Semi-Automatic Classification of Power Lines by Using Airborne Lidar

Dragana POPOVIC, Vladimir PAJIC, Dusan JOVANOVIC, Filip SABO, Jovana RADOVIC, Serbia

Key words: LIDAR, Power Lines, Cadastre, Classification

SUMMARY

Light Detection and Ranging (LIDAR) can be used for collecting spatial data of power (transmission) lines providing more accurate geometric information of the power lines and vegetation/object near power electric network. However problem with this kind of data is extraction and classification of raw point cloud data. There is no perfect automatic classification of points, so it is necessary to process data with semi-automatic classification.

This paper describes the method of applying automatic and semi-automatic classification to point cloud data in order to extract valid 2D/3D cadastre data. Also, this paper analyses the combination of orthophoto and oblique images with LIDAR 3D data for the area of interest. By using the combination of the two datasets, it is possible to detect more details. After 2D/3D vectorization and point classification, derived data is used to create Digital Terrain Model (DTM), longitudinal profiles, cadastral maps. Obtained data can be used in cadastre, Electrical Control and Energy Management System.

Semi-Automatic Classification of Power Lines by Using Airborne Lidar

Dragana POPOVIC, Vladimir PAJIC, Dusan JOVANOVIC, Filip SABO, Jovana RADOVIC, Serbia

1. INTRODUCTION

Electricity distribution infrastructure represents important part of a country infrastructure. The main purpose of electrical power distribution network is to provide power to consumers. Power line networks are often in areas which are not easily accessible and therefore, the power lines network may be difficult to survey. It is necessary to find an adequate method of collecting data that will enable fast, effective and accurate output data for power lines infrastructure.

More recently, the LIDAR system is introduced as a cheap and effective method for data collection that is capable to quickly capture 3D scenes. Another benefit of this automation in data collection and map generation is that it allows a previously unattainable level of detail. Both surveying and photogrammetric mapping required extensive human labor, making it costly to map at a high level of detail. Lidar mapping, being highly automated, can shoot many laser pulses a second (Krogstad & Schiess, 2004).

Also LIDAR data can produce highly detailed topographic maps with high accuracy. This data can be used in many cases, but mainly for the purpose of cadastral information system and management of electricity distribution infrastructure. The crucial elements which had to be extracted in this work are poles, wires, power lines, substations and nearby objects. It is necessary to process recorded data with certain operations that enable right amount of information. This technology provides accurate position (spatial) information of wires, structures, vegetation and the ground along the power line corridor.

This paper presents a solution for mapping of power lines using LIDAR data, with it's advantages and disadvantages. Workflow of this work is given in Figure 1 below.

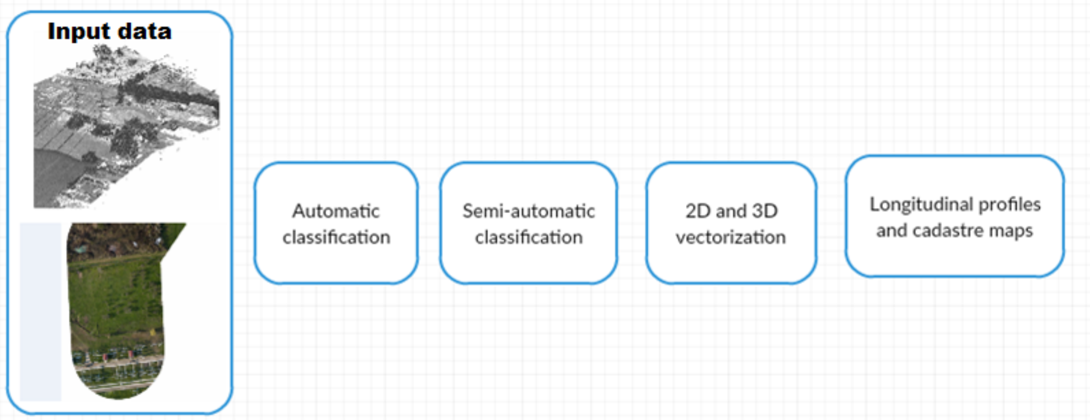


Figure 1 Study workflow

The problem of identifying and monitoring of power lines can be solved by using different solutions. For example, the problem of automatic identification of power lines can be solved by forming an algorithm called Voxel-based Piece-wise Line Detector (VPLD) (Jwa, Sohn, Kim, H. B. 2009). The algorithm proposed by Sohn is based on the segmentation (linear and planar segment) using Markov Random Field (MRF) classifier that identifies the power lines of linear segments, as well as objects from planar segment (Sohn, Jwa, Kim 2012). Application of extraction lines in forests in Finland is represented by a method which consists of statistical analysis and image-based processing (Zhu, Hyyppä, 2014). The first phase provides selection of candidates for the power line, while the second phase comprises of converting the candidates in a binary image, after by the image-based processing. The results showed that 93.26% of power lines were appropriately classified. Cheng et al. (Cheng, Tong, Wang, Li 2014) and other similar works performed extractions of power lines using a voxel-based hierarchical model in which the geometric elements are calculated for each voxel. Then, from below upwards by filtration belonging to the power line. The process is iteratively performed to identify each power line. Bo Guo describes a robust algorithm for reconstruction of power lines based on automatic classification (RANSAC) of five target class before reconstruction. RANSAC algorithm is used for reconstruction of the power lines. The experiment showed that the proposed method is most effective for the extraction of power lines(Guo, Li, Huang, Wang, 2016).

2. DATA AND STUDY AREA

Study area consists of locations that represents main electric infrastructure of Serbia. Eight hundred kilometres of main power line network was recorded using LIDAR technology. Network consists of power lines, poles, substations and other objects nearby. Two datasets were used for this project, LIDAR data and ortophoto with oblique images. LIDAR system is complex, multi-sensor systems consisting of at least three sensors, the GPS and INS navigation sensors, and the laser scanner system (May, Toth 2007). Figure 2 represents just part of 800km of trajectories of captured power lines. Trajectories were marked with red lines.

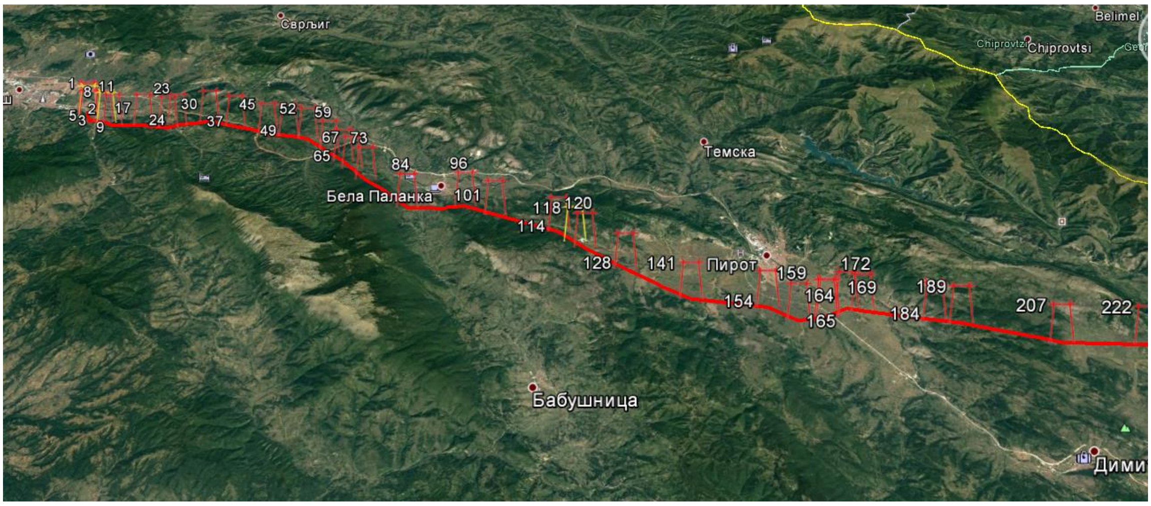


Figure 2 Example of trajectories of power lines in south-east part of Serbia

Datasets used for this project were raw LIDAR data and ortophoto. Ortophoto and oblique images were captured with Riegl MS-q680 camera that was integrated with LIDAR system. The long-range *RIEGL* LMS-Q680i airborne laser scanner makes use of a powerful laser source, multiple time around (MTA) processing, and digital full waveform analysis. This combination allows the operation at varying flight altitudes and is therefore ideally suited for aerial survey of complex terrain. His best features are high laser pulse repetition rates up to 400 kHz, multiple-time-around (MTA), processing up to 266 000 measurements/sec on the ground, high ranging accuracy up to 20 mm, wide scan field of view up to 60°, interface for smooth integration of GPS, high scan speed up to 200 lines/s (Riegl).

LiDAR dataset was given in Universal Transverse Mercator (UTM) World geodetic system 1984 (WGS 84), zone 34N - horizontal coordinate system. Vertical coordinate system was given in Elipsoid WGS 84. Figure 3 represents an example of raw LIDAR data represented by elevations and ortophoto corresponding to the selected point cloud.

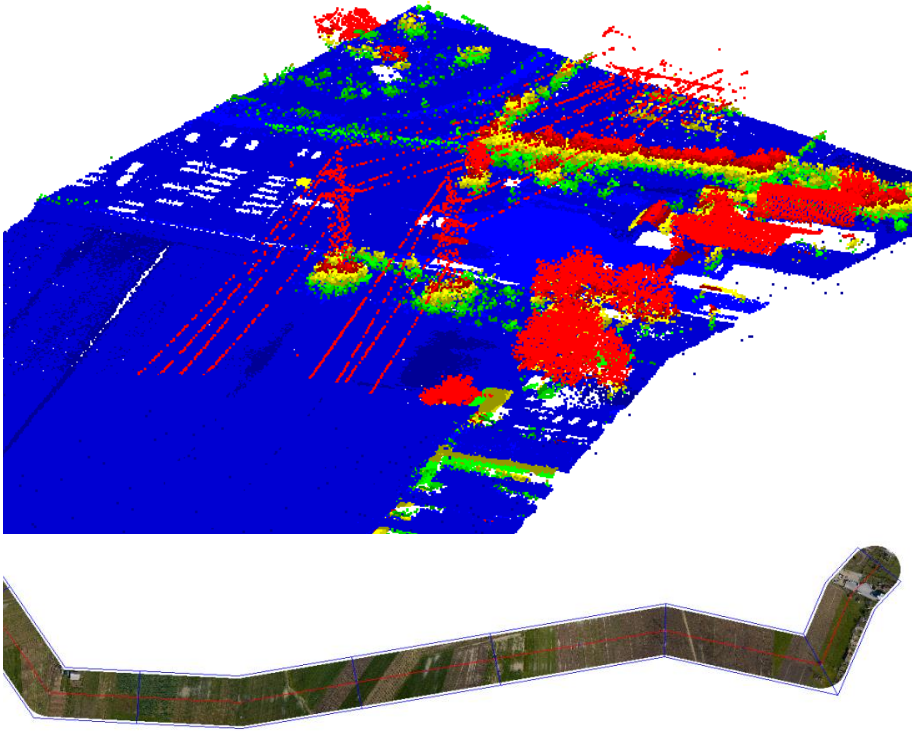


Figure 3 LIDAR data and ortophoto

3. METHODOLOGY

3.1 Automatic classification of LIDAR point cloud

Applications used for data processing were TerraScan, TerraModeler and TerraPhoto. TerraScan is the main application in the Terrasolid Software family for managing and processing LiDAR point clouds. It offers import and project structuring tools for handling the large amount of points of a laser scanning campaign as well as the corresponding trajectory information. Point cloud management, processing and visualization is only one part of TerraScan. In addition, the software provides tools for creating 3D vector data based on the laser points. TerraModeler creates surface models (TINs) from various sources, such as LiDAR points stored in binary files or loaded in TerraScan, XYZ ascii files and graphical design elements. TerraPhoto is specifically developed for processing images captured together with laser data during a survey mission. The software enables the production of rectified images and ortho mosaics based on ground model that has been extracted from the laser data (TerraSolid).

Due to large amount of data collected and due to the fact that point cloud processing is highly memory demanding , blocks 500m x 100m with imported points were created. After the data pre-processing, automatic classification was applied with thirty two classes and appropriate attributes. For the purposes of automatic classification macro files were created with parameters which define density of points and altitude. Automatic classification resulted with the points being classified in more than one class, or the points were misclassified. In this case, only 3 classes were possible to extract. Those classes were vegetation, building and ground. Results of this classification are given in Figure 4. It is clear that those classes do not fulfil the whole classification requirements. For deriving all defined 32 classes semi-automatic classification was applied.

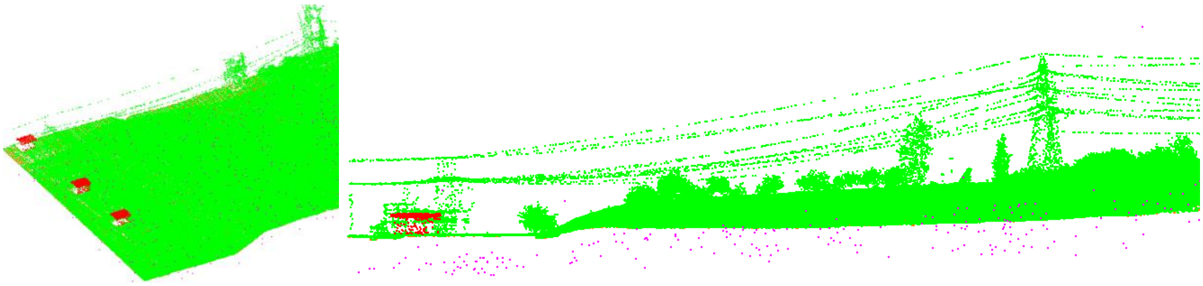


Figure 4 Result of the automatic classification

Table 1 contains 8 most frequently used point classes with defined labels, levels, colours.

Label	***Level***	***Color code***	***Color***
Ground	2	6	🟧
Vegetation	3	2	🟩
Power Pole	4	105	🟦
Building	10	3	🟥
Power Wire	66	200	⬛
Lightning wire	67	216	🟦
Other wire	61	168	⬜
Other pole	75	105	🟦

Table 1 Legend of mostly used point classes

3.2. Semi-automatic classification of LIDAR point cloud

Because automatic classification could not extract classes such as poles wires at different voltages, crossings, etc, and because each point that belongs to specific object in point cloud has to be in appropriate point class (32 classes are defined), semi-automatic classification was used. Using specific tools, points from class *vegetation* were transferred to class *wires* at different voltages, poles, substations etc. In this part of the classification, it was necessary to manually defined area of interest and change classified point value from one to another class. Figure 5 represents the classification of vegetation points into class pole. Pole is represented with blue points.

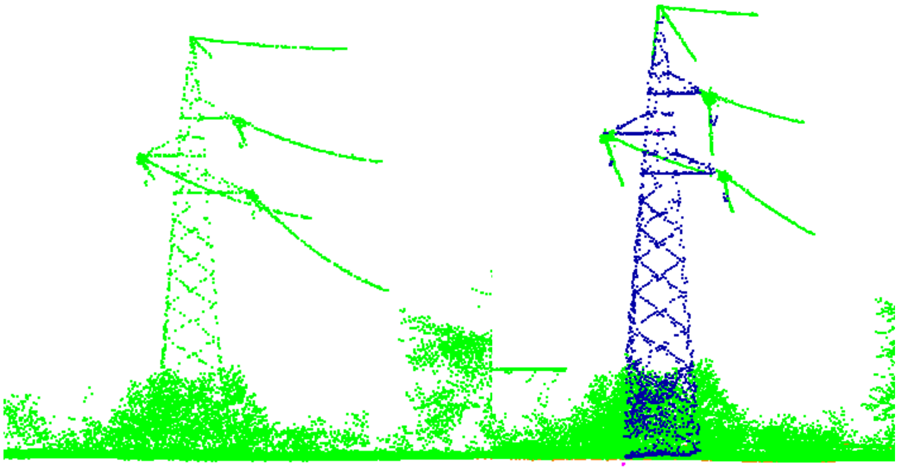
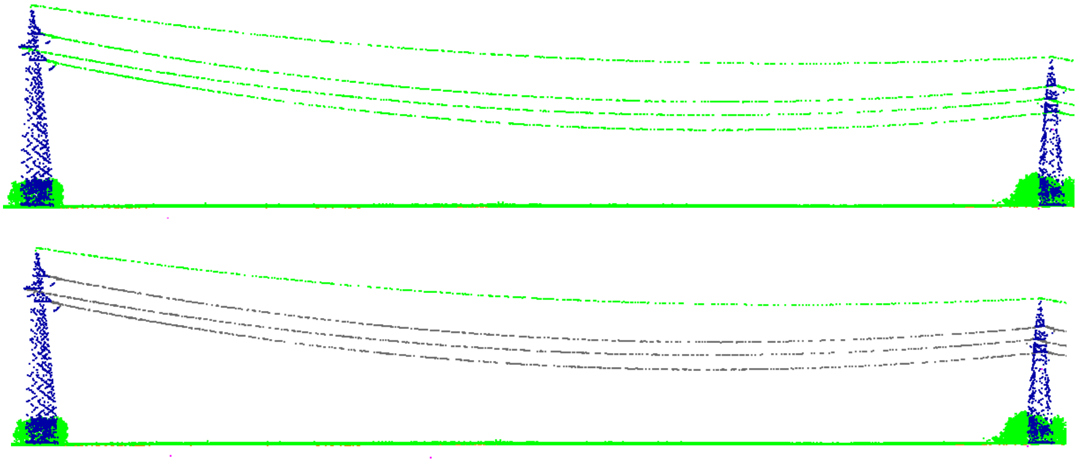


Figure 5 Reclassification of misclassified points of pole

One of the problems with power lines are catenary strings. They also can not be extracted by using the automatic classification. This problem was solved by using tools that allowed changing point classes by using an integrated algorithm. By choosing the right profile and defining 5 points that surely belong to catenary string it was possible to classify all points that belong to catenary string. Figure 6 contains visual review of catenary classification from class vegetation to wire class (grey points) and lighting wire (turquoise points).



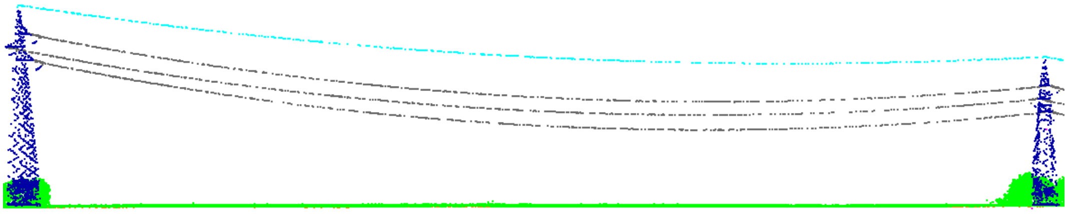


Figure 6 Classification of misclassified points of wires

Also, there was a problem with detecting different kind of street elements close to vegetation or some other objects. For this kind of problem ortophoto and oblique images were used. Those images are georeferenced and matched with the point cloud data. Image enabled visual inspection and manual classification was possible. It was easier to detect smaller object in different profiles from different viewing angles. Figure 7 represents combination of the two datasets and the detection of the pole with close to vegetation.

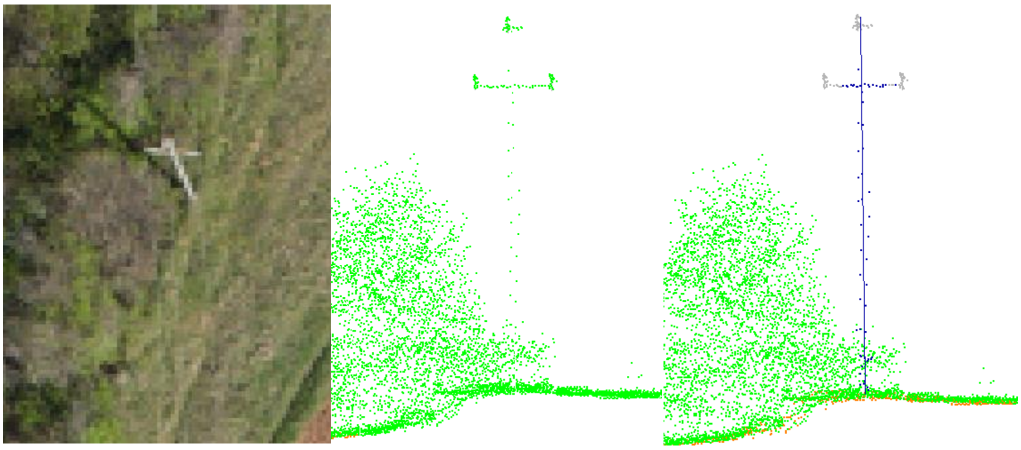


Figure 7 Detection of points close to vegetation that belongs to pole

3.3. 2D and 3D vectorizaton

Vectorization converts point cloud, raster or some other formats to vector data type with certain geometry type such are lines, points, polygons, curves, etc. Compared to the input data, output data provide higher order of control and more attributes which are used in geographic information systems (GIS). For the purposes of this project, 32 different vector layers were used. *Table 2* contains mostly used layers with attributes.

Label	***Number***	***Colour code***	***Colour***
Power line	1	3	🟥
Power Wire	6	160	⬛
Power Pole-Centre	7	15	🟦
Power Pole - foundation	8	5	🟪
Building	10	3	🟥
Road	41	9	⬜

Lightening wire	68	7	🟦
Other wire	69	88	⬛
Other pole	72	105	🟦

Table 2 Used layers

Main objective is to extract 2D and 3D data for poles and wires. In a point cloud, a pole is represented as a cluster of points, which points toward the vertical direction. Foundation of pole can be obtained by using points which are classified as *pole*. Creating rectangle using boundaries of points it is possible to extract centre of pole. Example for 2D and 3D vectorization of pole is given in Figure 8.

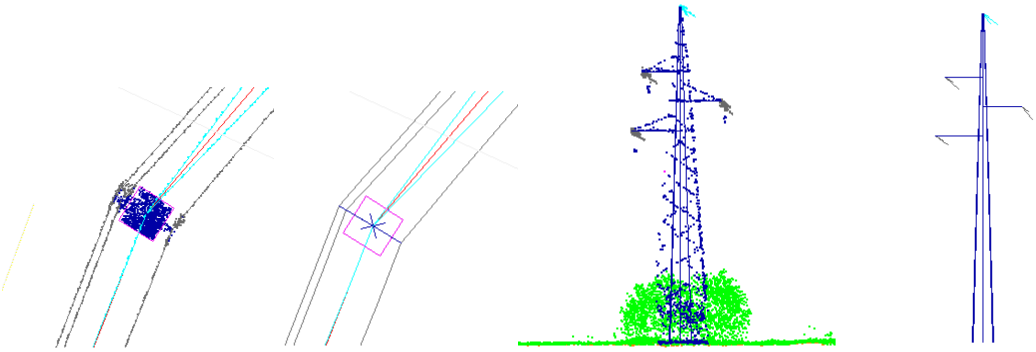


Figure 8 2D and 3D vectorization of pole

3D vectorization for wires is similar with classification of wire points. Path of the wire is given with 5 points that are located on the wire. Figure 9 contains poles with wires including classified point cloud, and 3D vectorized wires and poles without point cloud.

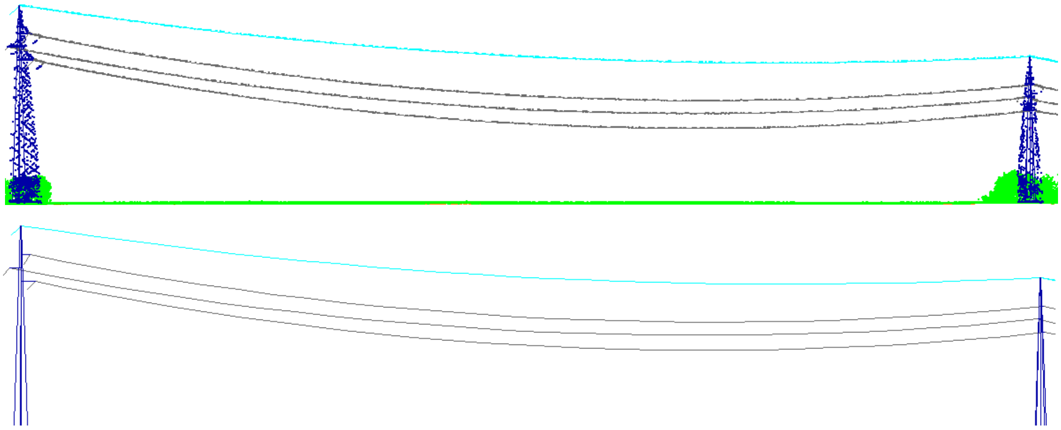


Figure 9 3D vectorization of wires

4. RESULTS AND DISCUSSION

The main objective of this paper is to prepare data for land registration according legal basics of Republic of Serbia (Republic geodetic authority, Serbia). Longitudal profiles and cadstral maps with all necesary data for land registration were final product. Longitudinal profiles represents differences of heights between two points or one trajectory, which demonstrate different partial slopes and distances and at the origin of the track (trajectory). Database of the cadastre lines as a subsystem of geodetic and cadastral information system of the Republic Geodetic Authority contains geospatial data, data on property rights and data of holders rights (Republic geodetic authority, Serbia).

Figure 10 shows example of longitudinal profile and cadastre map. Elements are displayed with unique colour such as power pole (dark blue), power wire (dark grey), vegetation (green), ground (brown), other wire (light grey), foundation of pole (purple).

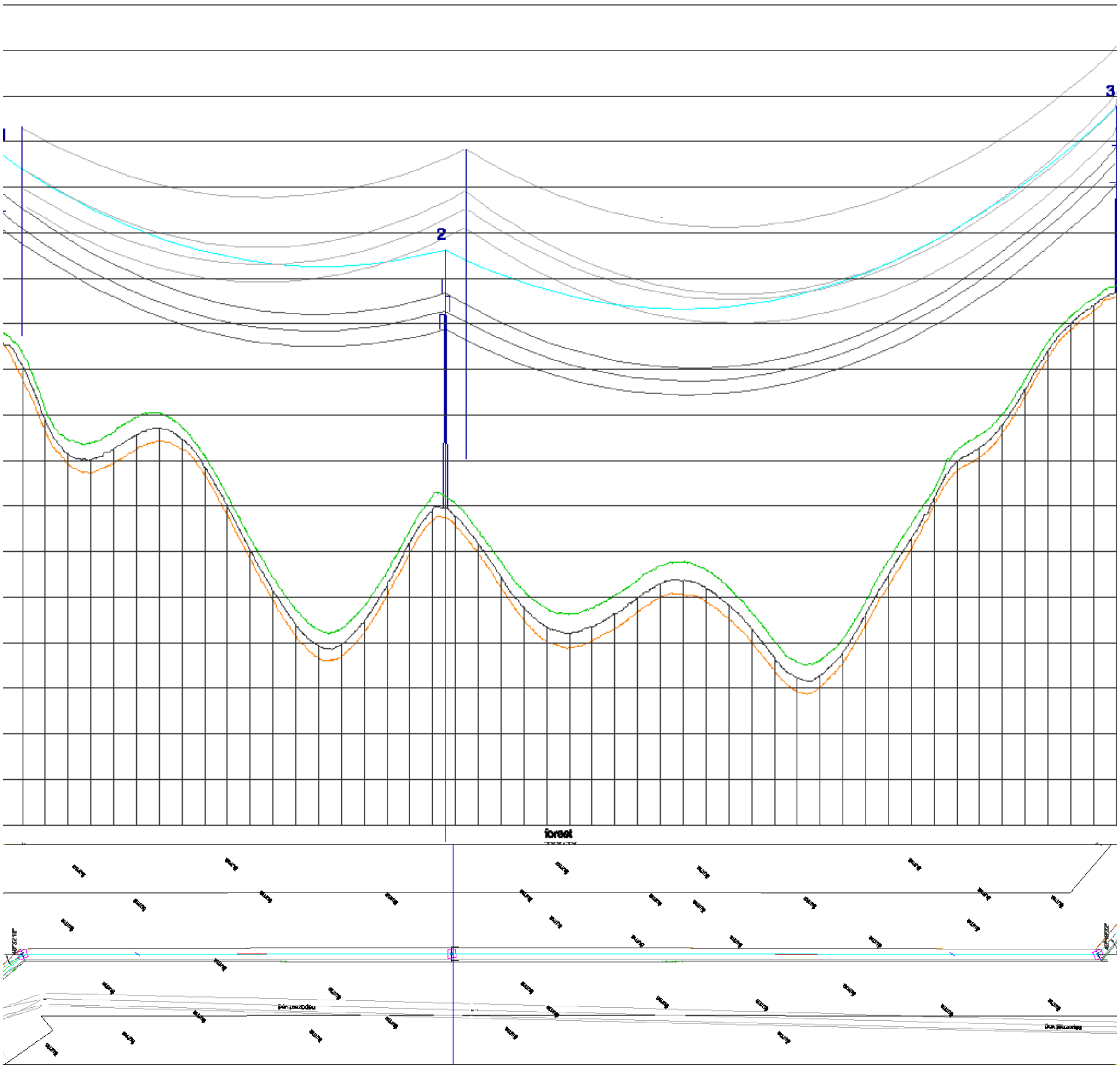


Figure 10 Longitudinal profile and cadastre map

Given the importance of data obtained by processing LiDAR data for the realization of the mentioned work and the fact that the data processing was carried out independently for each transmission line, it is necessary to carry out control measurements, positional accuracy and vertical accuracy for each power line. It consists of two datasets, first dataset is data produced by LIDAR and second is data that was obtained with standards surveying methods such as GPS using Real-Time Kinematic method. According to the legal basis of the topographic surveys in Serbia accuracy is permitted up to 15 cm. Analyzing the table 3 and table 4, it can be conclude that data satisfies the required accuracy.

Table 3 represents the comparison between control points obtained from GPS survey and LIDAR data data and GPS using Y and X coordinate. Table 4 contains results given by difference between LIDAR data and GPS using height H.

Ordinal number	***Point***	***dY [cm]***	***DX[cm]***	***dP [cm]***	***Description***	***LIDAR conditions***
2	1027	10	0	10	wire	good
4	1028	5	0	5	wire	good
24	1421	-9	0	9	foundation pole	very good
26	1423	-13	0	13	foundation pole	very good
28	1423	-13	-6	13	lighting wire	good
34	1525	-13	1	13	lighting wire	good

Table 3 Positional accuracy

dy- difference between Y coordinate of LiDAR data and GPS data
dx- difference between X coordinate of LiDAR data and GPS data
dP- square root of the sum of squares of the standard deviations of X an Y
Column LiDAR conditions in Tabes 3 and 4 shows does accuracy of processsed data is interval of accuracy that LiDAR method offers.

Ordinal number	***Point***	***dH [cm]***	***Description***	***LIDAR conditions***
2	1027	14	wire	good
4	1028	7	wire	very good
24	1421	-13	foundation pole	good
26	1423	-15	foundation pole	good
28	1423	-13	lighting wire	good
34	1525	10	lighting wire	very good

Table 4 Vertical accuracy

dH- difference between height H of LiDAR data and GPS data

5. CONCLUSION

Power lines are very important components in the power sector and their monitoring has very important role. Monitoring and detection of power lines can provide strong support throughout management system in electric network of country.

Monitoring of power lines with application some of the classical methods of survey does not give good results. The term good results does not apply only on the accuracy of the data but on the availability of data in a short period of time.

Semi-automatic classification gave good results and completed goals such as fast data processing, required accuracy and appropriate classified point cloud. This method can be applied on surveying of different parts of country infrastructure.

The new LIDAR technology is a quick and efficient method for collecting data on lines, with high precision and is therefore widely accepted technology for tracking power lines. It allows obtaining the desired product in a very short time. The advantage of using LIDAR data over other standard surveying methods is in speed, reduced human resources, large amount of data that can be used for another purpose than cadastre, data processing is relatively quick. LiDAR method is more suitable method than standard surveying methods when it comes to collect data of the power lines on inaccessible areas, which was in this case. Also, reference is made to the financial side of this whole idea of monitoring the transmission line. Overall, LIDAR system is more expensive, but provides effective results.

Future work will be focused on finding the ideal solution for semi-automatic classification and vectorization. Solution should be basic automatic classification that would classify much more point classes that automatic classification could not classify.

REFERENCES

Cheng, L., Tong, L., Wang, Y., & Li, M. (2014). Extraction of urban power lines from vehicle-borne LiDAR data. *Remote Sensing*, *6*(4), 3302-3320.

Guo, B., Li, Q., Huang, X., & Wang, C. (2016). An improved method for power-line reconstruction from point cloud data. *Remote Sensing*, *8*(1), 36

Jwa, Y., Sohn, G., & Kim, H. B. (2009). Automatic 3d powerline reconstruction using airborne lidar data. *Int. Arch. Photogramm. Remote Sens*, *38*(Part 3), W8.

Krogstad, F., & Schiess, P. (2004, June). The allure and pitfalls of using LiDAR topography in harvest and road design. In *Joint Conference of IUFRO* (Vol. 3).

May, N. C., & Toth, C. K. (2007). Point positioning accuracy of airborne LiDAR systems: A rigorous analysis.

Republic geodetic authority, Serbia http://www.rgz.gov.rs

Riegl http://www.riegl.com/products/airborne-scanning/produktdetail/product/scanner/23/

Sohn, G., Jwa, Y., & Kim, H. B. (2012). Automatic powerline scene classification and reconstruction using airborne lidar data. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci*, *13*(167172), 28.

TerraSolid https://www.terrasolid.com/home.php

Zhu, L., & Hyyppä, J. (2014). Fully-automated power line extraction from airborne laser scanning point clouds in forest areas. *Remote Sensing*, *6*(11), 11267-11282.

BIOGRAPHICAL NOTES

Dragana Popovic is PhD student and works on Faculty of Technical Sciences in Novi Sad as Teaching Assistant in the fields of Geospatial database. She graduated from the same institution in 2013 and in 2014 obtained Master's degree. Her bachelor thesis referred to the application of LiDAR data in surveying of railroad infrastructure.

CONTACTS

Dragana Popovic
Faculty of Technical Sciences, Novi Sad
Trg Dositeja Obradovica 6 21000
Novi Sad
Serbia
Tel. +381 69 16 32 640
Email: draganapop@uns.ac.rs