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THE USE OF TERRESTRIAL LASER SCANNING IN MONITORING OF THE RESIDENTIAL BARRACKS AT THE SITE OF THE FORMER CONCENTRATION CAMP AUSCHWITZ II-BIRKENAU

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Summary

The technological development of the remote sensing systems more and more often meets the requirements related to archiving the cultural heritage of humanity. Today, terrestrial laser scanning (TLS) is a very useful tool in acquiring spatial data about monuments of architecture. However, construction features of these monuments, their shape, size and kind of materials they are made of often set limits to the use of TLS technology in documentation of the condition of these objects. When archiving the state of barracks of the former concentration camp Auschwitz II-Birkenau proved necessary, the authors of this paper suggested and implemented the idea of monitoring the technical condition of the objects by using terrestrial (ground-based) laser scanning technology. This method, backed by a traditional geodesy, allowed for archiving the barracks' state with a satisfactory accuracy, while minimizing the inconveniences caused by the construction features of buildings.

Keywords

monitoring objects of cultural heritage • documentation • conservation • terrestrial laser scanning

1. Introduction

An obligation to ensure legal, organizational and financial conditions enabling long-term maintenance of historic monuments, preventing their distraction and control of their state is imposed by the Act of 23 of July of 2003 on the protection and guardianship of cultural monuments [Ustawa...]. The law does not impose methods and technology of maintenance of architectural monuments, it suggests however that safe and non-invasive ways of conservation of cultural heritage should be used [Ustawa...].

There are four principal geodetic methods of monitoring cultural monuments [Scherer 2002]:

- manual measurements of objects of cultural heritage,
- geodetic surveys of cultural monuments carried out with the use of electronic total stations,

- photogrammetric methods [Piech 2013],
- laser scanning methods [Armesto-González et al. 2010, Kuznetsova et al. 2015].

In recent years, the terrestrial laser scanning, as a non-invasive technology of fast data acquisition, has revolutionized graphic and metric representation of documentation with regard to architectural monuments [Armesto-González et al. 2010]. This technology is gaining supporters in various disciplines, such as archaeology [Lamberts et al. 2007], civil engineering [González-Aguilera et al. 2008] and geology [Buckley et al. 2008]. One of the most popular TLS applications creates 3D documentation of monuments [González-Aguilera et al. 2008, Sharaf et al. 2009].

The authors, inspired by the use of terrestrial laser scanning in monitoring architectural monuments, have began a scientific research to check if is possible to use TLS technology to monitor constantly degrading, brick residential barracks at the site of the former concentration camp Auschwitz II-Birkenau. The requirement of permanent assessment of the barracks' condition was the basis for designing and implementing the idea of monitoring the technical condition of these objects by using ground-based laser scanning. This method, backed by a traditional geodesy, allowed for archiving the barracks' state with a satisfactory accuracy, while minimizing the inconveniences caused by the construction attributes of buildings, such as their shape, size, and the kind of materials they are made of.

2. Materials and methods

In 2012 Maintenance Department of the Auschwitz-Birkenau State Museum in Oświęcim decided to prepare detailed documentation of the preservation state of the prisoner barracks B154 and B159 of the former extermination camp in Auschwitz-Birkenau. The decision was motivated by the necessity of monitoring the stability of load-bearing walls of the barracks. Over the years, the material durability of the barracks' structure has been degraded (Figure 1a), and it had to be strengthened by wooden beams (Figure 1b, 1c). The Maintenance Department of the Museum commissioned the preparation of the comprehensive documentation of the technical condition of the barracks, in order to evaluate the effectiveness of the adopted solutions and to determine how the degradation process would evolve.

The residential barracks designated for archiving located in a wet area of the former concentration camp Auschwitz II-Birkenau are brick, elongated buildings, with wooden bunk beds. The construction features of the studied objects: shapes, size, colour, material of which they were made of, the number of window and door openings made the use of ground-based laser scanning difficult. The geometric features (the shape, size and number of window and door openings) determined the location plan of laser sites, so that the recording of point clouds of the interior and exterior of the building was possible. The physical attributes of the barracks (building material and the colour of the objects) determined the absorption degree of laser beam through objects' walls, and thus dictated the number of laser sites located inside and outside of the barracks.

The fundamental research problem was to design the measurement in such a way that the in analysis of the point clouds, the orientation of spatial data of the inside and the outside of the barracks, under the assumed frame of reference, had a satisfactory accuracy. Another research problem was that the inside of the barracks is filled up with wooden bunk beds, the colour of which had a low reflection coefficient. To improve the level of accuracy and technical capacity of the analysis of the point clouds, at the stage of scanning the inside of the barracks the number of scanner sites should be as low as possible, and the assumed average distances between the point clouds of 2 mm should be maintained.

Source: http://www.auschwitz.org

Fig. 1. The technical state of prisoner barracks in the former extermination camp Auschwitz II-Birkenau: a) the state of inner surfaces of load-bearing walls, b) inner supporting beam structure of the barrack, c) outer supporting beam structure of the barrack

The monitoring of the residential barracks of the former concentration camp first required a number of design works. The adequate planning of measurements was a condition of ensuring the best accuracy of the results. The a priori accuracy of a singe measurement with ground-based laser scanner equals to [Glotov and Smolij 2009]:

$$m_s = \sqrt{m_p^2 + m_m^2};$$

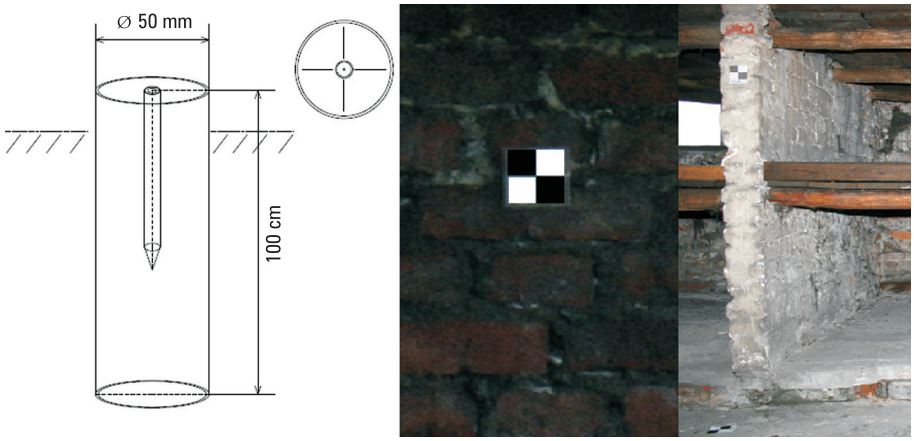
where:

m_p^2 – error of a single measurement,
m_m^2 – errors of surface modelling.

In a measuring equipment made by Z+F, model 5010, the a priori value of a single measurement was 2.24 mm. The design works were focused on local geodetic control network, observation network of control points and tie points, permanently fixed in the structure of the barracks. The tie points were used to record the point clouds of the

outside and inside of the object. The tie points were the basis for georeference of point clouds of the barrack. The main research problem during the creation of the geodetic control network project, the project of location black and white control points and tie points, consisted in designing these points in such a way that after matching, in the process of orientation of point clouds, it would allow for the reduction of the mean error of TLS data orientation. For the purpose of terrestrial laser scanning of the barracks the local geodetic control network has been designed, consisting of six points permanently marked (stabilized) in the terrain in the form of the concrete posts 1 m long and 5 cm in diameter (Fig. 2a). The next stage of works preceding the measurement of the barrack was the preparation of the project and fixing the observation network of black and white control points (Fig. 2b) and tie points (Fig. 2c) in the horizontal and vertical planes of the barrack's construction. If natural details of the objects were chosen as tie points, there would be a reduction of accuracy of point clouds orientation due to the lack of unambiguous identification. The black and white target plates that fulfil a tie function for a scanner station were also fixed to the panes of window openings, and it allowed for the orientation, in an assumed frame of point clouds, of the inside and the outside of the scanned barrack.

The monitoring of a residential barrack consisted of geodetic survey of a marked, local measurement control network (total station Leica TCR 805), levelling of control points and terrestrial laser scan, with a phase-based laser Z+F Imager 5010, of the outside and inside of the object. The barrack's construction, its inside arrangement and the requirement of high accuracy of the object's representation in the form of point clouds justified the use of 110 scanner stations inside and 20 scanner stations outside each barrack.

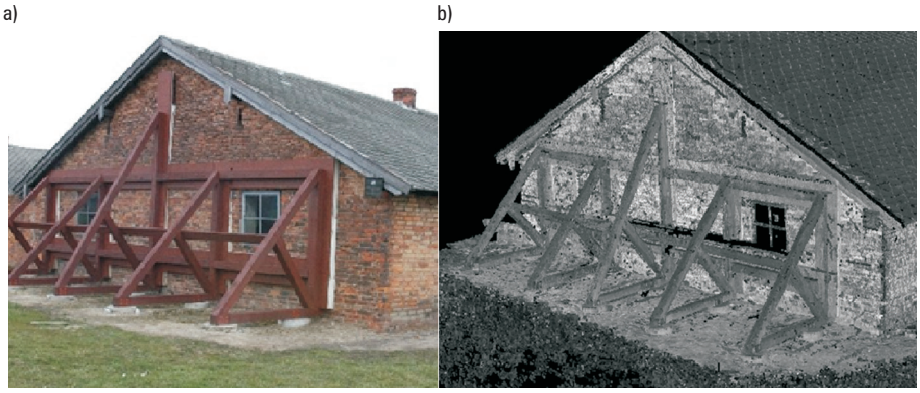


Source: authors' study

Fig. 2. The method of establishing: a) points of local measurement control network, b) control points, c) tie points of point clouds of the scanner stations

3. Results and discussion

The basis of a conscious policy of protection and guardianship of culture monuments, which would also determine the scope of necessary conservation measures, is a detailed information about the state of these objects. The data on which plans of conservation of cultural monuments are based should have sufficient precision that would characterize the location of spatial objects and accuracy of spatial representation (Figure 3a, b).



Source: a) http://www.auschwitz.org, b) authors' study

Fig. 3. Degraded wall of residential barrack: a) digital photography, b) a fragment of oriented point clouds

In order to constantly monitor the objects, the method of analysing barracks' condition has been developed and implemented, involving terrestrial laser scanning with the help of traditional geodesy. On the basis of data collected from records the gradual orientation of point clouds have been made, connecting spatial data from scanner stations located inside and outside of the barrack, and then successively matching point clouds with coordinates of control points (levelled on the basis of local geodetic control network). The stages and results of orientation of point clouds are presented in Table 1.

Table 1. Results of orientation of point clouds

Orientation of point clouds				
Stage	**Elements of orientation**	**Annotations**	**Accuracy**	
1	Tie points	Inside the barrack	RMS constraints	0.002 m
2	Tie points	Inside + outside of the barrack	RMS constraints	0.003 m
3	Control points	Fitting point clouds to adjusted geodetic coordinates	Mean error of fitting	0.006 m

Source: authors' study

The analysis of the ground-based laser scanning technology used in monitoring the residential barracks of the former concentration camp Auschwitz II-Birkenau proved that the detailed plan and implementation of the idea of digitally archiving the object ensure sufficient accuracy and avoid difficulties caused by the construction attributes of the buildings. The research material, in the form of oriented point clouds, is a perfect basis for further studies:

- projections and cross-sections for the purpose of maintenance works,
- maps of external walls' deformations in reference to fitted vertical planes – hypsometric and contour maps,
- the analysis of deflection in two axes of structural columns – hypsometric maps, a graph of axis position on XZ and YZ planes,
- the analysis of deflection of two axes of chimneys, hypsometric maps, a graph of axis position on XZ and YZ planes,
- the analysis of deformation of construction beams in two planes – horizontal and vertical (graph of beams' axes position),
- differential models of walls, between zero measurement and successive measurements.

Ground-based laser scanner allows for the surface coverage of object with measurement data and for defining the coordinates of millions of points. The potential of the ground-based laser scanning in surface analysis of deformations and damages of buildings, and the fact that they can be determined with higher accuracy than the precision of the single point cloud, have been confirmed by many scientific research on the subject [Alba et al. 2006, Gumus et al. 2013, González-Aguilera et al. 2008, Heine et al. 2007].

4. Conclusion

Because of the special historical significance of architectural monuments of the former concentration camp Auschwitz II-Birkenau, these objects should be carefully monitored and data collected in control measurements and observations should be used as a basis for assessment of the condition of the objects. Today, monitoring the technical condition of the barracks, is of particular importance, since most of them are older than their operation period, and their resistance to the passage of time and constant deterioration is diminishing. The Maintenance Department of the Auschwitz-Birkenau State Museum in Oświęcim points to the necessity of reinforcement of the barracks' foundations, strengthening of walls' construction, especially the deformed gables, fortifying roof trusses, conservation of historic substance: brick front elevations, plasters, multiply paint layers, wall drawings and pictures, floor joinery. In the article the idea of using terrestrial laser scanning technology in monitoring brick residential barracks has been presented. The modern measurement technology, backed by traditional geology, proved useful both at the stage of the description of the barracks and at monitoring

the deformations of buildings, and for its extensive archiving and in various analyses. The TLS technology, despite the limitations due to the construction of the barracks, ensured the comprehensive data coverage of the object, which makes it a valid complement of the previous solutions.

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