TERRESTRIAL LASER SCANNING – POINT CLOUD IN BUILDING CONSTRUCTION

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ABSTRACT

3D laser scanner refers to terrestrial (stationary), mobile (vehicle-mounted), or aerial (aircraft-mounted) scanning devices. Terrestrial Laser Scanning (TLS) is increasingly used in the Architectural, Engineering, Construction and Facilities Management industry (AEC&FM) due to the significant performance improvements that it can support. TLS is a modern technology that is revolutionizing surveying works. One of the key advantages of laser scanning is the ability to quickly obtain large amounts of data in a short time. The result of laser scanning is a point cloud. Point cloud is essentially a three-dimensional (3D) imaging system which is used for the digital representation of the existing respectively of the real state of building objects. Point cloud has in building construction a very wide application. The aim of this article is explain what is TLS, what is a point cloud and describe how to use him in different areas of building construction.

Key words: *terrestrial laser scanning, laser scanner, point cloud, digitizing, building construction*

1 INTRODUCTION

In context of construction we often meet with the requirement to document the real state as a background for projection purpose. This requirement relates to many shortcomings, e.g. time demands, inaccuracy during the measurement, complicated measurement using traditional methods for complex structures, project documentation isn't accurate, isn't topical or doesn't exist (Makýš, Funtík 2015, p. 66). Currently in construction it is often talking about modern technologies and especially about the digitization, which represent three-dimensional (3D) imaging systems. Three-dimensional (3D) imaging systems are tools which allow us to rapidly spatial measurements of building structures with error in measurement approximately ± 1-3 mm (Randall 2011, p. 797). One of the innovative tools at present which allows non-contact surveying of spatial data is 3D laser scanning. Laser scanning is a modern technology that is revolutionizing in surveying works (Bosché, Guenet 2014, p. 212). Laser scanning is a method of capturing a real world environment or object in three dimensions (WARNER SURVEYS). Laser Scanning systems use the latest pulse laser technology for distance measurement and determines the position of points spatial polar method (Kašpar *et al.* 2003, p. 31).

> *In recent years, the use of terrestrial laser scanning (TLS) technique in engineering surveys is gaining an increasing interest due to the advantages of non-contact, rapidity, high accuracy, and large scale. This technique delivers millions of accurate 3D points (mm level accuracy) with a very high point density in a short time (up to 1 million points per second), which makes it a valuable alternative or complementary technique for classical topographical measurements based on total station or digital photogrammetry* (Wang *et al*. 2014, p. 325).

3D laser scanning of solid objects such as buildings has proven to be an effective method of capturing data and modelling buildings for heritage or remodelling purposes (Stanley 2013, p. 9). Further use of laser scanning in the construction industry is a surveying the real state of the steel structures, complicated technological units and structures, static calculations of steel structures, highway construction (roads, tunnels, bridges), etc. (Kašpar *et al.* 2003, p. 31).

2 TERRESTRIAL LASER SCANNING (TLS)

TLS has become a more widely used technology for many applications, e.g. building modelling, architecture, deformation modelling, structural monitoring, heritage preservation, as well as crime scene analysis (Stanley 2013, p. 8, 17,). This technique delivers millions of accurate 3D points with a very high point density in a short time, which makes it a valuable alternative for classical topographical measurements (Kang *et al.* 2009). Some of the main benefits of TLS data acquisition is the increased speed of data capture, accuracy of plans, elevations, profiles, volumes and area calculations able to be extracted from scans. They are also capable of safely acquiring data that cannot always be easily accessed such as bridge beams, rock faces and highway information. The construction industry has used TLS as a tool for reduction of costs by eliminating 3D design errors and to accelerate projects completion timeline. Also when a project is complete, an accurate record of the as built project can be recorded for future reference (Stanley 2013, p. 8, 17,).

The scanning process can be divided into three steps:

Scanning **ON SITE** is an automatic process. The laser scanner captures an object from different positions. Number of positions is individual and depends on the size of the measured object. The scan time depends of the number of positions the scanner, quality and resolutions, requirements of the investor, complexity of scan object, etc. Aspects that influence the scanning time is a lot.

PRE-PROCESSING the raw scan data is the next step which begins the process of registration. Registration of the raw scan data in the same coordinate system is the most important step in processing of terrestrial laser scanner measurements (Altuntas, Yildis 2010, 1). In other words, registration is the process that brings together all the scans. The result of registration is a **3D model point clouds. Point cloud is simply said a true image of reality transferred to the virtual environment to scale 1:1.** Every point of the point cloud has coordinates X, Y, Z. The next step of pre-processing is cleaning and filtration of a 3D model point cloud from redundant points.

Point cloud is used for many purposes, including to create as-build documentation, point clouds are converted to mesh models, 3D CAD or BIM models, quality control during construction, accurate bills of quantities, etc. These applications represent **POST-PROCESSING**.

Fig. 1 real state / 3D model point cloud

3 POINT CLOUD IN BUILDING CONSTRUCTION – POST PROCESSING

So, we have prepared a realistic 3D model point clouds some construction, but what to do with him now? Point clouds after processing in pre-processing is only the raw product which has a small use. In the area of historic buildings is a common requirement also the presentation of the results objects. Whether it's capturing the current state before reconstruction or presentation of the renewed buildings, these realistic models from point clouds are very appropriate. There are several possibilities of professional presentation: Digital models in PDF format - simple display of 3D object; Digital models in 3D printing - printed realistic 3D model to scale (from point cloud to mesh); Video-clips on virtual objects - very interesting and engaging animations, fly-around and overflight around an object, we can see various details and perspectives on building from places where the camera can't normally get (Ornth 2015). Two important applications of TLS are ***as-built/as-is modeling*** and ***construction quality control*** (Bosché, Guenet 2014, 214). 3D laser scanning is a fast, precise, reliable and cost-effective method for creating as-built drawings or models (WARNER SURVEYS). With the use of 3D scanning, it can capture the interior and exterior of existing structure in 3D and create a precise 3D model with 2D as-built drawings, directly from the captured scan data. Laser scanning provides more accuracy than traditional measuring tools (LASER DESIGN). For creating 2D project documentation or 3D CAD models from point clouds there are several of ways. Exist a simple free products such as the open source product CloudCompare which allow viewing of point clouds or simple measurement. In this case, we perform a classical distance measurements on an object from point clouds and of these distances in a CAD program we design vector drawings. This method is slow, drawing is simple, but for many purposes it is sufficient. A little better are the CAD systems (e.g. AutoCAD or Microstation) that allow simple operations with point clouds. The advantage of this way is that drawings we design directly from point clouds that is shown in the CAD environment. We have a better control over the creation of the drawing. Processing of large amounts of drawings or objects with a complicated shapes, spatial wooden or steel structures and piping systems, it is a more difficult problem. There is appropriate use software such as (Descartes, PointSense (Fig. 1 – left)) that allow complex CAD elements automatically replace geometric elements. For example, software by clicking on the pipe (Fig. 2 – right) alone identifies his shape and dimension and replacing it with geometric shape (Ornth 2015). From historic buildings to international airports, terrestrial laser scanning is an ideal 3D as-built documentation solution for any building or survey project's needs (LASER DESIGN).

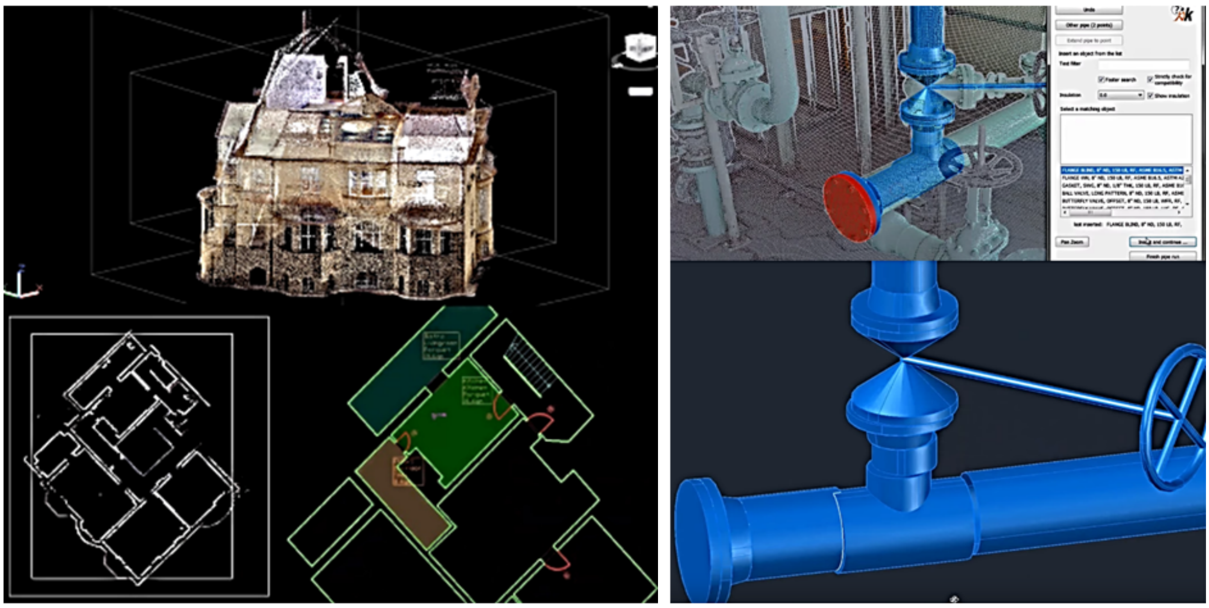

Fig. 2 as-built documentation from point clouds / automatic modeling

This was a few options how to work with point clouds in the *planning phase*. In this phase (*as-built/as-is modelling)* is the greatest potential of using the laser scanning technology, e.g. also, especially for the reconstruction of buildings where the project documentation doesn't exist, isn't accurate, isn't complete etc. But we know use of laser scanning in other phases of the life cycle of the building. 2D or 3D CAD models from point clouds gives us information only about the geometry of the object. Which it is of course very important information but if we want to get more information from the model, it is possible to create a 3D model of object in *BIM environment*.

Whatever your role in construction, it's more than likely that you've heard the term "BIM Model". But what do people actually mean when they say this? On a typical construction project, a lot of information is produced. The trouble is that information is often unstructured, poorly co-ordinated and difficult to find. In the context of construction, BIM is the process of delivering and operating built assets using well-structured digital information that all the necessary parties have access to. Operating in this way - requires all parties to collaborate and share the information they create in a mutually accessible online space known as a *common data environment* (CDE). Information 3D models can be used to inform all stages of a built asset's lifecycle; from inception right through to operation and renewal (THE BIM). Than we can write: *Building life cycle = BIM life cycle.*

TLS and information 3D BIM model – ***planning phase*** – intelligent model that contains all information about an object.

TLS and 4D in BIM environment – ***realization phase*** – Having an accurate 3D representation of elements from scanned data allows for further use of the data when considering the 4D time aspect associated with each construction element (Gleason 2013, p. 6).

TLS and 5D in BIM environment – ***realization phase*** – Scanning of work before construction has also proven to be a value-add as the quantifiable information coming from 3D elements allows for more detailed cost planning (Gleason 2013, p. 7).

TLS and 6D in BIM environment – ***use/maintain phase*** – A clear benefit to laser scanning can be identified when considering the final deliverables that will go to the owner at the end of a project. Being proactive when managing the building offsets the cost of scanning (Gleason 2013, p. 8).

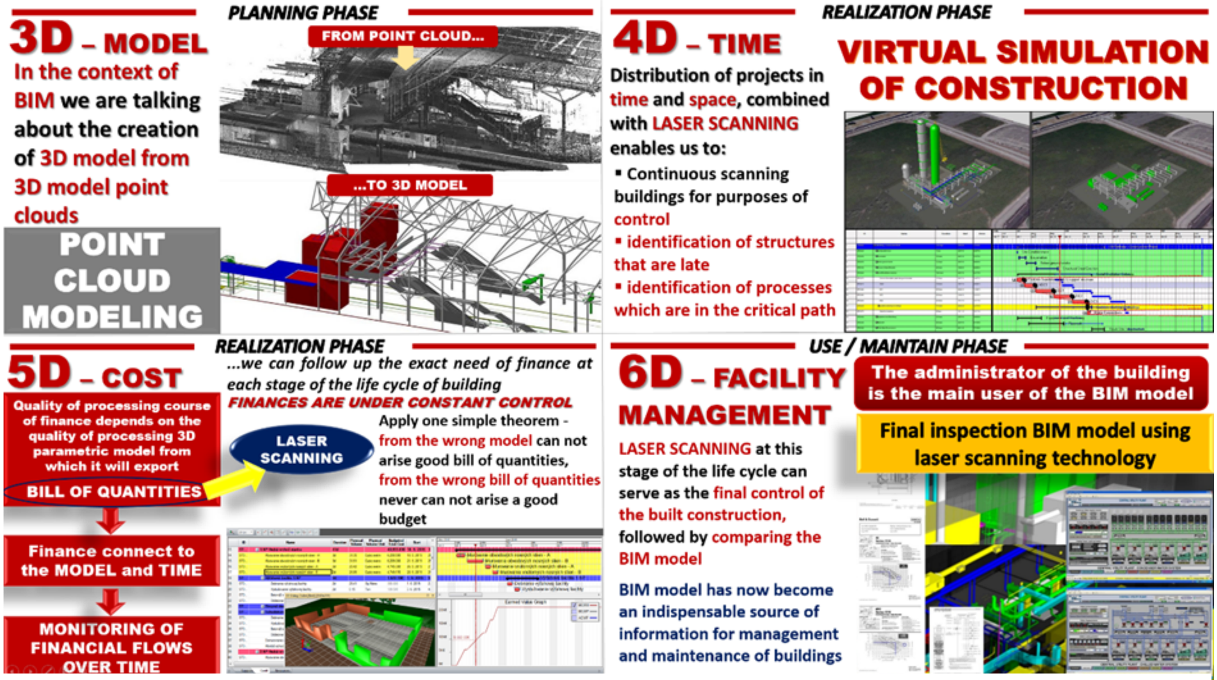

Fig. 3 laser scanning and life cycle of building in the BIM environment

Oftentimes renovation projects include a mixture of existing to remain elements with newly placed elements. This is a space for further use TLS, and it; construction quality control or quality control of 3D model. A practical example is the modernization of hospitals in Melbourne, where at first was created the BIM model from available project documentation. Investor dwelled on eliminating errors which represent increase time and financial demands. It was an existing building, so the BIM model was created from existing project documentation. The architect wasn't satisfied with the information which weren't verified. The hospital was measured using TLS and the resulting model of point clouds was connected with existing BIM model (Makýš, Funtík 2015, p. 67). The laser scan proved invaluable in upgrading the accuracy of the BIM. In some areas, windows and columns were displaced by up to 150mm from their actual position. The spatial upgrading of the BIM ensured that the model was accurate enough for construction design (AAM 2016).

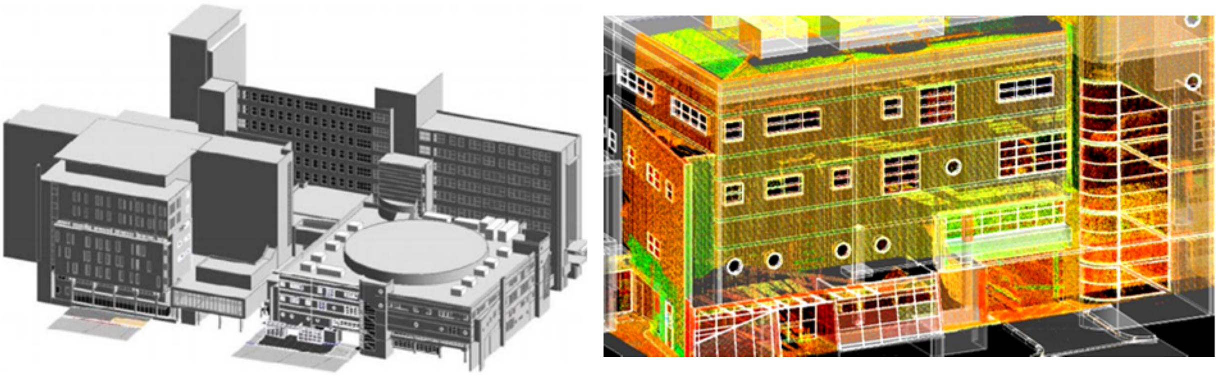

Fig. 4 BIM model created from an existing project/ integration BIM model with a model of point clouds

4 CONCLUSION

Creating as-built documentation has never been easier, more accurate, or more complete than it is now, with the use of laser scanning. Laser scanning is a method of capturing a real world environment or object in three dimensions. Through the use of laser scanning technology, scanner captures information about a building structure or site in a point cloud file and then uses that data to create deliverables that are useful to Architects, Engineers, and General Contractors. These deliverables can range from the raw data itself to 2D drawings and 3D models. Laser scanning gives the design team more information up-front, which allows design decisions to happen sooner and makes for a more complete set of bidding drawings. This, in turn, allows contractors to have confidence in their bids. Architects and engineers can make critical design decisions sooner and with more complete and accurate information. Additionally, they can creatively utilize the point cloud data directly for construction documents, minimizing their drawing or modeling hours. Contractors can streamline their construction process and prefabricate more materials off-site. This can result in reduced labor costs, fewer schedule delays, and the satisfaction of delivering a project on time and under budget.

Acknowledgements

The article presents a partial research result of project VEGA – 1/0677/14 „Research of construction efficiency improvement through MMC technologies".

The article presented a partial research result of project: CE II, ITMS: 26220120037, Excellent integrated research centre of progressive building construction, material and technology

The article is the result of the Project implementation: University Science Park TECHNICOM for Innovation Applications Supported by Knowledge Technology, ITMS: 26220220182, supported by the Research & Development Operational Programme funded by the ERDF.

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