

The usage of ground laser scanning for construction and building informational modeling

B F Azarov and I V Noskov

Civil Engineering Faculty, Polzunov Altai State Technical University, Barnaul,
656038, Russia

stf-ofigig@mail.ru

Abstract. The article defines ground laser scanning (GLS) as a process of total geodetic survey with the survey system, which measures the distance between the instrument and the object's surface and records corresponding directions in horizontal and vertical planes. The components of GLS system and data obtained during the scanning are indicated. The necessity of processing the data obtained by GLS is pointed out. The main usage of laser scanning which is the obtaining of precise geometric characteristics of an object complemented with any attributive data is stated. Thus, GLS can be widely used in buildings and construction information modeling. Analyzed the range of Russian documents regulating common requirements and developing rules and the usage of information models of massive building objects for applied tasks during different object life-cycle phases as well as usage of contemporary project and survey technology, particularly GLS. The conclusion is made stating on the idea of information modeling supposes its usage containing information characterizes the building object model during the different phases of its life-cycle. In relation to stated facts the role and position of GLS in information model development of a construction site, executive and operational models of an object are pointed out.

1. Introduction

Ground laser scanning (GLS) is the process of total geodetic survey with the survey system, which measures the distance between the instrument and the object's surface with high speed (from several thousands to a million dots per second) and records corresponding directions (horizontal and vertical angles) [1]. The GLS technology is the process of object scanning with the purpose of creating tridimensional model with specified accuracy and detalization.

The system of GLS includes a laser surface scanner and a field personal computer with specialized software which forms the tridimensional image of an object's model – a scan with redundancy of information.

The scanning results are [1]:

- A scan, the raster image which pixel values are vector elements with the following characteristics: measured distance, intensity of reflected signal and RGB-component, indicating the real color of a dot (most laser scanner models receive this characteristic value from nonmetric digital camera).
- The dots array of laser reflection from an object in the field of a scanner view. The dots have 5 characteristics: X, Y, Z coordinates, intensity and real color. Operating a scanner and processing the scanning results require specialized software [2]. Most laser scanner manufacturers also develop the software for their scanners.



The measurement results received from laser scanning need preliminary processing, including [3]:

- Conversion of physical measurements to geometric, i.e. calculation of spatial coordinates considering multiple corrections (weather, instrument error, refraction etc.);
- Data filtering, i.e. the deletion of “false” measurements, which are the results of laser signal interaction with environment and local objects under different circumstances;
- External or relative data orientation, i.e. reduction to a specified or a single coordinate system.

Depending on receiving accuracy of spatial coordinates of scanned objects we can define the following GLS fields’ application [1]:

- Topographic surveys (average square error of spatial coordinates $\leq 10\text{sm}$);
- Planning surveys ($\leq 5\text{sm}$);
- Architectural and building surveys ($\leq 1\text{sm}$);
- Expert or precision surveys ($\leq 1\text{mm}$);
- High-precision surveys ($\leq 1\text{mm}$).

GLS is actively used in different surveys for nearly 20 years. The main purpose of scanning is obtaining of an object precise geometric characteristic which can be supplemented by any attributive information. Basically, laser scanning is a method that allows to create the digital model of the surrounding area by representing it as an array of dots with spatial coordinates. Currently in Russia GLS technology is used in designing renovations and reconstructions of engineering constructions, building facades, historical sites, roads and railways. GLS is also applied in particular architectural and construction surveys, including buildings and constructions information modeling.

2. Role and place of the GLS in the BIM process

Nowadays, the GLS technology can be widely used in buildings and construction information modeling. These documents regulate common requirements and rules of developing and information models usage of massive construction objects don’t mention the usage of GLS for BIM purposes. Although the project documents are mentioned the GLS and specified the phases of information model development, where this technology could be used. In the first edition of rules set “Building information modeling. Modeling guidelines for various project life cycle” [4] in review of an object (construction or building) life-cycle during pre-project construction preparation in p. 5.4.1 GLS is stated as one of the modeling ways of the existing construction site situation. Further the same document reviewed the process of combining the GLS data with a building digital model in order to measure the deviation of its actual position from the project (p. 5.6.3). Practically it meant that survey data obtained with electronic measuring instruments including laser scanners must be used for “as built” (p.5.6.4 set of rules project) information model development. As a recommendation on digital model development p.9.5.3 if rules set project stated “as built”, information model should be based on executive survey documents which may include dot array files obtained using GLS method.

Basically, the idea of digital modeling is to use data models containing digital models, which characterize the object during different phases of its life-cycle. According to p.3.9 of rules set 333/1325800/2017 entered into effect 19.03.2018 “Building information modeling. Modeling guidelines for various project life cycle stages” [5] the object data model includes a digital data model (DDM) of an object and engineering digital area model (EDAM). DDM is defined as a tridimensional model representing physical, functional and other object parameters in digital form. EDAM is used as a means of topographic plan representation in objective-spatial form and developed using contemporary engineering and survey technology. Despite its obvious advantages over the traditional geodetic methods, the usage of GLS in engineering surveys is slowed down by the absence of actual regulatory and technical bases. Today there are no sectoral regulatory documents stating the rules and methods of laser scanning and the cameral processing of laser scanning data. The set 47.13330.2012 “Engineering surveys for construction. Fundamentals. Updated edition 2013” [6] laser scanning is mentioned in rules as a possible way to conduct a large-scale geodetic survey (p.5.1.3.2.2) and as a mean of obtaining the data for cameral tracing and choosing the optimal way of the linear object route projecting (p.5.1.4.3) [7]. Anyway, certain steps are taken toward filling the gap in regulatory base.

For example, the project of GOST “Design and survey work. Methods of laser scanning. General technical requirements” was developed at the initiative of “Geoproektizyskaniya” Ltd. The discussion of GOST first edition was held in 2016 [8].

Rules set 317.1325800.2017 entered into effect 23.06.2018 “Engineering geodetic survey for construction. General regulations for execution of work” [9], developed as an expansion of rules set [6] contains direct guidance on the possibility of different laser scanning methods usage (air, ground mobile and ground static) in large-scale topographic surveys (p.5.3.2.2). In addition, given rules set states (p.5.3.2.19) GLS can be used in geodetic surveys during construction process, renovations of buildings and constructions and in already built objects surveys. In the rules set [5] geodetic marking (p.5.6.3) and geodetic control (p.5.6.4) are viewed as the field of data modeling application during construction. First case suggests the usage of DDM and EDAM for implementing project solutions into work and the second one suggests combining the geodetic data with DDM and usage of EDAM corrected according to the results of geodetic surveys of a built object, engineering networks and landscaping. It is obvious that meeting such challenges at a high technological level and providing precision and objectivity of quantitative data is impossible without GLS.

Besides, when reviewing the rules of developing the data models in construction process the rules set [5] specifies the availability of “construction site model” (p.9.2.1) in development of DDM. Practically it means that the construction site model must include digital area model (DAM) created using the data of geodetic survey or obtained from large-scale topographic plans of the area. It must represent the area landscape before construction preparations. Also this model must include temporary constructions, main types of used assembly and lifting machinery, temporary roads and networks, fences, external engineering networks including the ones subjected to taking away, temporary and newly built constants. Practically, DAM should serve as a basis for tridimensional construction site layout. Such layout can be created by combining the project of infrastructure maintaining the construction process with DAM developed with SLS methods which will guarantee the availability of common coordinate system for creating a consolidated digital model of an object.

Finally, GLS can play an important role in development of “executional” data model. Such data model must contain actual sizes and actual realization dates of elements and constructions. Aside from structured data of completed work, object’s constructions and systems confirmed by acts of commissioning, acts of completed and inside works inspection changes coordination records and executive plans the mentioned digital model must be developed and corrected using these documents [5].

A digital model of already built object can be used as a reference for data usage in different data systems during object maintenance. In this case an “executive” model can be transformed into a digital “operational” model by removing the excess data related to object operational management [5].

An important but not properly highlighted aspect in regulative documents on BIM technology usage is the file format of 3D model object based on SLS data which should be used to develop and transfer the digital models for further processing. The rules set [5] states that “software solutions for development and usage of DDM must support export and import to the open IFC format (version 2x3 or higher)” (p.6.2.2), which is an international standard of data exchange in digital modeling in maintenance of civil buildings and constructions. However, in practice of SLS for BIM purposes file formats used for exporting a 3D-model base on GLS data are the formats supported by software which is used by project designers. Since the main software program used in project design of building objects in Russia is AutoCAD, the GLS data can be exported as .DXF, .DWG, .LAS and .PTC files.

3. Examples of GLS using for BIM in Russia

The above information can be illustrated by a few examples of GLS use for information modeling of buildings and structures in our country. Practically this kind of work is done in the form of single pilot projects mainly for the unique historic buildings, religious buildings, nuclear power plants, skyscrapers, etc. So, in 2015 the scanning of two buildings on Mokhovaja street (one – in three floors, another – in two floors) was carried out at development of the architectural solution for the Book

Museum of the Russian State Library in Moscow for the purposes of BIM-design. GLS was performed on two buildings on the street Moss (one – in three floors, another – in two floors) [10]. Information models of buildings were supposed to be used in their reconstruction. Before scanning area and a specified accuracy of work (± 20 mm) were defined. Two hours of time was spent on shooting, 22 scans were received. Data processing was to combine the obtained scans into a single whole, or to create a cloud of points of the entire scanning area, as well as to remove "noise" – foreign objects that were displayed during scanning (people, machines, trees, dust clouds in the atmosphere). The result of processing was a 3D-model of the shooting area, containing two buildings to be reconstructed (Figure 1). The model, built according to the data of the radar, was used by architects-designers to create a 3D model in the REVIT environment.



Figure 1. 3D model of two buildings on Mokhovaya street.

It can be illustrated with some examples of using GLS for buildings and constructions data modeling in Russia. Practically such work finds its use in single pilot projects of unique objects: historical and cult buildings, nuclear power plants, skyscrapers etc. For instance, the GLS of two buildings (a two-storey and a three-storey one) [10] on Mokhovaya street in Moscow was conducted as part of the architectural manifestation design of the Book Museum of Russian State Library for BIM project purposes in 2015. The data models of the buildings were planned to be used during the renovation works. The area and the precision (± 20 mm) of the scanning were set before the scanning start. The scanning itself took 2 hours and 22 scans were obtained. Cameral processing included the merging of scans together to form a dot cloud of the entire scanning area and the deletion of "noise" or interfering objects (such as people, cars, trees, atmospheric dust clouds). As a result the 3D-model of scanning area containing 2 buildings subject to renovations was developed. The model was built based on GLS data and used by project architectures to develop a 3D model in REVIT environment.

Another example of GLS usage for data modeling is the laser scanning of "Bogolyubovskiy" ore-dressing plant, Main Building in Krasnoyarsk region [11]. In January 2016 the scanning was applied to develop an "executive" BIM model of a manufacture building because the change of ownership from one economic operator to the other revealed the absence of full project and executive documentation and the further operation, as well as renovation or modernization of the factory. Due to these circumstances it was decided to use GLS and BIM to restore the lost documentation because laser scanning allows obtaining quickly precise construction measurement and BIM provides not only

the storage and management of spatial and attributive data but also the usage of supplementary documentation inside one data model.

The scanning of an industrial building with area of 3000 m², its additional constructions, equipment and communications placed on different levels took 2 days of work. The dot cloud obtained as a result was used by project designers to develop a precise and relevant BIM model of the factory (Figure 2). Cameral processing of the scanning data took 3 days and included reciprocal equalizing or merging into common coordinate system, quality control and dot cloud export into file format supported by Autodesk RCP software.



Figure 2. BIM-model of the factory, built according to laser scanning.

As a result, the contractor got not just the executional documentation for the operating factory but also a full BIM model which serves as a basis for further renovation, stores engineering data, allows planning renovation and maintenance and designing various renovation options.

For unique industrial and civil objects, the GLS is used as the means of construction monitoring. Practically, such objects as nuclear power plants and skyscrapers are designed and built with the use of BIM technology. For example, the project of Novovoronezh NPP-2 was developed using Integrator Smart Plant software with project 3D-model generation. The object was scanned during its construction and the obtained 3D-model was loaded into the project system where the actual 3D-model was compared to the project one. Then the data was analyzed by overlapping the certain sections of the dot cloud with the project model to reveal the ‘collisions’ or the deviations of actual geometric parameters of the construction elements from their project values. These data was used in supervision of the construction process [12].

One more example of GLS usage in construction supervising is the construction of “Lakhta-Center”, which is an ultramodern multifunctional social and business complex placed on the shore of the Finland Gulf with area of 400,000 m² and 462m high tower as the main axis. The tower of “Lakhta-Center” is twisted around its axis by 90°. Each new floor plate is rotated by 0.82° relative to the building axis creating the visual effect of building twisting to its top. Aside from the headquarters of Gazprom companies group, “Lakhta-Center” will be a scientific and educational complex, a planetarium, a medical center, a multifunctional hall for congresses and conferences, theater performances, musical and costume shows, a sports center, an outdoor amphitheater and a number of

public services (banks, shops, restaurants, cafes). This object is unique in its complexity and its construction monitoring is a pressing issue. Initially the contractor ordered to maintain a 3D supervision of the construction, which is the overlapping of an actual building with its project by comparing the corresponding 3D models. The executive schemes of metal structures, elevator shafts, and stairwells are made in the form of deviation color maps obtained from the data of GLS. The result of GLS will be an actual 3D-model of the constructed object, which will be used in its further operation [12].

4. Conclusion

In conclusion we would like to formulate the main results:

1) Nowadays level of GLS informational technology is the fundamental instrument of an object's precise data model development. The objectivity of data obtained with GLS is provided by almost complete absence of human factor. Basically the laser refraction dot cloud is a rapidly obtained data model which at least can be used for analysis of geometric properties and attitude of an object itself and construction site as well.

2) A data model of an object is complete when it is supported and updated during all phases of its life-cycle. The data containing deviation of a built object actual model from the project model can determine the object's maintenance expenses.

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