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APPLICATION OF LASER SCANNING IN INTERNAL SURVEYING OF PREMISES AND DEVELOPMENT OF 3D MODEL OF BUILDING

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Abstract
Nowadays, along with the classical and experienced surveying methods, modern technologies are rapidly developing and entering into the economy. Laser scanning has many benefits and uses. Application of this technology results in a point cloud from which it is possible to create three-dimensional models which can represent topographic properties, structure dimensions, and spatial relationships. The aim of the research is to investigate the application of three-dimensional laser scanning in the internal surveying of premises and in the development of the 3D model buildings. The task of the research is to apply the application of laser rangefinder and ultrasonic rangefinder method in the scanning of a building that is characterized by complex architecture, an interior garden, many protrusions, and a special layout of windows and doors. The use of the Stonex X300 laser scanner and Stonex M6 laser rangefinder has been described as well. To achieve the goals and objectives of the research, laser telemetry and ultrasonic telemetry method, method of three-dimensional modeling, as well as analysis of scientific literature, mathematical calculation methods, and analysis of documents and factual materials have been used. As the result of the investigation 3D model of a building consisting of 47 individual point clouds was developed. The main conclusion is that three-dimensional modeling as a computer graphics method for the three-dimensional representation of any object or surface can be used.
Key words: internal surveying of premises; laser scanning; laser telemetry; ultrasonic telemetry; 3D model.

Introduction

Nowadays, along with the classical and experienced surveying methods, the latest technologies are rapidly developing and entering into the economy. Increasingly, surveying companies use GNSS receivers, photogrammetry, and unmanned aerial vehicles, as well as laser scanning systems (LiDAR) in their daily work (The Rising Demand). Laser scanning procedures use laser beams, advanced sensors, Global Positioning Systems (GPS) (An improved solution…2011), Inertial Measurement Units (IMUs), electronic receivers, and photodetectors. Laser scanning has many benefits and uses. The application of this technology results in a point cloud from which it is possible to create three-dimensional models and represent topographic properties, structure dimensions, and spatial relationships (Challenges and opportunities, 2016). Using all these components, the laser scanner can calculate the exact coordinates of surfaces and structures.

Methodology of research and materials

Technical justification of application of three-dimensional laser scanning in internal surveying of premises and development of the 3D model of the building has been approbated on the example of the building of the Faculty of Environment and Civil Engineering of Latvia University of Life Sciences and Technologies in Jelgava. Stonex X300 laser scanner and Stonex M6 laser rangefinder were used to measure the object. To achieve the goals and objectives of research appropriate methods have been used– analysis of scientific literature, mathematical calculation methods, analysis of documents, and factual materials. To give a practical expression of the research results, the author applied laser telemetry and ultrasonic telemetry method, as well as methods of three-dimensional modeling. These advantages of QGIS software were used in research as well as abstract-logical method – to generalize and outline conclusions.

Discussions and results

Advantages of using laser scanning. Laser scanning has several advantages over alternative remote sensing methods, such as photogrammetry. Some reasons for using three-dimensional factor scans for surveying purposes are:

- currently the laser scanning method is the fastest method of earth exploration;

- within the laser scanning process can be collected millions of data points per second, reducing the time and human resources required to perform surveying work;
- laser scanning systems can be mounted on land or air vehicles, as well as mounted on simple measuring stands;
- using laser scanners can be reduced health and safety risks by obtaining information from dangerous or hard-to-reach places, as well as inspecting inaccessible areas (Airborne Laser Scanning), (An approach…2007).

Using LiDAR systems, surveying companies can collect point cloud data even from the most inaccessible areas. As laser scanning is a non-contact measurement method, it can also survey and collect data on protected areas or historic sites. From the detailed three-dimensional models created from the scan data, it is possible to create three-dimensional design (CAD) models. These models can be used to analyze the topographic situation, soil structure, and transport corridors, as well as to simulate construction or urban planning projects.

Spatial scanning is commonly used to scan the interior of buildings and interiors. Today, CAD applications offer advanced rendering and animation capabilities that allow better visualize the design of products (3D laser scanners, 2018; How 3D Laser scanning). One of the biggest disadvantages of laser scanning is that the laser beams cannot pass through some surfaces without creating reflections (Deep structural information…2022). Laser scanning can be divided into three types:

- terrestrial laser scanning;
- mobile laser scanning;
- laser scanning.

Terrestrial laser scanning is suitable for measuring compact objects, such as parking lots, bridges, buildings, shorter road sections, etc. This method ensures an accuracy of a few millimeters.

Because the laser scanner is placed on a moving surface it is important to know its location, therefore laser scanner must be synchronized with the global navigation satellite systems (GNSS) or internal measurement unit (IMU). This method is suitable for large line objects, such as coastlines, street networks, port berths, highways, railways, etc. Mobile laser scanning provides an accuracy of a few centimeters.

When using the ariel laser scanning method, the term LiDAR (light and radar) can often be heard. Scanners are usually attached to unmanned aircraft, helicopter, or airplane. This method provides an accuracy of a few decimetres (Why use a laser). In the practice of surveying work, there is often a desire to obtain data with an accuracy of 1 mm, although an accuracy of 2 cm would be quite sufficient (Mūsdienīgās uzmērīšanas tehnoloģijas, 2016).

Point cloud.

As a result of the application of the laser scanning method, a point cloud is obtained, as a result, processing of which a point cloud model is created, which is attached to the coordinate system (georeferencing). The point cloud is made up of millions of points, and each contains information about the coordinates of its location and the intensity of the signal's reflection (How to create a 3D, 2019). The point cloud can be called a document that contains information about the current state of surveyed area or object. The resulting point cloud can be used for different purposes in different ways:

- as data necessary for design;
- as reference information for the developed model by unmanned aircraft;
- two-dimensional section can be created from the point cloud model and a two-dimensional drawing can be developed based on it;
- various three-dimensional models can be developed from the created model, for example, soil models (solid-models);
- use in change monitoring, compare point clouds obtained at different times and identify changes;
- to compare control measurements with the point cloud information and with the project to detect deviations from the project, etc (Point Cloud (2019); Point Cloud and 3D).

The essence of a point cloud is the simplest form of a three-dimensional model (Figure 1).

Point clouds are created by scanning an object (Georeferenced Point Clouds, 2013). Scanning is completed using a laser scanner or a process called photogrammetry. The point cloud can be used as a visual record of the building, or it can "go through" the building, making accurate dimensional measurements as needed. Point

cloud files are a good way to store and use spatial data in three-dimensional modeling (How to create a 3D, 2019). Point cloud data must be recorded.

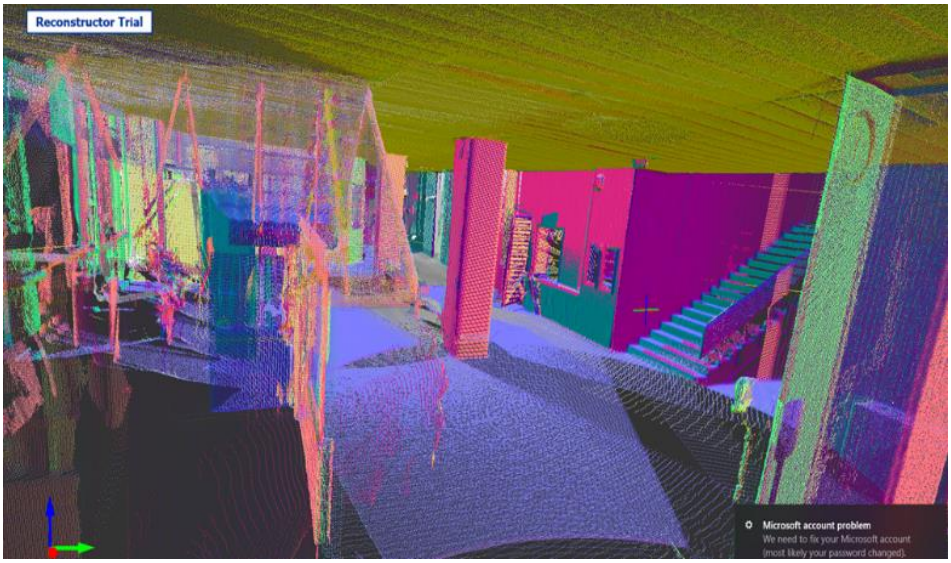


Figure 1. Network of point cloud (source: developed by author)

Only by merging together in an alignment process which is called point cloud registration, is it possible to create a cloud of all the points obtained. To create an accurate three-dimensional model, point cloud registration must be performed with the same accuracy as each point cloud internally. If not done correctly, any created model will be inaccurate and potentially worthless.
In surveying of premises can be applied methods as follows.

- laser rangefinder method;
- ultrasonic telemetry method (Ratkevičs et.al. 2017).

Laser telemetry method. Data processing allows the device to add, subtract, calculate areas, and volumes, and create triangulations. With a laser rangefinder, two sides of the right triangle can be measured, and the third can be calculated using the Pythagorean theorem (Figure 2).

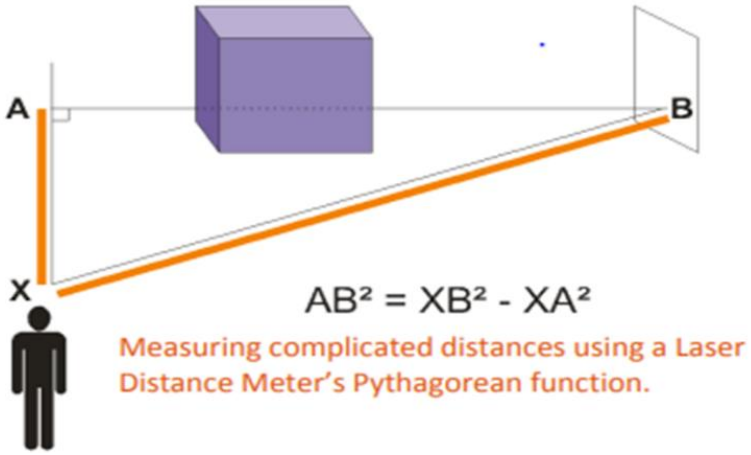


Figure 2. Measurement of complex distance with the laser rangefinder method (source: www.transcat.com)

Ultrasonic telemetry method. An ultrasonic rangefinder is less accurate than a laser rangefinder because the sound is much harder to focus than laser light. If the laser rangefinder provides an accuracy of a few millimeters, then the ultrasonic rangefinder has an accuracy of several centimeters. Ultrasonic telemetry measurements require a fairly large, smooth, flat surface as a target, which is a major limitation in their use. The use of

ultrasonic rangefinders is limited by obstacles in the path of the audible signal if a small target is selected or the signal is not strong enough (Figure 3).

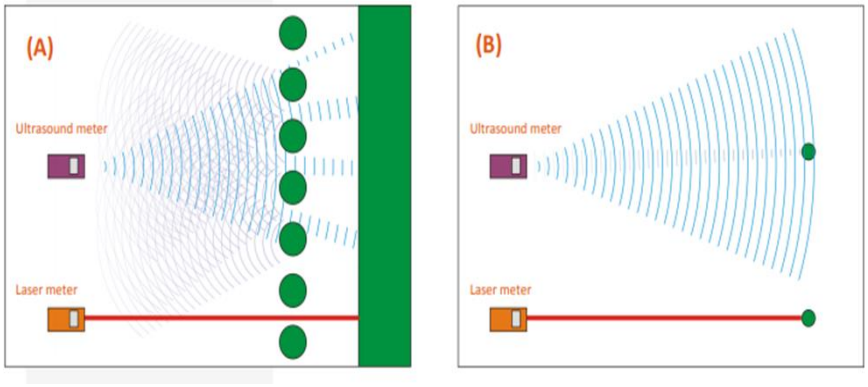


Figure 3. Limitations on the use of ultrasonic rangefinders (source: www.transcat.com)

Laser rangefinder Stonex M6 was used in the study (Figure 4).

Figure 4. Laser rangefinder Stonex M6 used in the study (source: author's photo fixation)

It is easy and convenient to work with this instrument. This tool not only performs primary –point-to-point measurement but also offers many different functions - area and volume calculation, determining the angle at the moment of measurement, etc.

The laser rangefinder method was used to compare data obtained with the laser scanner method. It was concluded that the laser rangefinder can be used as a control measurement method for an indoor three-dimensional model.

Application of laser scanner Stonex X300 in object measurement. The object to be surveyed is characterized by very complex architecture, an inner garden, many extensions, a special arrangement of windows and doors, etc. Work began on an approximate flow chart. The total number of scans was initially 68. Combining them areas where additional scans were needed were detected to cover the object with a point cloud. A mobile smartphone was used to transfer the data. Data were processed using Stonex X300 Manager software, which allows the resulting data archives to be converted to the required format so that they can later be uploaded as separate point clouds to Stonex Reconstructor and data processing begins.

Computer programs. The resulting scan archive needs to be uploaded to the Stonex X300 Manager PC software. It is possible to choose the format of the point cloud, and if necessary, it is possible also to create text files that display X, Y, and Z coordinates, as well as the ability to change image formats, etc. The three-dimensional model was processed using the computer program Stonex Reconstructor, which has many different functions for model processing, variation, and information acquisition (Figure 5).

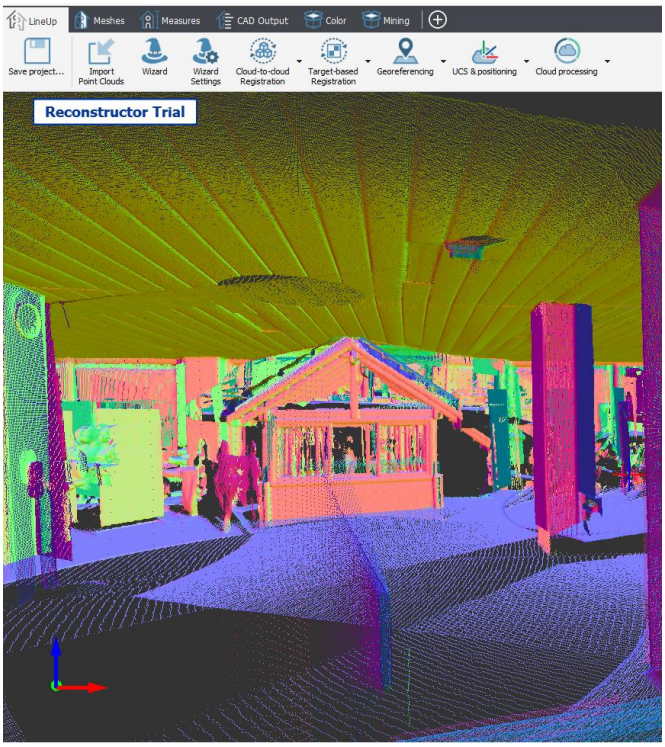


Figure5. Features offered by the Stonex Reconstructor computer program (source: developed by the author)

The initial action was to upload the modified file, i.e., cloud upload for each scan point. There are several ways to connect scan point clouds, but the study used the manual connection method. Two scans were selected that show the same objects in the room. The minimum number of common points must be 3. This function converts the resulting point cloud to a two-dimensional format. It is possible to convert this two-dimensional image of the model into the color format, light black and white or black and white, to make it as easy as possible to identify and find common points. The location of point clouds in the three-dimensional model is shown in Figure 6.

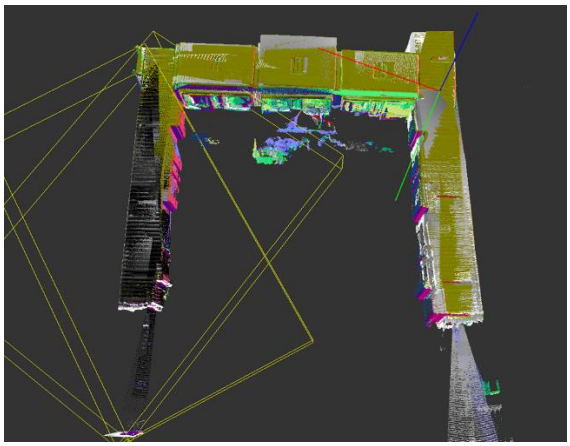
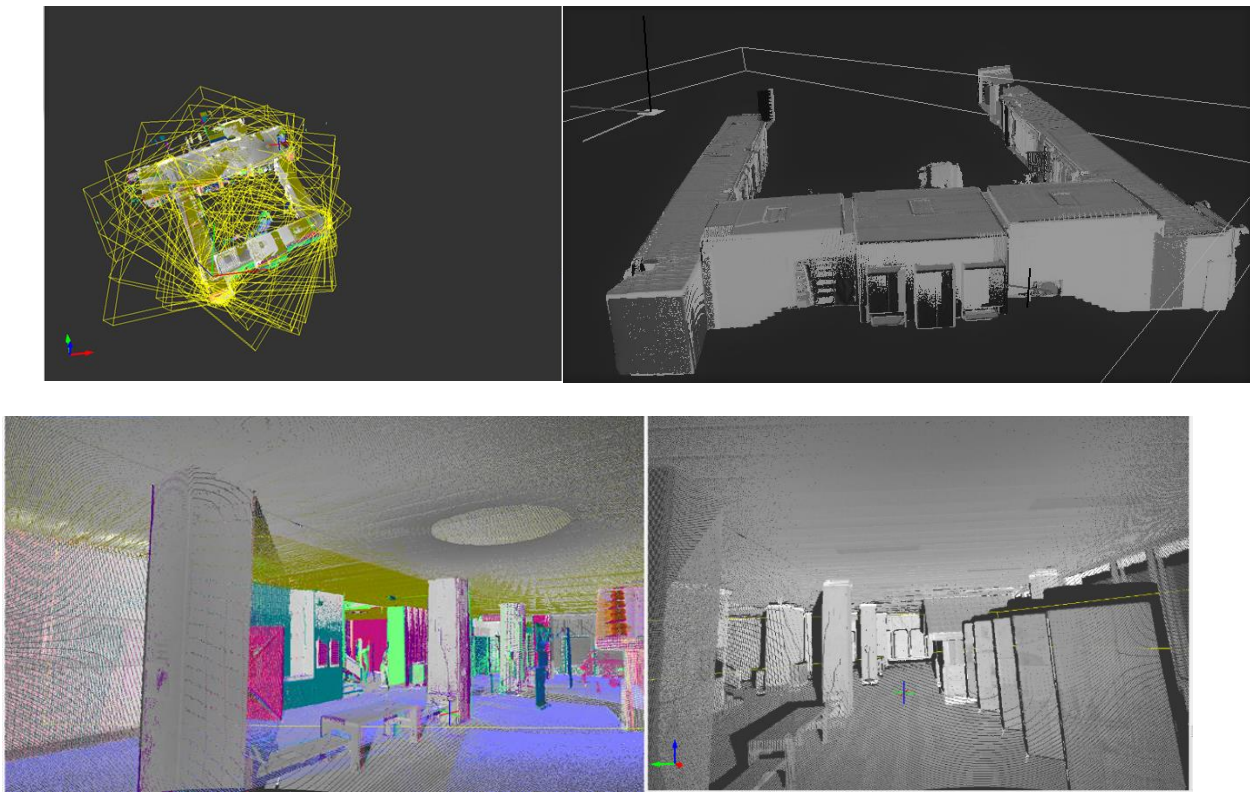


Figure 6. Location of point clouds in the three-dimensional model (source: developed by the author)

Indoor 3D model. Three-dimensional modeling is a computer graphics method for obtaining the three-dimensional surface representation of any object or surface. This three-dimensional model can be generated automatically or created manually by distorting the network or otherwise manipulating slopes. The core of the three-dimensional model is the network that is best described as set of points in space. The three-dimensional

model of an object consists of 47 separate point clouds, which are manually combined to form a common point cloud that forms a three-dimensional model. Because it is difficult to display three-dimensional model in two-dimensional environment, fragments of the model are shown in Figures 7, 8, 9, and 10.



Figures 7, 8, 9, and 10. Fragments of the indoor 3D model (source: developed by the author)

A laser scanning survey has been performed and a 3D model was created in the lobby of the building. Some dimensions were checked with a laser rangefinder. Control measurements showed that the laser scanning product is correct.

Conclusions and proposals

1. The laser scanning survey method is gradually replacing the classical and traditional surveying methods. Classical surveying methods are still relevant if it is necessary to measure the distance or location of certain points or to carry out a survey on a construction site, etc.
2. Today, remote sensing in the surveying industry is entering rapidly and is making a huge contribution to the performance and quality of work.
3. The point cloud obtained by laser scanning can be used in different ways for different purposes.
4. The laser rangefinder is an accurate and fast method of determining distance and requires only one person to work. It is versatile and easy to use.
5. The laser rangefinder can be used as a control measurement method for an indoor three-dimensional model
6. Three-dimensional modeling as a computer graphics method can be used to obtain the representation of the three-dimensional surface of any object or surface.

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