will provide a concrete idea of the object and a clear final processing. Based on the images we capture, we can assign the actual colour to each point. This simply means finding the display and its parameters between the frame and the points in the
space. There is a symbolic relationship here that the frame coordinates $x'$, $y'$ are a function of spatial coordinates $X$, $Y$, $Z$ [7].

$$x' = f_x (X, Y, Z)$$
$$y' = f_y (X, Y, Z).$$

After cleansing of cloud of points, a triangular network representing scanned object is created (D.14.).

Figure 1. Process of 3D scanning of building object
Figure 2. Subprocess of 3D scanning of building object – Scanning using puncture points

Figure 3. Subprocess of 3D scanning of building object – Scanning using overlapping

An example of the final output – visualization of data object D.14. Triangle net of represented scanned object is shown in Figure 4.

Figure 4. Triangle net visualization of represented scanned object: The riding hall in Český Krumlov

5. Conclusion
The BIM way of thinking represents the new approach to digitizing of the AEC Industry (Architecture, Engineering and Construction Industry). Pursuance and monitoring of the whole building lifecycle, from the first idea to its demolition, within BIM Technology represents the use of modern technology leading to the better quality of constructions. Technology of 3D scanning objects is well known nowadays. This
paper reveals the research of effective process of 3D scanning of building objects. The process is determined on the basics of authors’ experiences in the field of gaining data representing object shape, dimensions and dimensions of single elements. The proposed process may be considered as an effective method for gaining basic data representing reality of building objects. Traditional method lies in measurements by laser rangefinder and the complex extraction of measured data into drawings, which are often inaccurate and therefore unreliable. Proposed process helps to effective and low-time demanding measurement of existing objects as a basics for creating BIM model, which may further gain the up-to-date and easily editable “digitwin”, where we can simulate the operation costs of building, environments negative impacts and benefit from many other aspects that BIM Technology offers. Model of physical form of a building can be acquired using 3D scanning. From 3D scanning, we are able to gain significant graphical data, as dimensions, shapes, material indentation and material structure, etc. Other properties (such as energy, mass, cost, etc) of building and building elements must be obtained other ways if necessary. These properties are part of further model development. BIM libraries may be helpful for this purpose.

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