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Section: Technologies of Geodesy and Cadastre

Application of laser scanning technology in the renovation works

Angelika Goszczyńska, Paweł Łata

Institute of Geodesy, Oczapowskiego St. 1, 10-719 Olsztyn, Poland

Abstract

The object of research is a historic altar, located in the chancel of the Roman Catholic Church under the invocation of St. John the Baptist and Saint Roch in Jonkowo (Poland, Warmia). This historical object takes its origin from 1715. The alter contains two floors. In the upper part there is a picture of Jesus Christ, which is surrounded by angels. In the lower, larger part, there is a picture of St. Roch. In addition, there occur side ornaments and carved columns and statues of St. Peter and St. Paul.
The result of the research was to perform ancillary documentation for professionals conducting renovation of the altar. For this purpose the laser scanner technology was used. The authors, during the field works, performed over a dozen scans and photos from both sides of the altar. All these data were register together by using special HDS targets. The acquired point clouds present the front of the main altar in tree-dimensional space. The obtained data allow us to perform the virtual visualization. After data elaboration simple measurements of details in the altar, in a special software, was possible to conduct. These results became the basis for comparison the appearance and shape of the object before and after the renovation work.
The paper presents the process of obtaining the data and shows how to solve the problems related to their elaboration process. In addition, author present the possibility of application new technology of laser scanning and the obtained data by specialists.

Keywords: laser scanner technology; point clouds; altar.

1. Introduction

The architectural inventory of the historic buildings is required not only in the architectural and construction projects, but also during conservation and renovation works. All these works are performed in order to preserve magnificence of the valuable objects. The documentation obtained in this process contains information about condition of the research object, which enable design and perform protective works. What is more, they become very often the reference data to comparethe effects of conducted works.

In the traditional approach, the documentation is created based on photographic imaging, direct measurements and the description made during the initial inspection. A close-range photogrammetry has become a very useful technology, which based on the captured images, from the measurement positions, allows us to create model of object, its vectorization and cover it with various texture. The next step in developing technology is terrestrial laser scanning. In comparison with the close range photogrammetry is faster and allows us to increase the accuracy and the amount of the acquired data. Indication the advantages of this method over photogrammetric techniques require prior preparation the project work, the optimization and adjustment to the physical conditions of the test object. Accordingly with the above requirements, before the measurements, it is recommended to determine the positions of the instrument and calculate the number of the measuring stations. This procedure allows to eliminate the shaded areas, which may appears during measurements because of the natural obstacles as trees, other buildings etc. The angle and range between the instrument and the measured object is determined to limit the increase of the laser spot diameter which cause additional noise of the data and thus influences on their accuracy. The final product of measurements are point clouds with three-dimensional coordinates, that show the measured object. Having data from terrestrial laser scanner a structures, deformation and nearly each cracks of the historic objects can be detected.

Corresponding author: Paweł Łata. E-mail address: pawel.lata@uwm.edu.pl
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2. Characteristic of the tested object

The object of research is a historic altar, located in the chancel of the Roman Catholic Church under the invocation of St. John the Baptist and Saint Roch in Jonkowo (Poland, Warmia). It is constructed in the Baroque style in the first quarter of the 18 century in two stages – the first one dating back to about 1700 years and another 15 years later. The decoration in the church are made by unknown author from the area of the East Prussia. Some elements of decoration and the type of setting suggest the Isaac Rigi from Konigsberg. In 1883 the church has been renovated.

Architecture of the altar is a single axle and extended of two storey (dimensions: height 5.5 m, width 3.2 m, depth 0.55 m). Beginning with the base it is worth to mention about brick mensa obscured the wooden antypendium in the front, which was made probably in the second half of the 20 century. It consists of two square reliefs, which their dimensions 0.78 to 0.78 m, which separate and surround the sides of the gilded openwork ornaments. Reliefs represent following scenes from the Old Testament – the "victim Melchizedek" (left side) and "The Sacrifice of Abraham" (right side). Before the renovation work, in this element, the crack occurred on a large scope and the material loss was visible. This damage was located in the central part of the scene and spread through the whole of its length. This decoration is much older than the same frame of antypendium. Its origin is determined on the year 1725 and originally was situated in church in Glotowo [1].

Fig. 1. Antypendium before the renovation work

A small tabernacle with side decorations in the form of bas-relief floral ornaments, completed on the top corrugated indentation and profiled cornice, is set in the central part of the mensa. Setting the first floor is flat and in its main point an oil painting, originated also around 1725, is located. It shows the figure of "Saint. Rocha – the patron of pestilence" painted by local artist, who was inspired by Italian painting. This work is embedded in a carved gilt frame. Symmetrically to the picture the colonnade with decorative heads are placed on both sides. Between the columns the sculpture of St. Peter is placed in the left part and the St. Paul sculpture on the right side. They are situated on the front – end pedestals. The space above the saints heads is beautified curled lariat leaf. The setting from the side is complemented by the openwork ears composed of the carbon ribbons. Mounting them to the bottom using the wider part is incompatible with the state illustrated in the archive pictures. The second storey is separated from the first with wide modeled entablature, which greatly front – end over the mensa and which forms the foundation for the upper column. The upper part of the altar is narrower and gives the impression of rounded on the sides. The picture placed therein was made in the first half of the 19 century and shows the "Risen Christ". It is surrounded by a gilded frame profiled in the shape of an octagon. Between the picture and the column, on decorated brackets, the statues of the two saints nuns are situated. The left side of the picture occupies St. Gertrude the Great with the burning heart and crosier while across of her the sculpture of St. Hildegard von Bingen holding in her hand an open book takes place. The opposite sides of columns are decorated with openwork miniatures ears of the lariat leaves, which is the perfect background for the smaller statue –St. John the Baptist on the left and St. Sebastian on the right side. Ending entablature is also wide and strongly profiled, fractured on the sides and forwarded over the area of the upper colonnade. It is decorated with gilt openwork floral ornament with flowers rose. In the middle of the picture a decorative cartouches containing the cross is placed. Above the altar, on the cornice, a gloria formed with entwined clouds and directed to the bottom beams is placed. Above the clouds statue of Christ the Redeemer with a radiant aureola is situated. In its neighborhood sculptures of angels in flight, as evidenced by their dispelled robes and raised their hands towards the top, are situated. The location of the angels also do not match with the archival material [2].

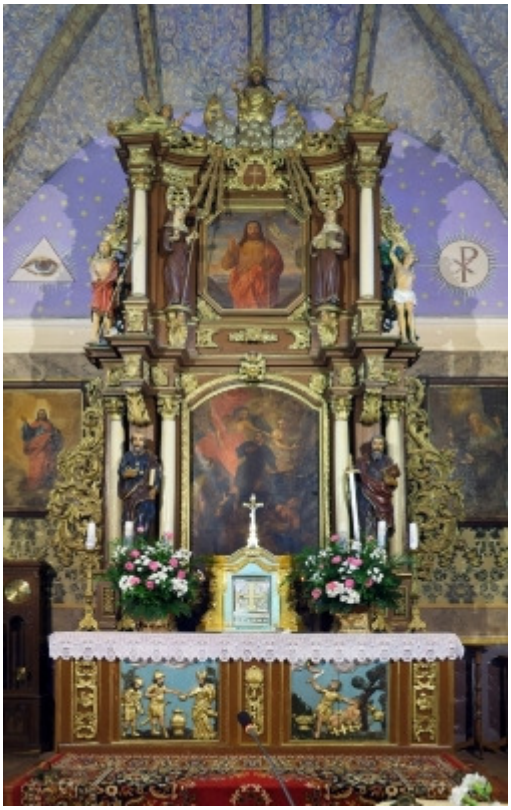

Fig. 2. Panorama of the main altar

3. The measurement technology

Laser scanning technology development provides increasing opportunities in applying this method of measurement in the geodesy. A growing interest in terrestrial laser scanning is shown by people, who in their work focus on the protection of historic buildings and digital heritage. This happens because of the new potential of the products that are obtained by using this type of equipment and measuring systems.

Nowadays, scanners allow us to capture even one million points per second, recording Cartesian coordinates in three-dimensional space, which are oriented in the local – scanner coordinate system. Obtained data provide the spatial presentation of the measured object and give the opportunity to perform various kinds of products. The point cloud itself, without further data processing, can be also considered as a final product. Among the recorded data, besides the X, Y, Z of the measured point, a fourth parameter, which is the intensity of the reflection of the beam in the direction of the analyzer is captured. This value depends on the type of material from which the item was made and its color. It has a great impact on the accuracy of the conducted measurement. What is more the stability of the substrate under the instrument also affects. Therefore it is recommended not to measure from the jibs, jacks and scaffolding. Despite these limitations, this is one of the best methods for elaborations of objects which are difficult to access and characterized by a complicated shape.

The size of the obtained set of measurement data is both an advantage and disadvantage of laser scanning [5]. Too much data can influence on the ability to compile the post processing step, which is dependent on hardware limitations. A partial solution to this problem is to adjust the scanning resolution to the physical properties of the scanned element. It is unreasonable to use high resolution in the case of objects with an uncomplicated structure.

Other advantages of this process is a significant automation process and the reduction of the time required to record the observations. This enables to use this solution in unfavorable conditions for the operator. In 2004, a special test relies on comparison the required time necessary to complete the elaboration of the same object using photogrammetric and scanning method was conducted. As a result, the second method (scanning) was more than the double better than the first one [6]. The measurement using scanner can be performed in low light condition and in smoky rooms. In such situations, it is only impossible to take pictures. These advantages should not give rise to claims that terrestrial laser scanning method displaces close-range photogrammetry. These methods complete each other.

The described technique does not require the direct contact with the measured element. What is more the type of light beam, which is used, does not destroy the structure of paintings and sculptures. Non-contact measurement is very important for fragile and valuable antiques. During a single measurement session a set of data is achieved that can be repeatedly processed and elaborated. It contains the information necessary to perform analyzes and also other which in the first process may seems unimportant. In such cases it is not necessary to perform additional measurements.

Complete and proper use of the advantages of this technology is possible with proper preparation of the whole measurement process. Below is a list consisting of four steps that should be carefully carried out before the scanning:

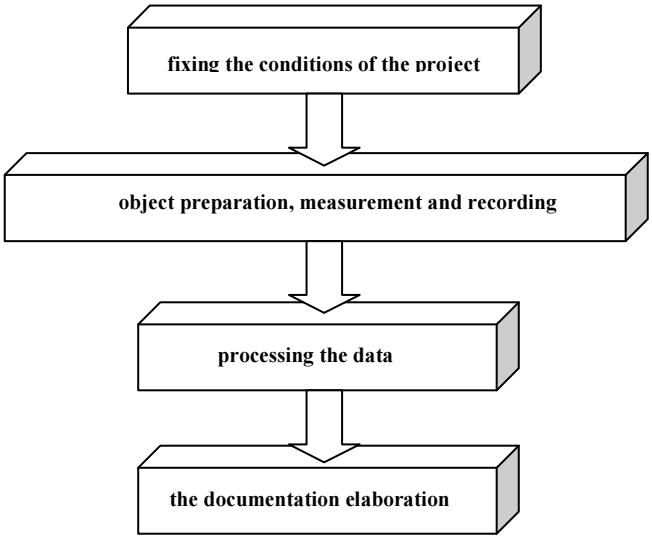

Fig. 3. Scheme of preparation and conduct of the works

It is possible to assign the radiometric quantities of dedicated pallets, natural colors or gray shades to the derived data. This option is used in creating recesses maps and Digital Terrain Model. In other products we can enumerate a various kind of documentation possible to generate from the vector elaboration. These include: projections, views, cross – sections and 3D models.

4. Description of the measurements and data elaboration

The measurement of the historic altar in the Roman Catholic church in Jonkowo performed on 18 January 2014. The measurements were made from two stations placed symmetrically on both sides of the altar. Scan resolution, which was set during the measurement from the first position, was 1×1 mm. It has been reduced twice in the next set. In total, about 50 scans of individual elements of the altar were obtained during few hours of scanning. During the scanning a certain regularity was observed in significant increase the time interval needed to perform the scans of the same area, but in different elongation directions. The scanned time areas extended in the horizontal direction was much longer. Obtained point clouds from two measurements stations were registered in corresponding software. To combine the point clouds HDS targets, which were scanned from both positions, were used as a common points. Finally, completed 3D view of altar was achieved in a local coordinate system.

The measurement was done by using impulse terrestrial laser scanner ScanStation from Leica company. Data obtained during the scanning were processed in Leica Cyclone software, which was also used to operate ScanStation scanner.

The first step of elaboration was to registr scans gained from two measuring positions into one whole with the aforementioned registration module software. The registration consists in determining the coordinates of HDS targets (in our case 4 such targets were used during the scanning) and next the transformation data into a one coordinate system. Table 1 shows the accuracy of the performed transformation.

Table. 1. Summary of the transformation errors using HDS targets

target ID	Error [m]	Error Vector [m]
T1	0.004	(–0.004, –0.001, 0.002)
T2	0.003	(0.002, –0.001, 0.002)
T3	0.003	(–0.001, 0.002, –0.002)
T4	0.003	(0.003, 0.001, –0.002)

The next step was point cloud filtration realized to remove unwanted and measurement noise components, which do not belong to the scanned objects and which were unnecessary for the further study. Figure 4 shows the result of initial elaboration of the object.

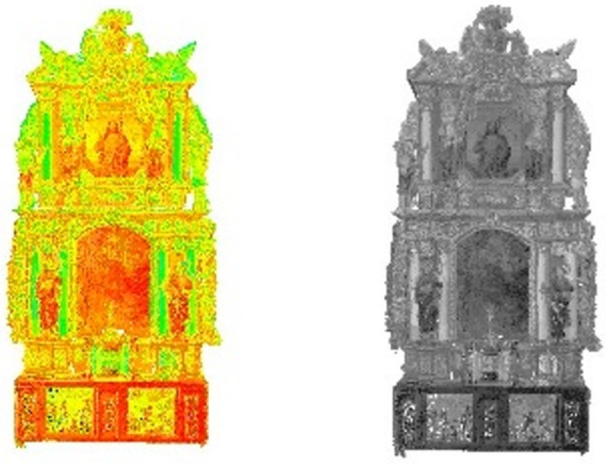

Fig. 4. The point clouds of the altar in the Intensity Map Multi-Hue and Intensity Map Grayscale

One of the parameter that is possible to obtain from the point clouds is the intensity of the light beam reflection from the surface. Basis on the recorded values, it can be specify the type of material from which a test object is made [3]. The obtained point clouds enable to perform a number of studies useful for architects, as well as conservators and also to visualize the scanned object. Dedicated software for the scanner, which was used in measurements, allows us to export the point cloud into multiple formats e.g. DXF, ASCII,. xml,. tif,. ptg,. ptf. It is also possible to "publish" point clouds with photos in a format of overlay on a web browser e.g. Leica TruView [4].This software enables simple measurements on the cloud points and also:

- dimensioning (with an accuracy of a millimeter);
- reading and recording the coordinates of the selected point;
- performance the screenshot (snapshot) and its save anywhere on the disk;
- insert text, dimensioning lines, and tags for the coordinates of the selected points.

All these features allow us to receive in quick and easy way information about a scanned object. The classical methods used by conservators or photogrammetric method to obtain information about the shape and dimensions of the object are much more time consuming.

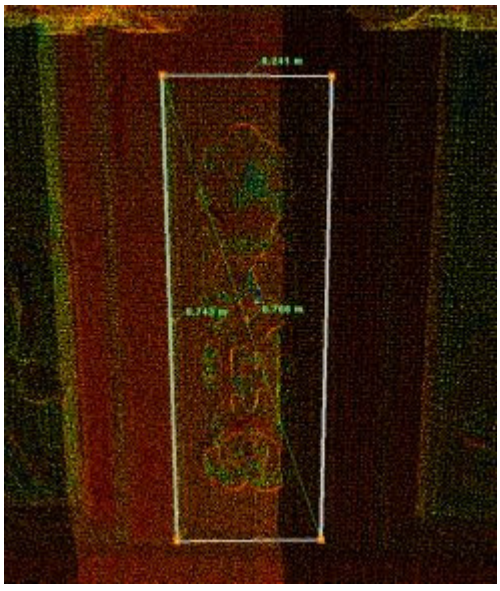

Fig. 5. Example of dimensioning

In the recent years, on the market, many simple tools for visualization and publication point clouds acquired from terrestrial laser scanner measurements have appeared. One of the free available software is CloudCompare. With a simple and intuitive menu, user can in quick and easy way gain a lot of useful information. This tool is very helpful for analyzing the intensity of reflection of the laser beam. Using the available features and plug-ins we can perform histogram for a given area before elaboration and we can make filtration of point clouds according to pre-defined parameters. Figure 7 shows the final visualization product of the object described above.

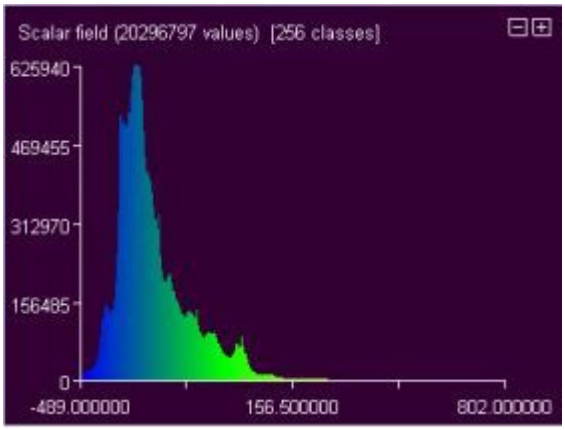

Fig. 6. A histogram of the scanned object element

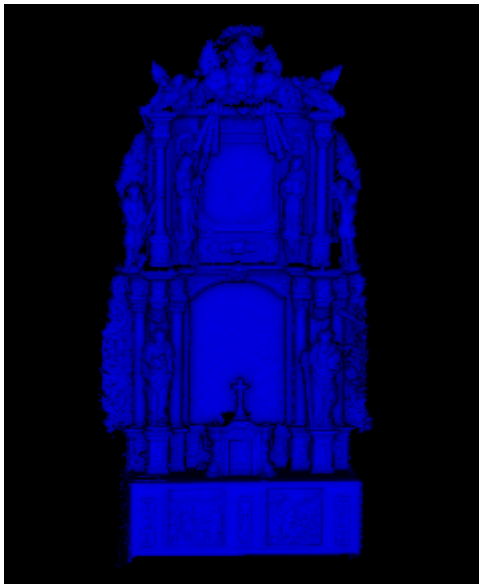

Fig. 7. The modeled altar

Depending on the needs and reasons why the measurement using terrestrial laser scanner is conducted, scanner software and other programs available in the network allow us to performed more detailed analysis of the acquired point cloud. The following applications should be distinguished:

- Mikser;
- MashLab;
- ccViewer and CloudCompare;
- Geomagic.

Using available functions of the software the following products can be made: drawings in 2D space, cross –sections of the object, projections, photoplans, ortoplans, material analysis from which the scanned object is made and many other studies adjusted to the needs of the customer.

5. Conclusions

It can be said that terrestrial laser scanning is a measurement technique that can be successfully used for the documentation of historic buildings. The main advantage of this technology is the speed of measurements. Within just several minutes can be scanned each object. This speeds up documentary work considerably compared to those method that are used by conservators. A huge number of points allows us to create an accurate reproduction of all details that are in the object. With noninvasive measurement technique object structure is intact. The point clouds as a result of scanning in itself is a great documentation. Due to the fact that the whole object is measured in a short time, it eliminates the need to repeat the measurement, which in case of other methods is sometimes necessary. A significant advantage is the simplicity of data archiving and the ability to use them in case of need. Documentation performed using terrestrial laser scanner is fully complete and reliable. Based on the obtained measurements reconstructions of objects which, which over time have been destroyed can be performed without any problems.

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