Identification of shorelines for natural watercourses with the use of point cloud

Ewa Sudoł[1,*]

[1]Wroclaw University of Science and Technology, Faculty of Geoengineering, Mining and Geology, 27 Wyb. Wyspiańskiego St., 50-370 Wroclaw, Poland

Abstract. The article presents the method of identifying the shorelines for natural watercourses located in agricultural and forest areas in accordance with applicable law. In the process of developing methods for identification and verification of the actual course of watercourses, data from the cadastral map was used in the form of a vector drawing of borders and a database with border points in ZRD, BPP attributes, metadata and point clouds. The identification of the course of a watercourse on shrubbery and wooded areas as well as on-screen vectorization of the shoreline is cumbersome, and in some cases even impossible. In connection with the above, it has been proposed to use a point cloud and vertical sections prepared on their basis that run perpendicular to the edge of the watercourse. On their basis, the course of the shoreline was recognized in accordance with the definition contained in the Act on Water Law. Pursuant to § 9 para. 3a, beginning of the regulation that the land occupied by the natural seepage constitutes a separate cadastral plot within the boundary line, the suggested procedures for verifying the boundaries of watercourses can be used to update the land and building register databases. The identification of the boundaries of registered parcels made on the principles described in the publication may precede the activities of accepting the boundaries to the division of real estate. On the other hand, the course of the identified, in the mode of § 82a, the regulation the boundaries of registration plots constituting natural watercourses can be shown in the land and building register on the terms specified in art. 24 sec. 2b point 2) geodesy law, in order to replace data inconsistent with the actual state and applicable technical standards, respectively, data consistent with the actual state and applicable technical standards (§ 45 section 1 point 1 of the Regulation).

1 Introduction

The natural boundaries of watercourses have changing their course over the years. Rivers located in agricultural and forest areas often strongly meander, form oxbow lakes and change the course of the main river bed within a short period of time. The above processes occur in an irregular way, difficult to predict. Keeping a cadastral map with regard to the boundaries of watercourses on agricultural lands in accordance with the legal requirements for maintenance of the registration data in the current state and periodical verification of record data using traditional geodetic measurements is expensive, time-consuming and quite onerous, especially in forest areas.

1.1 Location of the research area

In order to develop research methods, a number of analyses were carried out for data from the Oleśnica poviat. The fragments of the Oleśnica and Widawa rivers were selected as the test area. Due to the character of the works, fragments of watercourses running in natural channels were selected. The analyses carried out were to show whether the registered plots constituting watercourses indicated in the database of land and buildings records are a reliable and current source of information on the actual course of the rivers.

1.2 Structure of input data

The following data was used to identify this issue:
- cadastral map in vector format,
- database of border points (in terms of attributes, ZRD, BPP, date of data acquisition),
- data from laser scanning for six locations in the county of Oleśnica poviat in the period June-October 2017.

The input data was verified before performing the appropriate tests. In the first stage, the following layers of the cadastral map were selected: plot boundaries, border points, land boundaries, and land use designations. For such a selected area, a database of border points was created containing information on: point number, flat co-ordinates in the 2000/18 layout, ZRD attribute (source of data acquisition), BPP (error of average position of the point), date of data acquisition.

* Corresponding author: ewa.sudol@pwr.edu.pl

The laser scanning data used in the study were obtained by MGGPAERO at the request of the Oleśnica poviat as part of the development of aerial laser scanning and the classification of point clouds with coloring. The study area was 53.6 km^2. The scope of the study included built-up areas around 6 locations in the Oleśnica poviat, namely: Dobroszyce, Oleśnica, Bierutów, Twardogóra, Międzybórz, and Syców (Fig. 1).

Fig. 1. Location of the research area.

2 Light Detection and Ranging technology

Light Detection and Ranging (Airborne Laser Scanning) it measures the distance from an aircraft (helicopter or aircraft) to the points of the earth's surface. A laser scanner with very high frequency scans the area with a swing motion in a direction perpendicular to the direction of flight, and in mutually overlapping, parallel stripes. The LIDAR system is built from the aerospace segment, which includes a laser rangefinder, a data acquisition receiver, an inertial navigation system (INS), a flight trajectory (GPS) system, a video camera, a flight planning and management system, and a ground segment in which there is a terrestrial GPS reference station and a workstation for data processing. The processing of data from the distance, GPS and INS system allows calculation of the consecutive X, Y, Z of the cloud forming points, the rate of point density being sufficient to obtain a three-dimensional model representing the surface area and its coverage. In the process of processing the aerial data of airborne laser scanning, the main task is to determine the points belonging to the appropriate surfaces. The above process is called classification and filtration of cloud points. The standards binding in the classification process have been specified by American Society for Photogrammetry and Remote Sensing.

Classification must adhere to the following standard:

Table 1. ASPRS Standard LIDAR Point Classes [1].

Classification Value (bits 0:4)	meaning
0	Created, never classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	Reserved for ASPRS Definition
11	Reserved for ASPRS Definition
12	Overlap Points
13-31	Reserved for ASPRS Definition

The input data has been saved in the LAS 1.2 format. The LAS file format is a public file format for the interchange of 3-dimensional point cloud data data between data users. Although developed primarily for exchange of lidar point cloud data this format supports the exchange of any 3-dimensional x,y,z tuplet. Preliminary Classification and filtration was carried out using specialized software TerraScan package TerraSolid. Acceptable classification error of 5% for all classes except the "ground" class - where the permissible error is 1%. For better data visualization points cloud coloring in the RGB range of aerial photographs.

Detailed technical conditions regarding the data obtained are presented below:
- points cloud obtained by aerial laser scanning;
- density not less than 10pkt/m^2 - for a single series;
- air raid in east-west directions;
- registration of several reflections, not less than 4;
- scanning angle up to 50°;
- coverage between rows: min. 50%;
- registration and recording of the intensity signal (Intensity);
- accuracy of laser points location, understood as the average position and height error:
- altitude accuracy: mh≤0.10m, situationally mXY≤0.20m.

Classification and filtration algorithms used in specialized programs are not perfect, therefore they constitute a field for scientific research. We distinguish groups of methods using [2, 3]:
- resistant to linear predictions [4-6],
- iterative approximation of the selected starting area (TIN) to the measurement data [7],
- purchasing analysis [8, 9],
- operators of mathematical morphology (criterion of slope of land) [10],
- minimization total surface energy, depending on its slope (slope) [11, 12] and in a generalized form [2],

- frequency analysis techniques based on the FFT method [13] or wavelets [14].

3 Legal basis within the boundaries of watercourses

The principles of establishing and updating a cadastral map within the boundaries of plots have been precisely specified in the Act of 17 May 1989. Geodetic and Cartographic Law (Dz.U.2017.2101) [15] and the Regulation of the Minister of Regional Development and Construction of March 29, 2001 [16] on the registration of land and buildings (Dz.U.2016.1034) and the Act of 20 July 2017. Water law (Dz.U.2017.1566) [17].

Detailed guidelines on the identification of shore lines are described in art. 220 of the Act of 20 July 2017. Water law (Dz.U.2017.1566). According to its content:

„1. The shore line for natural watercourses, lakes and other natural water reservoirs is the edge of the shore or a line of permanent lichen grass or a line that is determined according to the average water level for at least the last 10 years.
2. If the edge of the bank is clear, the edge line runs along this edge.
3. If the edge of the bank is not clear, the edge line runs along the border of the permanent grass growth, and if the limit of permanent grass growth lies above the water level referred to paragraph 1 - the line of intersection of the water table in this state with the adjacent ground.
4. If the banks of the waters are regulated, the shore line runs along a line joining the outer edges of the regulatory structures, and in the case of wicker plantations on the land obtained as a result of the regulation - the border of the plantation from the land side."

According to § 2 Geodetic and Cartographic Law of the above-mentioned regulation, the boundary of the registered parcel is "part of the district of the parcel of land, in the form of a polyline or section, shared by two neighboring parcels or coinciding with the state border - in the case of parcels adjacent to this border". However, § 3a states that "land occupied by a natural sewer constitutes a separate register plot within the boundary line, regardless of whether the water in this watercourse flows through a natural channel or a regulated uncovered or covered channel".

The issue of determining the boundaries of registered parcels is defined in § 36 and 37 of the Ordinance of the Minister of Regional Development and Construction from March 29, 2001. on the registration of land and buildings (Dz.U.2016.1034). Paragraph 36 describes the basics of plotting land borders in records. According to its content: "the course of boundaries of registered plots is recorded in the records on the basis of geodetic documentation, adopted to the state geodetic and cartographic resource, prepared:

1) in demarcation proceedings;
2) in order to divide the real estate;
3) in merger and land exchange proceedings;
4) in proceedings regarding the consolidation and division of real estate;
5) for the purposes of court or administrative proceedings, and then used to issue a final court decision or final administrative decision;
6) when establishing, on the basis of previously applicable regulations, a real estate cadastre and records of lands and buildings;
7) by the Border Guard, if this documentation determines the course of state borders with accuracy appropriate for the records;
8) as a result of geodetic situational measurement of existing or renewed border marks or designated border points.

On the other hand, § 37 states that "if the documentation mentioned in § 36 is missing or if the data contained therein are not reliable, the data on the boundaries of the cadastral parcels are obtained as a result of geodetic field measurements or geodetic photogrammetric measurements preceded by the determination of these boundaries. The determination of the boundaries of registration parcels, including the location of the border points determining them, may take place based on aerial, satellite or orthophotomap images, if these images or orthophotomap are characterized by a resolution that provides visualization of situational details that may be relevant in determining the boundaries. " (§ 37 items 1 and 2).

4 Identifying methods the shorelines for watercourses using a points cloud

The test raw cloud of points comes from the raid carried out in the area Oleśnica poviat. Airborne Laser Scanning was performed in May 2017 by MGGP Aero [18]. Laser scanning was performed in the east-west direction. The projected density of a single scan was 15 point/m^2. The transverse coverage between neighboring scans (50%) allowed to achieve the final cloud density of points 24 point/m^2. Research was carried out for the area along the fragments of the Oleśnica and Widawa rivers located in agricultural and forest areas. Fragments were taken where the rivers flow in a natural riverbed through areas that are full of trees and trees (Fig. 2).

The data processing took place in the following stages:

- generating a points cloud (extraction, calibration, georeference),
- reduction of the height attribute of the point cloud to the geoid, based on the surface generated in the Geoida2001 program,
- clearing the point cloud by filtering the extreme altitude values
- LIDAR point cloud classification.

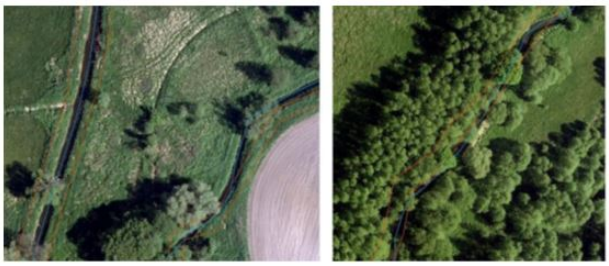

Fig. 2. Fragments of the Oleśnica river.

In the first stage, the process of classification of a selected fragment was carried out according to the generally accepted sequence diagram of assigning cloud points to individual classes. First, the points that extend significantly from the surface were captured (subject to the low point class). Subsequently, the ground was classified and the appropriate parameters were assigned to low, medium and high vegetation classes. The final stage is the classification of water. Then, a series of vertical sections were made using the GlobalMapper software (Fig. 3). On their basis, the course of the shoreline was recognized in accordance with the definition contained in the Act on Water Law. Identified edges of watercourses were allowed to be countered and compared with cadastral data. The input cadastral data was verified before performing the appropriate tests. In the first stage, the following layers of the cadastral map were selected: plot boundaries, border points, land boundaries, and land use designations. For such a selected area, a database of border points was created containing information on: point number, flat co-ordinates in the 2000/18 layout, ZRD attribute (source of data acquisition), BPP (error of average position of the point), date of data acquisition. On the basis of such collected and harmonized data, a number of queries were carried out, which allowed the assessment of the quality of the land and building registry database in the scope of:

- whether the riverbed is within the boundaries of the plot,
- whether the shoreline is poking with the plot line border.

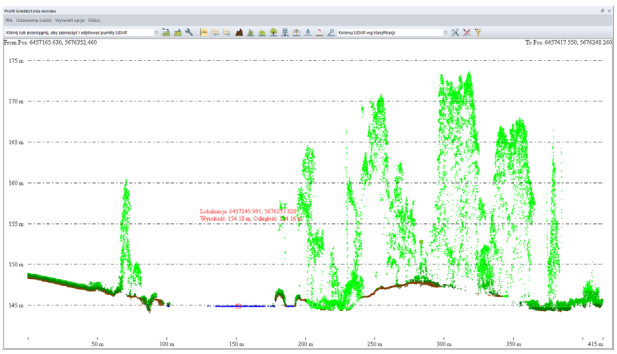

Fig. 3. Example of vertical sections made using the GlobalMapper software.

With this method it was possible to instantly identifies the actual location of the watercourse shoreline

As a result, areas for which cadastral data are incompatible with the actual state are marked, i.e. those for which the database should be made.

5 Conclusions

The article presents the author's method of examining discrepancies in the record boundaries constituting watercourses with their actual course using a point cloud to identify the actual course of the shoreline. The proposed procedure for verifying the boundaries of watercourses can be used to update the database of the Land and Building Register entered by the foreman. Suggested spatial query procedures detect discrepancies in boundaries that can be a tool used to verify these boundaries, eg in the work of modernization of land and building registry databases. The identification of the boundaries of registered parcels made on the principles described in the article may precede the activities of accepting the boundaries to the division of real estate. Additionally, it should be noted that after December 31, 2017. there were significant discrepancies in the watercourse record included in the Water Law Act and the Regulation on the Land and Building Records. This causes unclear situations in the manner of determining the manner of using the lands occupied under waters, and thus determining the ownership of these lands.

References

1. https://www.asprs.org/wp-content/uploads/2010/12/LAS_1_3_r11.pdf
2. A. Borkowski, PTIP, Roczniki Geomatyki, Vol. **III**, 4, 35-42 (2005, in Polish)
3. A. Borkowski and G. Jóków Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. **17**, 83-92 (2007, in Polish)
4. K. Kraus, Photogrammetrie. Band 3, Topographische Informatonssysteme, Dümmler, Köln (2000)
5. K. Kraus and N. Pfeifer, International Archives of Photogrammetry and Remote Sensing, Vol. **XXXIV-3/W4**, 23–30 (2001)
6. C. Briese, N. Pfeifer, P. Dorninger, International Archives of Photogrammetry and Remote Sensing, Vol. **XXXIV/ 3A**, 55-61 (2002)
7. P. Axelsson, International Archives of Photogrammetry and Remote Sensing, Vol. **XXXIII-1/B4**, 110-117 (2000)
8. M. Roggero, International Archives of Photogrammetry and Remote Sensing, Vol. **XXXIV-3/W4**, 227-232 (2001)
9. S. Filin and N. Pfeifer, ISPRS Journal of Photogrammetry and Remote Sensing, **60**, 71-80 (2006)
10. G. Vosselman and H.-G. Maas, OEEPEWorkshop on Airborne Laserscanning and Interferometric SAR

for Detailed Digital Elevation Models, 1-3 March (2001)

11. M. Elmqvist, E. Jungert, A. Persson, U. Soderman, International Archives of Photogrammetry and Remote Sensing, Vol. **XXXIV-3/W4**, 219-227 (2001)
12. M. Elmqvist, ISPRS, Commission III, Symposium Photogrammetric Computer Vision, Graz, September 9-13 (2002)
13. U. Marmol and J. Jachimski, ISPRS Congress, Commision 3, Istambul, Turkey, 12-23 July (2004)
14. A. Borkowski and W. Keller, 8th Bilateral Geodetic Meeting Poland-Italy. Wrocław, 22-24 June (2006)
15. Geodetic and Cartographic Law (Journal of Laws 2017. Item 2101), consolidated text, state of the legal act: in force
16. Regulation of the Minister of Infrastructure and Construction of March 29, 2001 inon the registration of land and buildings (Journal of Laws of 2016, item 1034), state of the legal act: in force
17. Water law sets of 20 July 2017. (Dz.U.2017.1566), unified text, state of the legal act: applicable
18. Technical report: Acquisition and processing of laser scanning data for 6 locations in the Oleśnicki poviat, MGGPAERO, Tarnów (2017)