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# Verification of Building Constructions Surroundings Based on Airborne Laser Scanning Data

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**Abstract.** *Light Detection and Ranging, as an active Remote Sensing Technology, enables gathering accurate, three-dimensional point cloud of scanned objects. Laser scanning might be provided on the terrestrial level for specific, defined constructions, as well as on the airborne level for aerial or linear objects. Using a laser sensor mounted on a moving platform is currently the most efficient way of obtaining in a short period, accurate positions of billions of points as a representation of a scanned area. Based on this kind of dataset it is possible to perform three-dimensional analysis of the safety of scanned objects without additional measurements in the field. This article presents the analysis performed in vMatic software on data from Airborne Laser Scanning for medium voltage power line verification of obstacles with the buildings. The analysis took less than 20 seconds for the detection of buildings points that are closer than 5m from conductors for seven spans wit a total length of almost 400m. Providing distance verification on 3D point cloud data is the fastest way to obtain a hazard awareness in a short time. Once acquired by LiDAR data can be used for other various analyses for any construction, depending on current, expected and future needs.*

**Keywords:** *Point Cloud, Laser Scanning, LiDAR, ALS, Remote Sensing, 3D Analysis, Hazards, Obstacles, Collisions, Power Lines.*

## 1 Introduction

Laser scanning is the most popular technology that enables obtaining accurate, three-dimensional point cloud of scanned objects in a short time. Scanning might be provided on the terrestrial level (Terrestrial Laser Scanning - TLS) for construction like architectural heritage (Pritchard *et al*., 2017), buildings (Karagianni, 2017), bridges (Truong-Hong and Laefer, 2015), and on the airborne level (Airborne Laser Scanning - ALS) using flying platform (airplane, helicopter, unmanned aerial vehicle - UAV), for aerial objects like forests (Hyyppä *et al*., 2012), environmental heritage, as well as for linear objects: power lines (Kwoczyńska and Dobek, 2016), roads, railways (Zhu and Hyyppä, 2014), etc.

Using a multi-sensors mounted on a moving platform, as a Mobile Mapping Technology (MMT), is currently the most efficient way of obtaining in a short time, accurate positions of billions of points as a representation of a scanned area (Tao and Li, 2020). MMT is using mostly in projects for aerial and linear objects reachable from a path of the mobile platform. Choosing a type of platform that carrying all technical equipment, have to be adjusted to the kind of object that have to be scanned and the purpose of the scanning. Using a car, as a mobile platform, for power line corridor scanning while there are no roads near the power lines, is not a good idea - it would be more propriety to choose a helicopter or a plane for this purpose. It has to be noticed that Airborne Mobile Mapping using airplanes or helicopters is much more expensive than using Terrestrial Mobile Mapping with a car as a moving platform.

### 1.1 Mobile Airborne Laser Scanning system

Mobile Mapping Systems (MMS) used in the ALS technique consist of among others laser scanner, Global Positioning System (GPS) receiver and Inertial Measurement Unit (IMU). The principle of the laser sensor is to release a pulse of infrared or near-infrared light, capture returned pulses and record the length of time the pulse reaches an object and is reflected to the sensor. Based on the recorded information distance to the reflected point from a laser scanner can be calculated. It's essential to record by GPS receiver using Global Navigation Satellite System (GNSS) a position of the flying platform and parallelly precise orientation of the laser scanner by IMU. This information is the key to calculate a highly accurate position in 3D dimensions of the laser scanner and all measured by scanner points during the acquisition.

## 2 Materials and Methods

### 2.1 Field Data

Vimap company, that provides MMT services for the energy sector, provided for research purposes a sample of a point cloud data acquired by Airborne Laser Scanning. Data was acquired in 2016, in Poland, near Ostróda city, for the MV power line corridor, as a test data for test flights before launching a commercial power lines ALS project. The sample test flight was done for about 400 m of power line in an urban area, which includes seven spans, from pole with a number of 14 to pole with a number of 19.

Vimap Mapping System was consisted of among other Riegl laser scanner, VUX1-UAV model, Trimble GPS receiver and IMU. All sensors were mounted on a helicopter. A mobile mapping platform with a mounted system presents Figure 2. The average flight altitude of the flying unit was approximately 40-50 m from ground level. Components of the system and flight parameters were set to fulfill requirements for the acquisition of 3D point cloud data of MV power line infrastructure and corridor of right-of-way.


**Figure 2.** Mobile platform with the measuring system.

Laser scanner that was used in the measuring system, Riegl VUX1-UAV, is dedicated to agriculture, forestry, archaeology, cultural heritage documentation, as well as corridor mapping for power lines, railway tracks, pipeline inspection, topography in open-cast mining and other.

Figure 3 presents Riegl VUX1-UAV laser scanner used in Airborne Laser Scanning (source: http://www.riegl.com/products/unmanned-scanning/riegl-vux-1uav/, 2020-04-13).

**Figure 3.** Laser scanner model used in ALS.

Technical parameters of the laser scanner, altitude and speed of the helicopter flight allow achievement of the density of 40 points per square meter. The technical specification of the laser scanner used in the Airborne Mobile Mapping System presents Table 1.

**Table 1**. Technical specification of the laser scanner used in the Airborne Mobile Mapping System.

| Parameters | VUX1-UAV |
|---|---|
| Laser Pulse Repetition Rate | 550 kHz |
| Max. Operating Flight Altitude | 350m |
| Max. Effective Measurement Rate | 500000 meas./s |
| Max. Scan Speed | 200 ans/s |

## 2.2 Point Cloud Data Elaboration

Acquired LiDAR data were processed in Riegl software. The accuracy of the measurement of horizontal coordinates (X, Y) RMSE = 0.05m, accuracy of point height measurement (Z) RMSE = 0.10m. The point cloud density equals 55 pts/m$^2$.

As the main reason for the Airborne Laser Scanning of MV power lines was to provide 3D analysis of the surroundings of the power line, two basic processes were needed - classification and power line modeling. In those steps, data was elaborated in TerraSoild and Microstation software.

### *2.2.1 Classification*

Classifying of the LiDAR data into categorical object instances is the most critical step for further 3D analysis and modeling. It's a process of assigning a label to the points that represent a specified object, like the ground, building construction, power lines infrastructure, vegetation, etc. Classification allows us to group bunches of points into the specified representative of an object class, which helps to provide further 3D analysis. The correctness of classification has a big impact on the results of analyses that might be performed on classified data. Figure 4 presents a point cloud acquired by a laser scanner, as an input data for the classification process. Figure 5 presents the point cloud after classification.

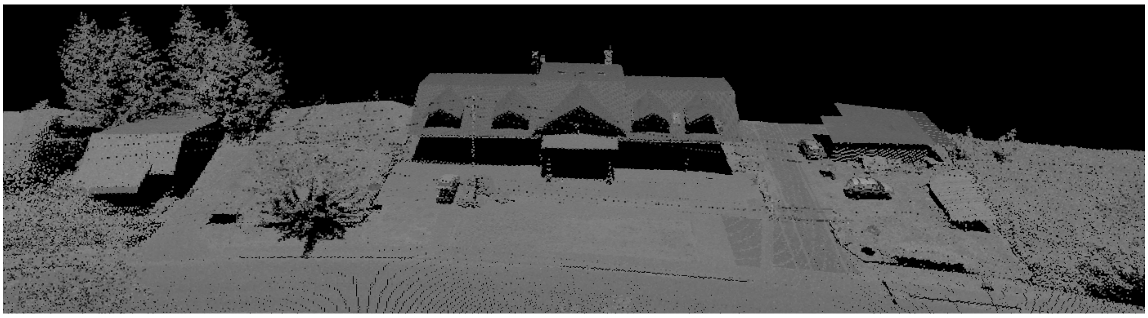

**Figure 4.** Point cloud with no classification - color by point intensity.

**Figure 5.** Point cloud with classification.

Sample of acquired LiDAR data was classified semi-automatically - using an automatic segment-based classification strategy and manual corrections of segment-based classification. There were extracted objects of following classes: ground, building, vegetation, power line wires, power line pylons pipeline, paved road, unpaved road, water, railway and not classified. Figure 5 presents classified objects in the following colors: ground – light brown, building – red, vegetation – green, power line wires – yellow, power line pylons – blue, paved road – gray, not classified – white. Classified objects were set due to restrictions that have to be checked for a power line infrastructure on the point cloud data.

### *2.2.2 Objects Modeling*

Poles and phase cables of the MV power line were digitized based on the point cloud and save to 3D ESRI shapefile. Visualization of the digitized 3D model in Google Earth Pro is presented in Figure 6.

**Figure 6.** Visualization of the digitized 3D model in Google Earth Pro.

### 2.3 vMatic Software

vMatic software, developed by Vimap company, enables point cloud presentation and automatic performance of three-dimensional analysis based on digitized 3D models. The user interface of vMatic software and visualization of point cloud and 3D model presents Figure 7.

**Figure 7.** vMatic software **-** visualization of ALS data.

vMatic software was designed mainly for the verification of the correctness of distances from power lines to nearby buildings, vegetation, ground and other objects that are close to the power line. The analysis in vMatic can be performed at the operating temperature of the power line, as well as at simulated, on any temperature conditions of the phase cables.

Classified LiDAR data and digitized 3D model of construction building - power line, are the basic inputs for 3D analysis in vMatic software. vMatic software allows detection of hazards to any 3D vector model. The collision searching mechanism is based on releasing a virtual cylinder with a radius specified by the user, along the course of the 3D model object and detecting whether the cylinder encounters points of the particular class.

## 3 Results

Based on acquired ALS data of the middle voltage power line corridor in an urban area, the detection of collisions with buildings was performed for digitized phase cables of the line for seven spans, from 14th pole to 19th pole (total length: 367m). Figure 8 shows the analyzed area on an orthophotomap, poles positions with their numbers are presented in yellow color.


**Figure 8.** Analyzed the MV power line corridor in the urban area.

The radius of a virtual cylinder was set at 5m. It means, that from each digitized phase cable detection of buildings point will be done in 5m distance and 360$^o$ range along the course of the conductor. The collision analysis for seven spans took 19 seconds in vMatic software.

Tool for automatic detection of building collision in 5m 3D range buffer from the power line conductors found in total 9 building obstacles. Two buildings were in a really close area to the power line, with the closest 3D distance equals 2.64m (span from 16$^{th}$ pole to 17$^{th}$ pole) and 2.77m (span from 17$^{th}$ a pole to 18$^{th}$ pole). One building was detected in 3.00 – 3.99m collision range, six buildings in a range from 4.00 m to 5.00m. The other fifteen buildings in the analyzed area weren't found due to 3D distance from power line wires to the building bigger than 5m. The results of the performed analysis with division into ranges of a 3D collision distance shows Table 2.

Figure 10 presents the visualization of buildings in the analyzed area highlighted in the range collision colors presented in Table 2. Buildings not treated as obstacles for the power line are presented in light green color.

**Table 2**. Results of performed buildings detections with a power line on LiDAR data.

| Collision ranges distances | Found building collision | Span name with a distance of collision |
|---|---|---|
| 0.00m - 1.99m | 0 | - |
| 2.00m - 2.99m | 2 | 16-17 2.64m<br>17a-18 2.77m |
| 3.00m - 3.99m | 1 | 15-16 3.85m |
| 4.00m - 4.49m | 2 | 18-19 4.12m<br>18-19 4.40m |
| 4.50m - 5.00m | 4 | 17a-18 4.56m<br>15-16 4.81m<br>15-16 4.84m<br>18-19 4.97m |


**Figure 10.** Buildings colored by a collision distance to the power line.

Figure 9 presents in vMatic software visualization of the closest collision from the power line wires to the building point with a distance of 2.64m (span from pole $16^{th}$ to $17^{th}$). The point cloud is visualized in RGB colors, the area of collision of building points closer than 5m from power line wires is highlighted in red color.

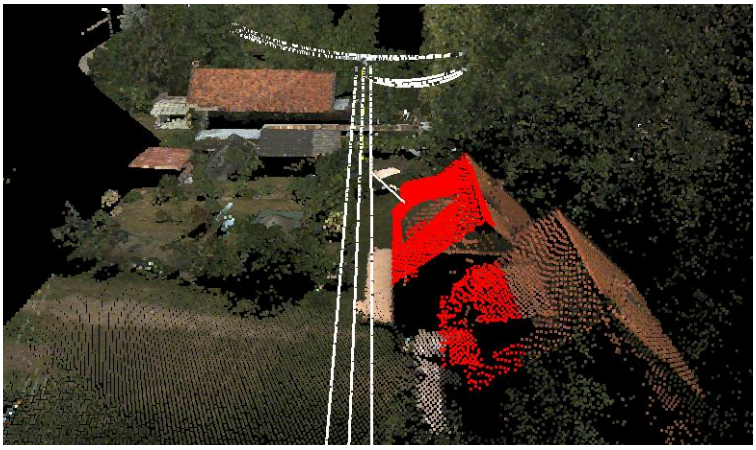

**Figure 9.** Found building close-up to the power line in vMatic software.

## 4 Conclusions

LiDAR data allows the performance of three-dimensional analysis for building constructions without any additional measurements in the field. Based on data gathered by remote sensing technology, verification of any construction surroundings can be performed in dedicated software to ensure the safety of the objects.

Performed in this article analysis of the power line obstacles were detected in vMatic software. The analysis took less than 20 seconds for the detection of buildings points (closer than 5m from conductors) for almost 400m length of the MV power line. vMatic software detected nine buildings that are too close to the power line.

Data from laser scanning, as a true representative of scanned objects/areas, might become a basic, complete product for providing 2D and 3D analysis. The results of the analysis performed on LiDAR data are reliable. Providing distance verification on 3D point cloud data is the fastest way to obtain a hazard awareness in a short time. Once acquired by LiDAR data can be used for other various analyses for any construction, depending on current, expected and future needs.

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