*M.Sc. Eng. Arch. PhD. Candidate*
*Emilia Dudzińska*[1)]
ORCID: 0000-0003-0201-8514
*M.Sc. Eng. Arch. PhD. Candidate*
*Karol Argasiński*[1)*)]
ORCID: 0000-0002-8250-7109

# Laser scanning as a source of information in the analysis of the facades of heritage at risk – the mansion in Kliczewo Male

## *Skanowanie laserowe jako źrodło informacji w analizie elewacji zagrożonego obiektu zabytkowego – dworu w Kliczewie Małym*

*DOI: 10.15199/33.2022.08.12*

**Streszczenie.** Artykuł przedstawia zastosowanie chmury punktów w analizie i dokumentacji elewacji zabytkowych obiektów zagrożonych. Na przykładzie skanu dworu w Kliczewie Małym wykonano mapy i przedstawiono możliwość ich zastosowania. Wykonano analizę odkształceń, ubytków i innych. Opracowania stanowią podstawę do prac związanych z dokumentacją wektorową. Wycinek chmury przedstawiający płaskorzeźbę został przekształcony w geometrię MESH, co umożliwia jego udostępnienie na platformach internetowych oraz druk 3D.
**Słowa kluczowe:** skanowanie laserowe; dziedzictwo zagrożone; chmura punktów; elewacja; dokumentacja.

**Abstract.** The article presents the use of a point cloud in the analysis and documentation of facades of historic endangered objects. In the example of a scan of the mansion in Kliczewo Male, maps were made, and the possibility of their applications was presented. Analysis of deformations, cavities, and others were performed. The studies are the basis for vector documentation. The point cloud segment showing reliefs has been transformed into a MESH geometry, which allows it to be shared on online platforms and 3D printing.
**Keywords:** laser scanning; heritage at risk; point cloud; elevation; façade; documentation.

The manor, the study's subject, is located in Kliczewo Male, in the north of the Mazowieckie Voivodeship, in the Zuromin borough. The building has been included in the Register of Monuments with the number 234-A since 1981. [1] and was built in the 4th quarter of the 19th century for the Baginski family, which it owned until 1939. From 1945 to 1998, the building housed a primary school. Along with the change of function, the facility underwent renovation. After that time, the building was devastated, and the historic stoves, woodwork and floors were destroyed.

The manor is a two-story brick building with a basement, a wooden ceiling above the rooms and a wooden roof truss with a rafter structure. The façade of the central part of the building was marked with a porch that does not exist today. The elements of unique architectural value are the decorative elements on the façade, such as cornices, bas-reliefs with motifs of human masks and a lion's head.

Currently, the building is in bad condition, which makes it impossible to access the interior of the building for security reasons. Window and door openings were secured to prevent any further devastation. There is no roof on the extension, and the facades have numerous defects in plaster. There are also defects in cornices and decorative elements. The best-preserved exterior wall finish and details are on the west elevation.

## Laser scanning

Laser scanning is a technology in which the device emits a continuous laser beam. It is then distributed by the rotating scanner and oscillating or spinning mirror. Once the beam encounters the object's surface, part of its energy is reflected back to the scanner. The time needed for this action is calculated, and the distance from the device is established. Additional parameters are also gathered and specified. Among them is the location of the point in the cartesian coordinate system (X,Y,Z coordinates) and RGB colour information of each point based on the photo taken by a built-in or external camera. The effect of laser scanning is a set of spatial data merged into a point cloud. The technology is characterised by high accuracy that is expressed in millimetres. The data obtained this way can be further used in an appropriate CAD/BIM or 3D application environment. Laser scanning allows a user of the tool to capture reality not only for common spaces but also for facilities that are too complicated and complex in spatial shapes, such as heritage structures mentioned in that article. Those structures specifically need to be measured in an "as is" state with complex accuracy (from millimetres to microns) in which classical methods of work cannot reproduce such shapes to that level of accuracy.

The building was scanned in November 2021 with the FARO Focus S70 laser scanner [2] (Photo 1), which enables measurements to be made with an accuracy of 1 mm. The weather conditions did not negatively affect the obtained point clouds. The scan was performed with one device from 19 positions in 3 hours and covered only the exterior of the building. A scan of the interior ele-

[1)] Warsaw University of Technology, Faculty of Architecture
[*)] Correspondence address: karol.argasinski.dokt@pw.edu.pl

ments visible through the unprotected window opening was made, making it possible to link the measurements in the future. Due to the height of the building and the slope of the roof, the surface of its structure is not fully covered in the scan. To include the roof with more data, additional drone photogrammetry data capture should be performed and merged with dedicated software. A spherical RGB image with variable resolution from 11 million pixels to 44 million pixels was also taken for each measurement.

**Photo 1. Mansion in Kliczewo Małe with a Faro laser scanner in the front**
*Fot. 1. Dwór w Kliczewie Małym ze skanerem laserowym Faro na pierwszym planie*

The scans were registered with FARO SCENE 2019.2 version [3], with a final accuracy of 5 mm to 10 mm by combined "cloud to cloud" and "top view" methods. The result was a point cloud file with RGB colour information. By combining those two methods of work, the laser scanner user is allowed to register without any external corresponding points. Cloud to cloud registration may analyze any scan points to improve the positions of reference objects. Later on, correspondence points are being found by an algorithm because it is not always possible to manually place an adequate number of artificial targets within the scanner's field of view due to inaccessibility or potential risks. In these situations, specific features or natural targets (i.e., planes, slabs, pipes, corner points, or rectangles) may be visible from multiple scanner locations and can be used to register scans. Those specific features create correspondences which are natural reference objects that can be extracted from the scan points manually or automatically and thus, helps to create a detailed point cloud.

Using traditional techniques, the measurement is taken with a measuring rod, laser measuring device and tape measure. The effect is a set of field notes that must be transferred to CAD software. Additional photo documentation is taken to supplement colour information. Ortophotoplans can be included, in which case they are overlaid in 2D drawing and are a source of both RGB and additional spatial data. Comparing laser scanning and traditional data acquisition techniques in the context of elevation drawings, the first-mentioned technology provides more data of higher accuracy, which can be supplemented with RGB information. The laser scanning accuracy provides more information on architectural details, for which detailed measurement with traditional techniques requires mounting the scaffolding. RGB information applied on the point cloud is a source of information for detailed measurements of defects, colour and material differences, often of irregular shape. Measuring such elements with traditional techniques would be highly challenging. In both techniques, the final 2D drawings need additional work.

The speed of a complete laser scanning survey highly depends on the amount of detail that the surveyor wants to get, weather conditions and the surveyor's experience. Surveying Kliczewo Małe Mansion's facade took 3 hours to be measured due to weather conditions and the amount of data types such as intensity data, RGB and delta analysis that the authors wanted to get in order to acquire research data of the building structure and elevations. Apart from that, laser scanning value should not be compared to the classical measuring methods. With traditional techniques, the surveyor cannot get a digital copy of the building and check building dimensions from that specific measurement later. If just the measurement is to be compared, it also depends on the surveyor's experience using classical methods. If the person is skilled enough, it can be possible to take main measurements faster than laser scanning itself, but in that case, it may also appear that some measurements lack detail or personal notes in the field were taken in an incorrect manner, thus creating typical human error.

## Documentation preparation

The heritage building's elevation documentation is used for renovation purposes (part of the building permit required for listed buildings), saving information about the current state and recording data for archival purposes. The last-mentioned purpose indicates that such documentation may be used for future research.

Elevation documentation contains 2D elevation drawings of all buildings' sides with dimensions and height information applied. The drawings include window and door openings, cornices, details such as reliefs, and material information. Heritage buildings are subject to processes of use, so information about the deformation, chipping, cracks and acts of vandalism are portrayed in the documentation. In the case of renovation works, this information is used to determine the scope of work, materials, and quantity.

From the architect's perspective, to deliver the most accurate data with no additional site visits, the survey should include a maximum range of information that can be processed and analysed. Laser scanning provides the solution within those constraints. The documentation provided for renovation purposes should be created in a standardized way. Laser scanning will make it possible to give the highest accuracy and detail to the documentation created.

The point cloud is the starting material for analysing the elevation of the manor house in Kliczewo Male presented in the article. In the discussed example, the documentation consists of elevation views with RGB information (Photo 2), Reflectivity map, Delta map and MESH geometry representing the selected detail. The basic form of the study is a flat drawing of the elevations. It is presented in a form similar to a photograph and eliminates the distortion of the perspective. With classical work methods, the point of error will always be higher than in laser scanning. A good example is tape measurements done by hand or profile creation out of specific wire – this might always be an assumption to some extent. The only human error that can happen with laser scanning is during registration. However, it can be fixed later during the registration process and does not in-

**Photo 2. View with RGB information of the front elevation of the manor house in Kliczewo Male**
*Fot. 2. Widok z informacją RGB elewacji frontowej dworu w Kliczewie Małym*

volve remeasuring structure – which in the worst-case scenario can be already destroyed by the time the next survey is performed or could be altered. Measured data also contains RGB information, on the basis of which it is possible to estimate the finishing materials and their colours shown in the Photo 2. Details, dirt, cavities and blooms are also visible. This study can be the basis for further detailed analysis developed in the form of drawing views with marked height information, dimensions and descriptions.

Another map that results from scanning is the Reflectivity map shown in Photo 3. It shows the strength of the laser beam reflection and can be used to analyse defects in walls [4], making them more readable. Using the Delta map, it is possible to visualise graphically and analytically the differences in the deviation of the horizontal and vertical planes with respect to the elevation plane. The study includes a colour scale and a numerical report. In the discussed example, the differences are caused by the cavities and the form of the building, not the deviations of the wall. Such an analysis is used to determine the condition of the wall and potential work related to its protection. In this type of map, the tectonics of the elevation and the location of pilasters, cornices and bas-reliefs are visible (Photo 4).

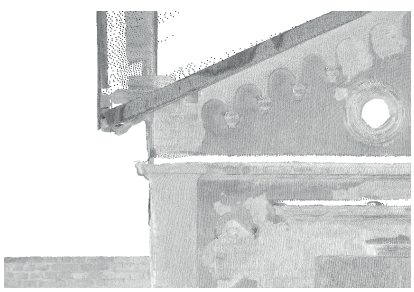

**Photo 3. A section of the Reflectivity map showing a fragment of the front elevation**
*Fot. 3. Wycinek mapy Reflectivity przedstawiającej fragment elewacji frontowej*

**Photo 4. Delta map of a fragment of the front elevation of a mansion in Kliczewo Male**
*Fot. 4. Mapa Delta fragmentu elewacji frontowej dworu w Kliczewie Małym*

The study indicates details important in terms of architectural value. There are, among others, three reliefs depicting masks and a lion's head. Using PointCab Origins Pro [5], based on a section of point clouds, a 3D model was made. It allows presenting the elements in the form of three-dimensional MESH geometry. Such files can be shared on web platforms like Sketchfab, and a reconstruction using 3D printing is possible [6]. In the context of detail documentation, tracing the element's outline, often of irregular shape, is laborious. The 2D drawing simplifies the 3D geometry with high information loss and deformation. Using hybrid methods of a fragment of elevation view along with basic dimensions applied can offer time-saving and higher accuracy of conveyed information, including shape, colour and material.

## Conclusions

This article presents selected possible applications of the point cloud, which is the starting material for developing flat documentation that meets the requirements of a technical drawing. After appropriate analysis and presentation of information, it can be used in processes related to the building permit and conservation works. Compared to the orthophoto, the resulting source material is complete and may be subject to a broader analysis. Maps, which are automatically created based on a point cloud in specialized software, enable an in-depth analysis of the elevation geometry and its behaviour. The outcome of the laser scanning process is a coordinated 3D data matrix which contains not only measurements but also correct natural colours, structure, the roughness of material texture and many more. That kind of data is impossible to gather in one place by the usage of classical methods of work with inventories. Thanks to three-dimensional information, it is possible to create a model of the entire object or, as in the example of Kliczewo Male presented in the article, of elevations and selected details

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*Przyjęto do druku: 18.07.2022 r.*