The use of terrestrial laser scanning for mapping bridges on electronic navigational charts

Zastosowanie naziemnego skanera laserowego do kartowania mostów na elektronicznych mapach nawigacyjnych

Jacek Łubczonek

Maritime University of Szczecin, Faculty of Navigation, Institute of Geoinformatics

Introduction

Navigational charts are the primary source of information about the objects that is used in the process of navigation. A large group of those objects includes barriers for navigation. In most cases they are underwater obstacles which are presented in maps as cartographic symbols, depths areas or soundings. Typical navigation dangers may be caused by wrecks, rocks or shallow waters. Navigable routes also include inland waterways, where bridges are one of the main obstacles to navigation. Bridge parameters which are limitations for shipping include the vertical clearance and the distance between the supports or pylons (horizontal clearance). In addition, it should be noted that – apart from those parameters – a bridge as a map object, should be characterised by the required topographic map accuracy. It becomes very important, since many harbours accept vessels of the maximum dimensions. They require the use of accurate navigation systems, what is often associated with the necessity to use a system of fixing the exact position with the accuracy of a few centimetres. Such systems should utilise suitable maps of objects characterized by an adequate topographic accuracy. In Poland marine and inland electronic navigation charts are used (Lubczonek, 2016b). At present, other studies are carried out in Poland which are related to technological development which supports navigation (Wawrzyniak et al., 2016; Lubczonek et al., 2016), data acquisition (Burdzianowski et al., 2016), extraction of coastline data (Lubczonek, 2016a) and data processing (Kazimierski et al., 2016).

Laser scanning can be presently applied to acquire metric data of bridges. Laser scanning can be applied for:

- ❍ the comprehensive inspection of bridges (Tang et al., 2007; Berenyi et al., 2010; Truong-Hong and Laefer, 2014),
- ❍ techniques and methodology of scanning (Lubowiecka et al., 2009; Troung-Hong et al., 2016),
- ❍ the bridge monitoring (Shen-En Chen, 2012), and
- ❍ measuring the vertical clearance (Zhang et al., 2013).

Generally, the use of laser scanning is related to acquisition of dimensions of bridges or their components, which in most cases are the subjects of further analysis and assessments of technical conditions of bridges. With other applications, scan data can be used for creation of three-dimensional models of bridges, as a part of the urban space – a standard City GML (OGC, 2012). For the purpose of 3D data modelling photogrammetric methods can be also applied. Laser scanning and photogrammetric methods are compared and discussed in (Hejmanowska et al., 2012).

This paper discusses the use of terrestrial laser scanning for mapping bridges in inland electronic navigation charts.

Analysis of data sources for mapping bridges

Different data, such as basic maps, orthoimages or technical drawings may be used for mapping bridges. Unfortunately, a variety of problems associated with obtaining vector data can appear during mapping. In the case of basic maps, supports are not always mapped. Based on the available studies it can be said that mapped supports sometimes have incorrect shapes (Fig. 1a). In turn, orthoimages have limited possibilities regarding mapping of bridges. Bridges on orthoimages are the land cover elements and they are the subjects of radial shifts resulting from photographic image registration (Fig. 1b). It is possible to map a bridge, when it is near the projection centre. Additionally, it should be checked whether the possible radial displacement of the bridge falls within the acceptable accuracy limits. It should be mentioned that during generation of orthoimages image distortion may often occur around bridges. It results from discontinuities of the applied digital terrain model between two banks and under the bridge. Additionally, bridge supports cannot be mapped, since they are situated

a   b   c
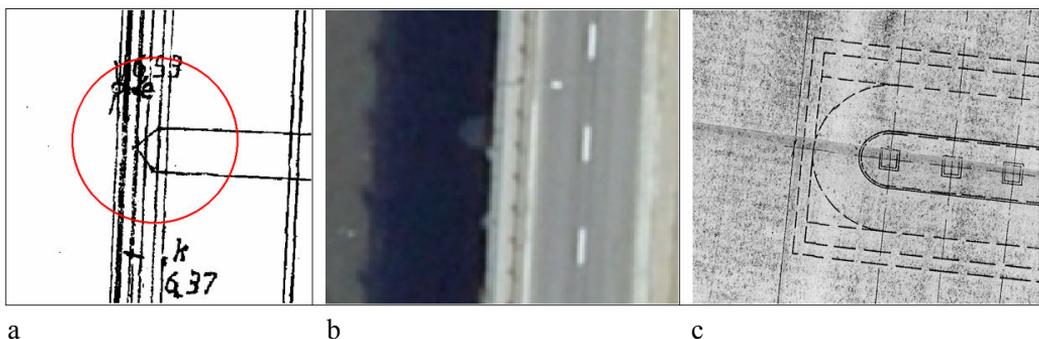
Figure 1. Selected problems related to mapping bridges with the use of different materials:
a – the basic map – incorrect shapes of supports shapes; b – an orthoimage – the radial displacement of the visible bridge support (in fact, it is covered by the span); c – a technical drawing – it cannot be registered into the coordinate system due to the lack of georeference marks

directly under the bridge span. The same problems appear in relation to true-ortho products. The last group comprises technical drawings (Fig. 1c). The problem in this case is often related to the lack of georeference marks and to presentations of a bridge that prevents the mapping of its outline (e.g. vertical view). All of these materials, and especially the older ones, are characterised by different accuracy.

Bridges as the content elements of electronic navigation charts

Bridges are important objects of waterways sections on electronic navigation charts. The bridge is an obstacle for navigation; it reduces the width of the navigable lane as well as the allowed height of the ship, which can safely pass under the span. The bridge itself is defined as a structure erected over the depression or an obstacle such as a water reservoir, a railway line, etc. to ensure the passage of vehicles, pedestrian crossing or the performance of public services (IHO Dictionary, S-32, 5th Edition). Bridge is also important for mapping other, related objects. They include navigation lights, radar reflectors, fenders or notice marks. Those elements can be arranged directly on the span, on the bridge support or they can be mounted on brackets (e.g. radar reflectors). Therefore, it is important that data is vectorised with the high accuracy in order to maintain correct topological relations between particular objects. An example of bridges as elements of the electronic chart is presented in Figure 2.
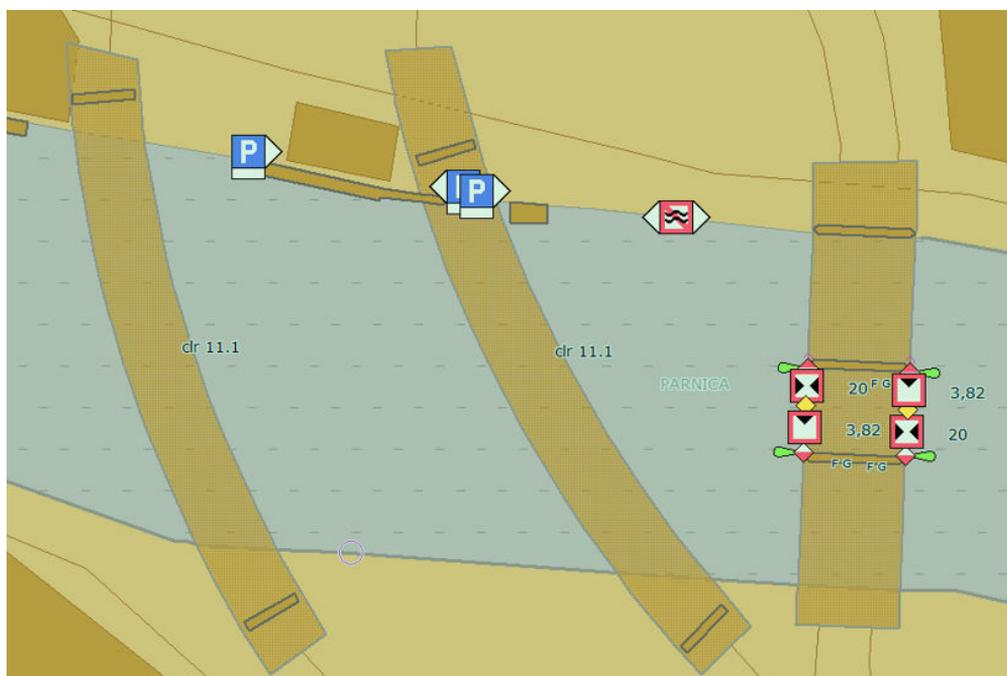
Figure 2. Examples of mapped bridges on the Parnica River in the Szczecin harbour presented in the electronic navigation chart. Notice marks and navigation lights are visible on the bridge, on its right side (SeeMyENC software)

Laser scanning of bridges

The object of scanning was a bridge over the Parnica River in the Szczecin Harbour. It is a road bridge, which length is 89 m and its width – 25 m. The bridge is located on the border between the internal sea waters and inland waters. The height above the water level during scanning was 8 m. The bridge is illustrated in Figure 3.

Figure 3. The Portowy (Harbour) Bridge (own picture)

The phase scanner, Faro Focus 3D was used for scanning. The scan range equals up to 120 m inside or outside in low ambient light when the laser beam incidents perpendicularly on the surface of 90% reflectivity. The distance error equals to +/– 2 mm. The measuring rate is 122 000 to 1 000 000 points per second.

For the purpose of scanning eight measurement stations were planned (Fig. 4). Four stations (S1, S3, S5, S7) were located closer to the bridge in relation to other four (S0, S2,
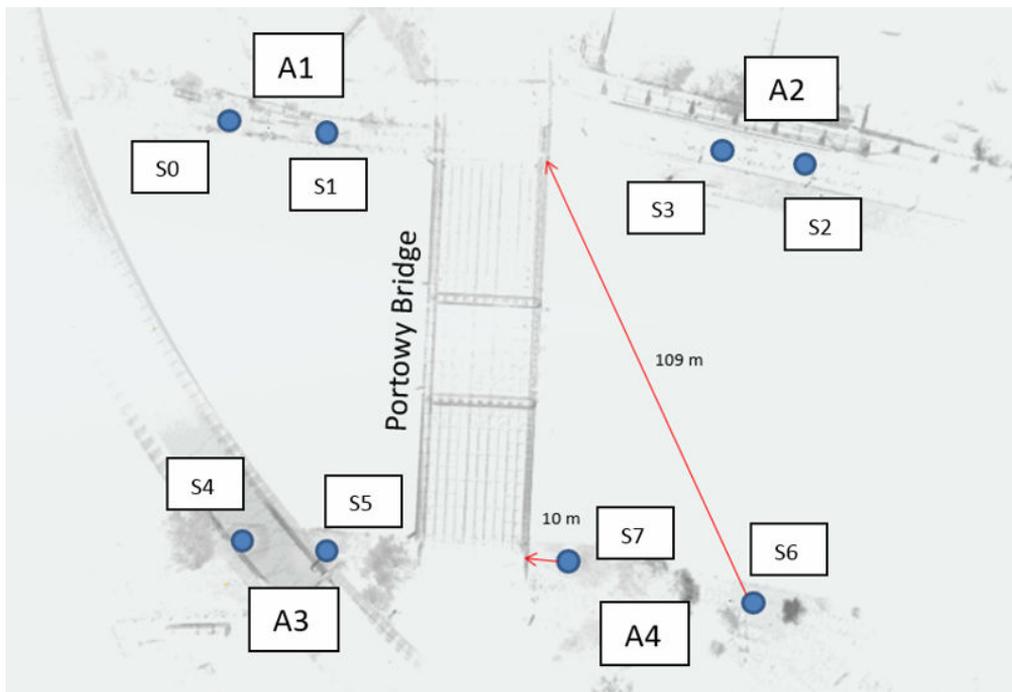
Figure 4. Distribution of measuring stations (prepared in FARO Scene 6.1 software)

S6, S4). Stations were located in areas marked as A1, A2, A3, and A4. Different distances between the scanner stations and the bridge were to allow for analysing the effectiveness of the scanner range. The shortest distance between the scanner and the bridge was 10 meters, while the longest distance achieved 109 m. The upper part of the bridge was not scanned, because all required data were collected from the land station.

Faro Scene 6.1 software was used for data processing. During the measurements eight point clouds were recorded. Each quarter of the bridge was scanned from two measurement stations (these areas are indicated as A1, A2, A3 and A4 in Fig. 4). In one case, the distance to the bridge was 10 m, due to the presence of a tree, which obstructs bridge in area A4. Three reference spheres were placed in each area (A1, A2, A3, and A4), in order to combine scans registered from two measurement stations. The exception was the measurement stations in the A4 area, where trees did not allow for distribution of reference spheres. The characteristics of measurement datasets are summarized in Table 1.

Table 1. Characteristics of measurement datasets

Measurement station	Data points	Distance to the bridge [m]	Measurement station	Data points	Distance to the bridge [m]
S0	56 701 803	48	S4	112 493 388	40
S1	47 549 688	28	S5	109 200 620	21
S2	61 472 280	62	S6	59 713 373	57
S3	64 720 090	41	S7	80 095 152	10

Processing of the project point clouds

To combine scans, FARO Scene 6.1 software was used. In the first step scans pre-processing was performed. At this stage additional filters, such as black points filter, distance filter, removal of random points filter were not applied. Images for point cloud colouring were also not used. During the initial processing the option of automatic searching for reference spheres and combination of scans was started. Scans might be combined using the reference spheres, the top view of scans and a cloud to cloud method. Although different methods were applied, it was not possible to automatically combine sets of data points, even if the scans were initially manually adjusted. This could be theoretically caused by very similar shapes of bridge scans. It refers to the top based view and cloud to cloud registration. Probably the matching algorithm was incorrectly recognizing the proper parts of bridge. In addition, the weakness of this type of registration resulted from significant reduction of the scanning range caused by sunny weather what decreased the number of points in overlapping areas. The real effective range varied between 60 and 85 m, what reduced the maximum possible range by approximately 50–26%.

A special case concerns combination of point clouds acquired from the opposite sides of the bridge, on the same river bank due to the limited number of common elements on scans. In such a case, only supports of the bridge appeared on the common parts of scans, allowing for selection of tie points and generation of reference planes.

Therefore, the composition of scans was performed in the following steps:

(1) The combination obtained from scans from the same scanned areas (areas A1, A2, A3, A4) on the basis reference spheres and tie points selected for the A4 area. Then the scans were grouped in a cluster that kept their constant mutual positioning.

(2) Combination of scans of the opposite bridge sides, acquired from stations located on the same river bank. This approach has allowed accurate fitting of scans lying on the same river side. The fitting accuracy was also controlled by the convergence of bridge supports outlines. Scan matching was performed by using tie points located on the bridge supports and the generated reference planes. Unfortunately, other scan matching options resulted in slight discrepancies of support outlines, as illustrated in Figure 5. After this operation data sets were also clustered.

Figure 5. Examples of 1.5–2.0 cm divergence of scans on the bridge supports

(3) Combination of clusters from opposite banks of the river. Tie points and generated reference planes were used for matching. They were located on the bridge span and supports. The obtained data sets were also clustered.
(4) The final optimization by using cloud to cloud method.
(5) Registration of scans to the coordinate system using the previously measured spatial coordinates of the reference spheres. The coordinates were determined by Trimble G9 receiver in the VRS network. The errors of X, Y, Z coordinates equalled to 1 cm. At this stage, it is worth to mention a problem associated with the coordinate values. In the case of the Polish PUWG 2000 coordinate system, all coordinates have very high values. The coordinates of exemplary point lying on the support of the bridge are X = 5 471 278.247 m, Y = 5 920 632 310 m. Such values are not required by programs for modelling individual objects which usually use the local coordinate system. However, the program can accept large coordinate values, but in the discussed case it was related to the acceptance of data optimization for point cloud displaying. In order to avoid any optimization, and perhaps programming interventions in a defined system, I preferred to reduce the coordinate values and work without additional optimization of the original coordinate values. After deducting the constant values for the point under consideration its coordinates were X = 278.247 m, Y = 632.310 m. All coordinates were transformed in that way to the local coordinate system. After this operation the project point cloud could be easily displayed. The same problem can be related to the use of data in any modelling software.
(6) Visual inspection of the quality and levelling of the project points cloud.

Table 2 summarizes the average registration errors. The clusters 1.1–1.4 concern two scans collected in the areas A1, A2, A3, A4. The clusters 2.1–2.2 are the combined clusters

that cover the half of the bridge located on the opposite banks. The cluster 3 is a complete project point cloud from all scans. Registration indicates an error of the registration in the local coordinate system based on seven reference spheres. According to (Kedzierski et al., 2015b), various scan combination methods are characterized by various errors.

In case of mapping the value of the final registration error to the coordinate system is important. These errors are listed in Table 3. For correct scan combinations the altitude error is important which indicates a potential deviation from the object vertical. As it may be seen, the mean error was 7.6 mm and its maximum value achieved 15.1 mm. Registration into the system based on the reference objects is very important due to the control of point cloud levelling. Data from the scanner inclinometer can be used in an automated process of scan combination. The user cannot influence the process of point cloud combination, hence the final data can be rotated in the XYZ space. For large or high objects, even a small rotation may cause a significant shift of mapped points in the XY construction plane. This problem may be solved by registration of the project point cloud to reference points. For the cloud levelling control visual assessment can be used, by comparing the horizontal elements of the object with the XY construction plane in dedicated modelling software tools (e.g. paralleling of the construction plane to the span of the bridge). The final project point cloud is presented in Figure 6.

Table 2. Mean errors of registration of individual data sets (in mm)

Cluster 1.1	Cluster 1.2	Cluster 1.3	Cluster 1.4
2.0	4.6	4.1	10.4
Cluster 2.1		Cluster 2.2	
18.6		22.5	
Cluster 3			
12.2			
Registration			
23.2			

Table 3. Errors of the georeferenced project point cloud (in mm).

| Maximum error	Mean error
36. 6	23.2
Maximum XY error	Mean XY error
35.9	21.5
Maximum altitude error	Mean altitude error
15.1	7.6

Figure 6. The final project point cloud (Bentley Pointools View software)

Day and night scanning

Considering the long time required for point clouds combination, I examined the influence of illumination conditions on the scanning range. The maximum range of the FARO Focus 3D phase scanner depends on low light conditions, while – in the case of the discussed project – registration was carried out during a sunny day. Undoubtedly, the light conditions affected the quality and the density of scans, especially when they were acquired from longer distances. So I decided to compare the scanning ranges with archival scans that were registered during night conditions. Scans presented in Figure 7 and 8 could be compared on the basis of reflections from the berths. It turned out that night scanning has a greater range – as declared by the manufacturer. In the case of daily scanning only a few points may be seen on the project point cloud (marked as ellipses). In addition, the project point cloud is apparently thinner in the span central parts which certainly resulted from combining the measurements sets. Generally, the quality of results of night scanning is better. In this case, it is worth to notice that the project point cloud consisted of 16 089 714 points. It is much less comparing to scanning in day conditions. However, better reflection of the bridge span and supports led to the better quality of the scan combination process, even if it was automatically performed. Thus it may be concluded that it is worth to scan at night or in low light conditions. But, unfortunately, it is not always possible.
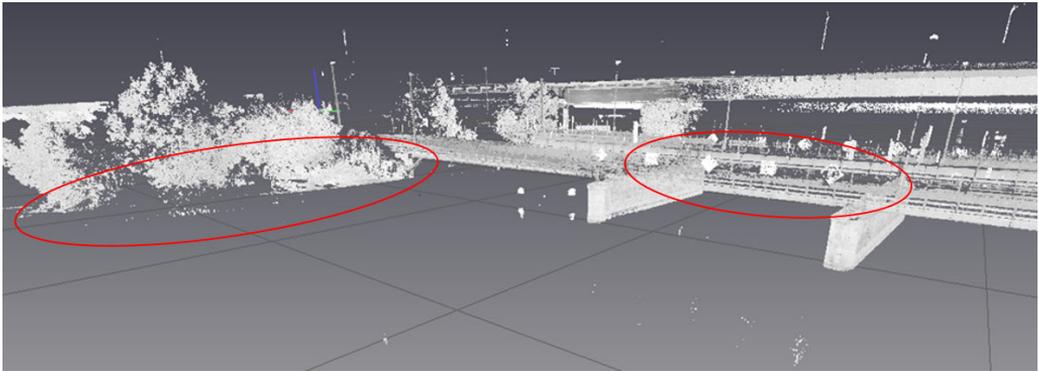

Figure 7. The project point cloud from daily scanning (Bentley Pointools View software)
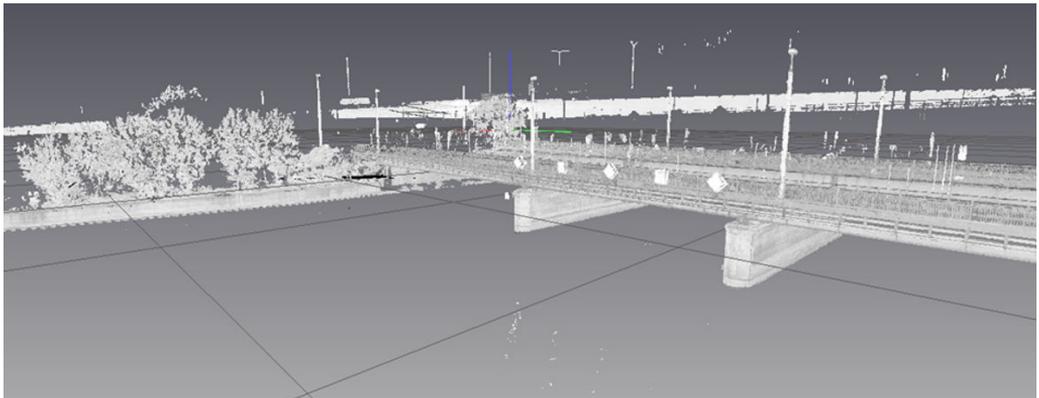
Figure 8. The project point cloud from night scanning (Bentley Pointools View software)

Acquisition of vector data using a point cloud

A point cloud is a valuable source of spatial data of any geographical object. Nevertheless, it requires appropriate software, which functionality allows, first of all to load large data sets and then to acquire vector data. Data modelling software tools are widely offered on the market. One can choose between dedicated software and various plug-ins. Further sections of this paper are dedicated to vectorization of data performed with the use of Rhinoceiros 4.0 software with the additional Bentley Pointools plug-in. Rhinoceiros is a complex software application for 3D modelling, but it requires extensions to load a point cloud and the functionality that enable its usage for vector acquisition. These tasks were realised by the Pointools plug-in, which allowed for setting the construction planes, creating the point cloud sections and assigning different colour scales. The advantage of Rhinoceiros was the possibility to visualise project point clouds in four viewports. A different view of the model (perspective, top, left and right) could be displayed in each viewport. This made working with the data much easier (Fig. 9).
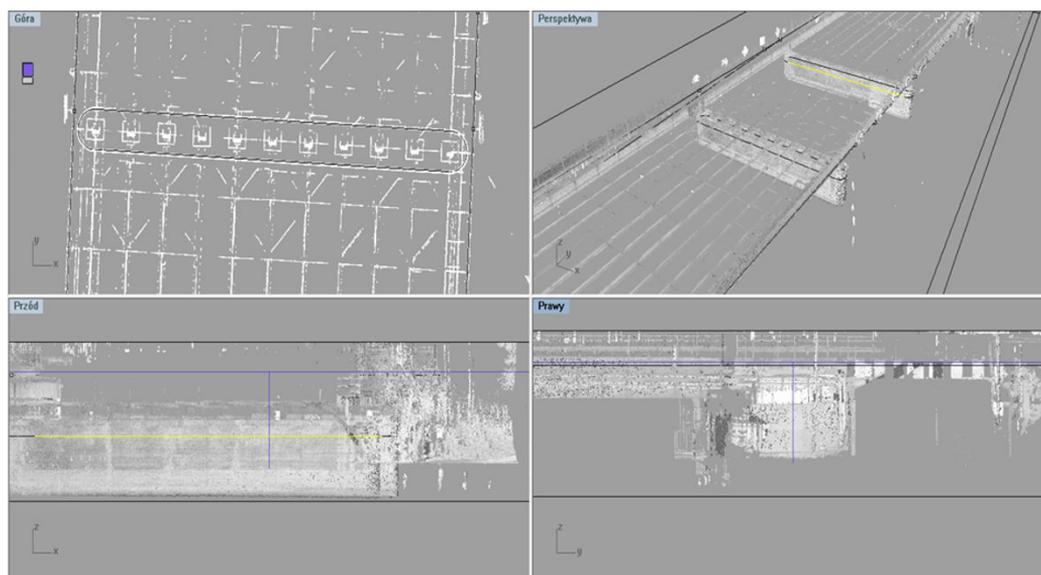
Figure 9. Working with a point cloud in four viewports
(Rhinoceiros 4.0 software with the Pointools plug-in)

The top view was applied for bridge elements mapping. The point cloud was cut into sections in the manually adjusted horizontal construction plane. The altitude of the construction plane could be set at the height of the mapped bridge elements, such as the supports or the span. Additional functionality enables to set the thickness of the section which is generally used to clearly visualise mapped elements. Special attention should be paid to identification of construction elements. The point cloud covers any part of the bridge, which is visible for the scanner. In other words, the point cloud can be regarded transparent, what – unfortunately – it becomes disadvantageous for vectorisation. Although an element may be selected by clipping it in the section, it is sometimes impossible to identify the mapped part of the bridge.
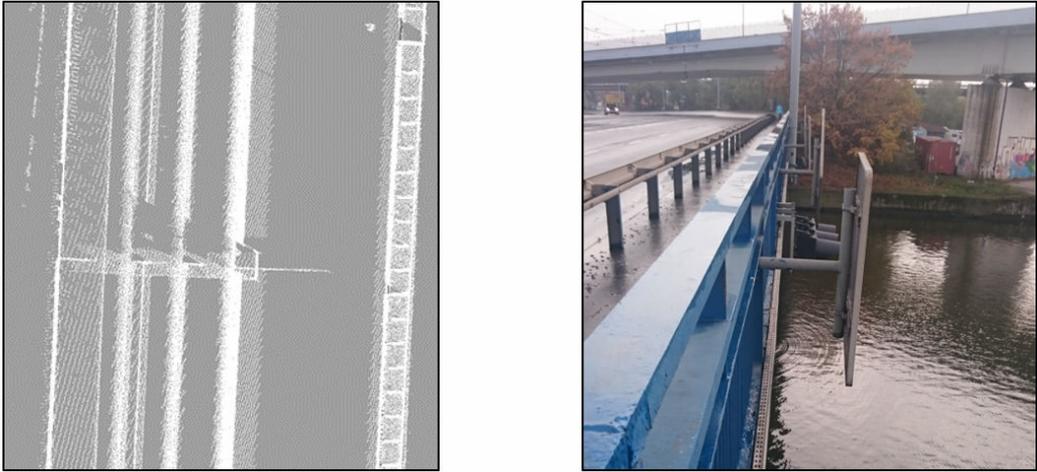
Figure 10. Visible elements in the extreme part of the span (left picture); identification was based on
additional photographs (right picture)

The span edge may be a good example. In the analysed case, the clouds contain points of the
upper and the lower parts of the span. As a result, it was difficult to state which part of the
scan represented the real edge of the span. In this case, identification was confirmed on the
basis of additional photographs (Fig. 10).

In order to obtain the vector data, vectorisation rules were set. This was dictated by the
fact that the point cloud has a certain thickness resulting from the accuracy of measurements
and combination of scans. They are generally not big values, but in order to standardise the
process of vectorisation the principles of acquiring vector data should be clearly determined.
The average thickness of the cloud point was 1.5 to 2 cm. Comparing to the accuracy of
mapping the bridge and supports required for inland electronic chart, which is 1 m, these
values are very small. Accordingly, it was found that the object will be vectorised in the line
of the outside element represented by the point cloud (Fig. 11). This approach facilitated the
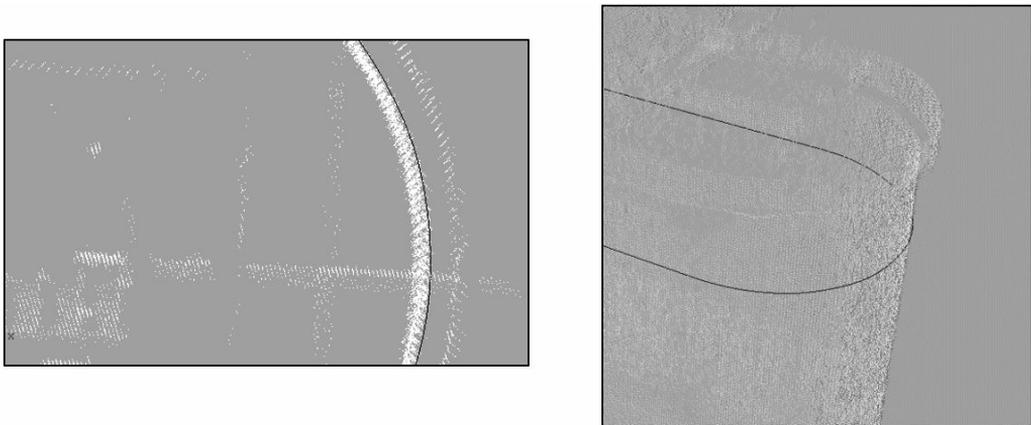

Figure 11. Example of vectorisation of the radiused part of the bridge support based on the outer edge
of the point cloud (2D and 3D views)

clear identification and precise modelling of mapped elements. For vectorisation purposes a drawing function of straight sections and a function of plotting curves passing through designated points were used. In this process the span, the supports and the fender located on the internal side of the supports were vectorised. Vectorised elements of the bridge (the span, the supports and the fenders) are illustrated in Figure 12.
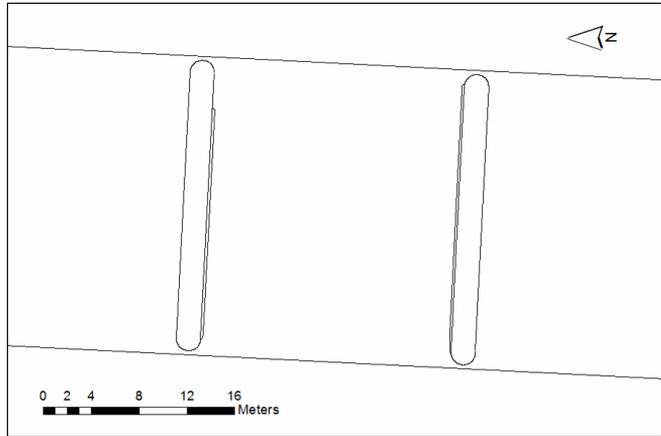
Figure 12. Vectorised elements of the bridge: the span, the supports and the fenders

Unfortunately, not all parts of the bridge were suitable for vectorisation. These include headlights and notice marks, mounted on the bridge span. The headlights are characterised by low reflections, due to the laser beam absorption by glass. Reflections from the headlights body were also weak, so it was impossible to identify the object. In some cases brackets of the headlights were much better visible. On the contrary, reflections from the notice marks were very high, but in any case the significant offset of the point cloud was visible. In good conditions the cloud of points should represent a thin line in the top view. In the analyzed cases, the thickness of the point cloud was 15–25 cm (Fig. 13). It was probably caused by the reflective surface of the sign, which specifically reflected laser beams. Unfortunately, such conditions did not allow to perform successive steps of vectorisation, due to the lack of unique identification of the real plane of notice marks.
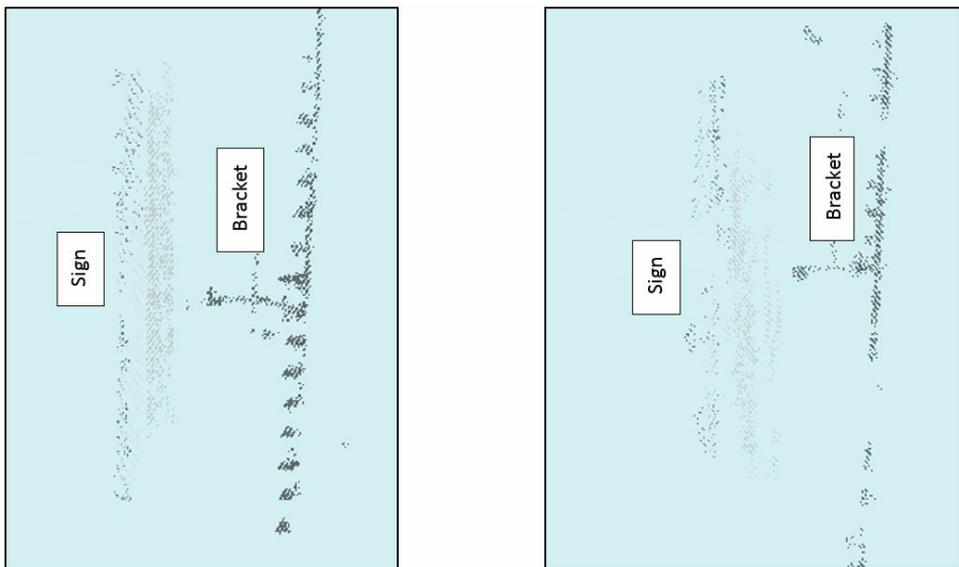
Figure 13. Reflections of navigation signs and headlight brackets (headlights were situated under the signs)

After vectorisation was completed, vector data were georeferenced to the coordinate system. Crosses determining centres of reference spheres were used as reference points. The affine transformations was performed for registration in the coordinate system. The final RMS transformation error was 2.2 cm. Vector data of the SHP format can be converted into the WGS84 coordinate system and then imported to a dedicated software application. In order to create a chart the Caris S-57 Composer software was applied. Then, resulting vector data were verified by an independent GNSS measurement of 1 cm accuracy. In order to verify vector data registered in the coordinate system 10 points were measured on the bridge span. The differences were calculated using the distance between the measured points and their orthographic projections on the span bridge vector. Obtained differences varied between 1cm and 8 cm, with the average difference of 4 cm. The results can be considered as very good, especially with respect to the required accuracy of 1 m. Possibilities to achieve higher accuracy for longer bridges is discussed in (Kedzierski at al., 2010), where the scanner with the longer range and reference targets placed on the bridge were used.

Workflow diagram

At the end of discussing the issues of mapping bridges on electronic maps I would like to present a methodological approach in the workflow diagram. Due to different scanning environments and scanning parameters it cannot be considered a universal. Depending on the bridge type, length, height, as well as the scanner type, its range, particular approaches to scanning may significantly differ from the proposed solution.

Basing on my experiences it may be stated that illumination conditions are of key importance point. As it was mentioned, the phase scanner does not perform very well in sunny weather. The best solution seems to be to scan at night. It is important to note that – depending on the season – some objects can be covered with dew in evenings what may negatively influence the scanning range. Water generally reduces the reflective properties of objects. During scanning at night we are obliged to be careful due to the limited visibility and the proximity to water. Sunny days may unfortunately considerably reduce the scanning range. Then, a good choice would be to perform scanning without the strong operations of the Sun.

Another element is the selection of measurement stations. In this case the proper distance to the bridge must be ensured, taking into account the angular distance to the extreme elements on the opposite bank. As mentioned above, the range of the scanner may be heavily dependent on the light conditions, so – basing on the parameters specified by the manufacturer – it may be significantly overstated. A good approach is to make a preliminary scan, with the adopted resolution, and to check the current range of the scanner. Selection of the amount of measurement stations may be an individual matter, related to the occurrence of overrides or the elimination of blind sectors. Sometimes it may be related to the physical availability of the station. Usually, it will be harder to find such a position in the non-urbanized area than in urbanized ones.

Combinations of scans are facilitated by reference targets in the form of planes, check board or spheres. In addition, a point cloud can be registered to the coordinate system using the reference targets. A problem with the reference targets is their location on the bridge. While this can be done on the span of the bridge, it becomes more problematic on the supports. Mounting references on supports requires renting a boat. Due to long distances,

these objects should be relatively large. A better solution is to ensure the quality of scans and to use algorithms for automated point clouds combination. Reference objects can be used to make scans of the same scanning area and to register the project point clouds in the coordinate system.

After the process of measurements scans are combined into a single project point cloud. The data processing and combination process will strictly depend on the software applied. Again, it should be stressed that the essential quality will depend on the set of points. However, increasing the density of measurements will not increase the scanning range. Even in the case of high-quality data a problem with cloud combination can occur due to the symmetry and similarity of the bridge elements. Some algorithms cannot correctly recognize the parts of the bridge. It will be always possible to combine scans manually. No matter which path is selected, the point cloud evaluation should be finally performed by visual inspection from different perspectives. The elements compliant at the top view will not always mean that the point cloud is correctly vertically fitted. A bridge has usually simple geometric shapes and sometimes it is difficult to notice even more shifts (e.g. in the vertical plane of supports).

Combined scans should be registered in the coordinate system. This is especially important for controlling scans levelling. Unfortunately, rotation of the project point cloud can lead to significant errors of mapped elements, which are projected onto the horizontal plane. It is important to ensure the adequate accuracy.

Mapping of elements will also depend on the software. Based on my experience, I can recommend working in a four viewport setup with the point cloud sections. In this way it is possible to accurately set the construction plane with respect to he object of interest, and then to perform vectorisation. Acquisition of vector data from the point cloud should be determined in advance. In the discussed case, I vectorised the outer contour of the point
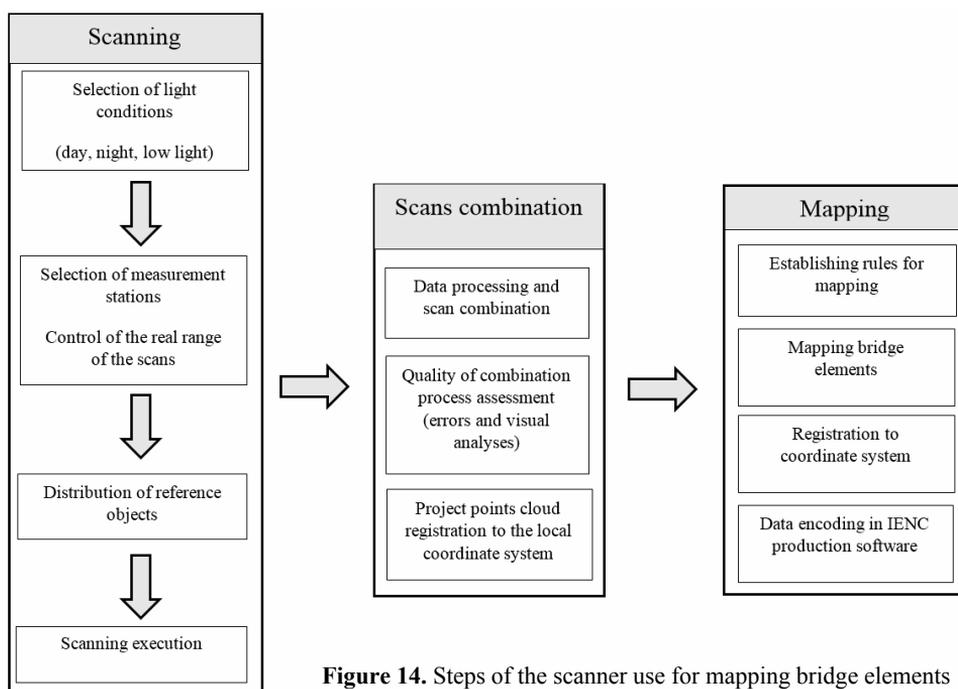
Figure 14. Steps of the scanner use for mapping bridge elements

cloud. One may also apply automated methods of generating planes from the clouds, but it will always be problematic in nonlinear parts. Apart from this, automated cloud generation can also depend on the type of material and the distance from the scanner (Kedzierski at al., 2015b). Besides, everything will depend on the final vector data accuracy.

Georeferencing is the last stage; it registers the vector data to the actual geographic coordinate system. Data in this form are ready to use in the program for creation of electronic maps. All steps are presented in Figure 14.

Conclusions

Basing on performed works and studies it can be concluded that the process of mapping bridges using laser scanning is performed in several stages. The first and the most time-consuming stage, is associated with data acquisition. It turns out that illumination conditions (especially the Sun impact) are the important elements of that stage. In order to obtain the maximum range of scanning the low – light or night scanning should be applied. As far as possible scanning in sunny days should be avoided. The next stage of scanning is associated with the processing the project point clouds. In this case, the quality of scans and their overlapping is important. Generally, this influences the speed of scan combination. In the case of manual combinations, it may be sometimes difficult to find the sufficient number of tie points, located on the span and supports. Hence, it is definitely worth to plan scanning in such a way that the maximum range specified by the manufacturer is achieved. It should be noted that the phase scanner was used for the discussed study. The use of a pulse scanner may lead to different results and conclusions.

An important element of this stage is the quality control of complex point clouds, comprising the analysis of datasets matching errors and the visual inspection from different perspectives. It is also important to control scan levelling. For this purpose, data registration to a local coordinate system was performed. Vectorisation was the least time-consuming stage; it required the practical knowledge of the software functionality. The rules of creating vector data from the point cloud should be developed. In the discussed project the external contours of the point cloud were used.

The results turned to be very good. Differences between the actual points and the vector data were calculated on the basis of the control points. The average error was 4 cm, and the maximum error equalled to 8 cm. Terrestrial laser scanners can be used for very accurate mapping of bridges based on combination of scans with the limited reference targets and using automated methods.

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Streszczenie

Mosty są jednymi z ważniejszych obiektów w elektronicznych mapach nawigacyjnych. Obecnie można korzystać z wielu źródeł do tworzenia map, takie jak mapy zasadnicze, ortoobrazy czy opracowania w postaci rysunków technicznych. Niestety, nie zawsze powyższe materiały są odpowiednie do pozyskiwania danych mostów. Na mapach zasadniczych nie zawsze zachowany jest rzeczywisty kształt podpór, na ortoobrazach wszystkie elementy pokrycia terenu podlegają przesunięciom radialnym względem środka rzutu zdjęcia, natomiast rysunki techniczne nie posiadają punktów referencyjnych umożliwiających zarejestrowanie danych do układu współrzędnych.

W artykule przedstawiono wykorzystanie naziemnego skanera laserowego do kartowania mostów, od etapu pozyskiwania danych do etapu pozyskania danych wektorowych. W badaniach dokonano analizy zasięgu skanera w aspekcie skaningu dziennego oraz nocnego, omówiono problemy związane ze składaniem chmur punktów, omówiono proces rejestracji projektowej chmury punków do układu współrzędnych oraz proces wektoryzacji. Finalnie sprawdzono dokładność danych wektorowych na postawie niezależnego pomiaru punktów kontrolnych. Uzyskane różnice pomiędzy punktami kontrolnymi a danymi wektorowymi w wielkości średniej wartości 4 cm oraz maksymalnej 8 cm, wskazują na zasadne wykorzystanie tej techniki do kartowania mostów w elektronicznych mapach nawigacyjnych. W etapie końcowych zestawiono wszystkie czynności związane z pozyskaniem danych oraz kartowaniem danych wektorowych w postaci diagramu przepływu pracy.

Abstract

Bridges are one of the most important objects of electronic navigation maps. Presently, multiple sources to create maps, such as basic maps, orthoimages or technical drawings, can be used. Unfortunately, these materials are not always suitable for collecting bridge data. Basic maps do not always present correct shapes of the supports, on orthoimages all land cover elements are subject to radial shifts, relative to the projection centre, and drawings do not have reference points to allow for data registration to the coordinate system.

The paper presents the use of terrestrial laser scanning for mapping bridges, from data collection to acquisition of vector data. The study analyzes the range of scanning performed in day and night conditions, discusses the problems associated with point clouds combination, discusses the process of the project point cloud registration to the coordinate system and the data vectorisation process. Finally, the accuracy of vector data was analysed on the basis of independent measurement control points. The resulting differences between the checkpoints and the vector data with the average value of 4 cm and the maximum value of 8 cm, indicate that the use of this technique for mapping bridges on electronic navigation charts is justified. In the final stage, all the activities related to the acquisition of mapping data and vector data are presented in the form of the workflow diagram.

Dane autora / Author details:

dr inż. Jacek Łubczonek
https://orcid.org/0000-0000-0002-9400-3426
j.lubczonek@am.szczecin.pl