Updating the algorithm for processing laser scanning data using linear objects as an example

D A Gura 1, A P Pavlyukova 1,2, A A Solodunov 2
1Kuban State Technological University, 2, Moskovskaya street, Krasnodar, 350072, Russia
2Kuban State Agrarian University, 13 Kalinina street, Krasnodar, 350044, Russia
E-mail: gda-kuban@mail.ru

Abstract. An increased specification degree concerning the received information about the object as one of the three-dimensional laser scanning technology’s main advantages is determined in the article according to the results analyzes of the Russian and foreign sources. Information redundancy of data at the stage of their processing can be considered as a disadvantage. This is illustrated in the article by the example of processing laser scanning data in the Credo 3D Scan program for the purpose of monitoring the air routes status. In the case under consideration, it was necessary to determine the deflection of the air routes wires over a point cloud. Before directly measuring the deflection, it is necessary to follow the procedure for processing the raw data described in the article. One of the algorithm stages is the automated search for supports and wires provided for the Credo 3D Scan program. It was found that the team accelerates the search for wires among an array of other objects. However, there is no command to calculate the numerical value of the wire deflection, that is why it is necessary to measure the distance from the points corresponding to the Earth’s surface to the lower point of each wire manually. It has been determined that the geoinformation data operative collection task has been generally resolved, while the process of their processing requires optimization. To do this, it is necessary to improve the “Power Transmission Lines Recognition” function by adding a function for automated deflection detection with visualization of each wire given value in the inscription form both in a three-dimensional model and in plan using a conventional symbol.

1. Introduction
A special category of infrastructure facilities is occupied by linear ones, one of which is air routes (AR).

Natural (weather, vegetation) and anthropogenic factors (damage to poles, failure to comply with technical standards during the construction of structures, illegal actions within the protection zone) affect the work of AR. Because of this, these objects are subject to deformations, which can lead to an emergency power outage, as well as become a threat to the citizens’ life safety who are in the damage zone. In this regard, there is a need for monitoring the AR structures status in order to identify deformations, eliminate them and prevent accidents.

One of the tasks of monitoring the air routes condition is to determine the dimensions of the wire above the ground (deflection) for further verification of compliance with regulatory values [1].

The size of the wire above the ground is the distance from the wire to the ground surface with the largest deflection.
In the modern world, AR monitoring can be performed by electronic tacheometers, electronic levels, laser light-range finders, satellite equipment and laser scanners.

The principle of the laser scanner operation is to measure angles and distances to terrain points in the vertical plane up to 270 degrees and in the horizontal up to 360 degrees with fixing for each XYZ coordinate point [2]. The combination of such points forms a three-dimensional digital geospatial image of the scanned array, presented initially in the form of a point cloud.

Laser scanning as a shooting method was known back in the 80-90s of the XX century, but did not receive wide distribution in the Russian Federation due to the high cost of technology and the socio-political tension existing in that historical period. However, a laser scanning increasing introduction trend has recently emerged in many areas of industrial and economic activity, including the infrastructure facilities’ state monitoring.

The use of laser scanning technology in monitoring the infrastructure facilities state is especially important, since it gives a possibility to obtain geoinformation data about a high-quality object, which is crucial for monitoring purposes. In addition, the use of laser scanning makes it possible to accelerate the process of collecting geodata due to a wide range of shooting and automation of laser beam guidance on terrain objects, increases the information saturation of the material [3]. However, a large number of data points obtained in the form of a set require optimization of their processing. For the linear objects, the task of improving the scanning data processing system is also relevant, due to their large extent.

Based on the foregoing, the objective of the study is to improve the processing of laser scanning data for the purpose of monitoring air routes using the example of measuring deflection in wires in the Credo 3D Scan program.

To solve it, it is necessary to conduct an analytical review of the scientific literature main sources on the issue of processing laser scanning data; to analyze the existing technology for processing laser scanning data in the program “Credo 3D Scan” for the purpose of monitoring air routes using the example of measuring wires deflection and identify its shortcomings.

2. Analysis of the research question status
The scientific work [4] is a review of remote sensing data sources for the power line corridors study. According to the authors, ground, mobile, and airborne (from unmanned carriers) scanning is a rapidly developing method of obtaining the data that requires careful research and analysis.

A significant part of the research in the field of laser scanning belongs to Professor V. Seredovich. In his writings, the author describes the methods for performing work using scanning for a particular process, assesses the data accuracy, analyzes the possibility and results of using ground, air and mobile laser scanning.

For example, in [5, 6], the issues related to the use of laser scanning in monitoring the state of a bridge, other industrial and natural objects and the changes identification in urban areas are investigated.

In [7, 8], deformation monitoring of tunnels and arched structures is considered. The first article shows the results of a three-dimensional tunnel scan with a description of the technology for reconstructing the geometric parameters of an object into a point cloud to detect the deformations. In the second - attention is paid to the extraction of point clouds.

The study [9] is aimed at studying the process of assessing the state of the transmission power lines supports using the surface laser scanning technology (SLS). The field and cameral stages of determining the geometric characteristics of elements and deformations of PTL supports are described. The data processing at the cameral stage was carried out with a software product (SP) “Cyclone”, when working in which an algorithm of actions is indicated, consisting of stitching scans, segmentation of points array, drawing all the PTL support elements, assigning a number to each element, determining its geometrical dimensions, type of neighboring elements connection, deflections sizes. According to the authors, “surface laser scanning technologies allow the most time-consuming part (namely, determining the geometric parameters of the support elements) to be transferred to cameral conditions”. This article correlates with the present study in terms of solving an applied problem with the help of laser scanning - monitoring the electric grid facilities state. However, it differs by the software product used at the data
processing stage, by the type of the determined geometric characteristics, and by the knowledge degree of the data processing issue.

In [10], the accuracy of laser measurements performed with the Leica Scanstation C10 and RIEGL VZ400 surface scanners is evaluated. Using the example of two measuring tools, the (SP) mean square errors are compared: angular, linear measurements, the coordinates’ determination repeatability. The results of the study show that the SLS actual measurement error is significantly less than it is declared by the manufacturer, while the latter is millimeters. Based on this work, we can conclude that the use of ground-based laser scanning for monitoring linear objects will allow obtaining high-precision data.

One of the data processing stages is the scans equalization. The authors in [11] distinguish the stage of calibration and data equalization as one of the most critical and having the greatest impact on the final accuracy. The article [11] describes the method of equalizing the mobile scanning data in the TerraSolid software package. The adjustment results, in which SP coordinates of reference points does not exceed 3 cm, are given. Unlike surface, mobile scanning as a way of shooting is more productive, but less accurate.

The entire data processing process is studied in [12-14].

To improve the processing of SLS results in [14], the issue of classification, the division of points into classes in accordance with the specified criteria, which in this work are the intensity of the reflected pulses, is studied. The authors indicate that an automated search for a number of areal and linear objects, as well as the three-dimensional model creation can be performed by the laser reflections’ intensity.

In the study [13], the authors distinguish the primary stage of data processing. The article discusses the principles of the IndorCloud system, which performs data preprocessing and intelligent classification of mobile laser scanning points. Pre-processing of data in the system consists of the following steps: equalizing GLONASS / GPS path points; orientation and thickening of the rover trajectory; point cloud generation; point clouds’ adjustment; coloring point clouds. Such actions are typical for processing the mobile scanning data, while with surface equalization of GLONASS / GPS path points and orientation, the rover path thickening is not required.

The article [12] explores the results of mobile laser scanning. A typical algorithm for obtaining a three-dimensional model for designing a highway with separation into field and camera stages is considered. In the latter, the authors distinguish the following actions: clouds equalization, noise reduction, color assignment, points classification, noise removal, allocation of model elevation points, the road structural lines digitization, objects digitization, export of materials to computer-aided design (CAD). The feature of the roads’ structural lines automated recognition, which is implemented in many programs, however, can be used for the newly constructed roads, is separately covered. The authors emphasize that “the order of data processing” is the connecting bridge between “data obtaining and results obtaining”.

A review of the most common programs used in cameral processing is considered in [15]. The authors distinguish three groups of software (software): “software from the laser scanners manufacturers”, “independent solutions”, “solutions inside large CAD”.

The first group includes: Leica Cyclone 9 (software), Leica CloudWorx (plug-ins) - Switzerland, FARO Scene 7.1 (software), FARO PointSense (plug-in) – USA, RiScan Pro, RiProcess – Austria, Trimble RealWorx 10.4 – USA [15].

The second group includes: Terrasolid TerraScan for Microstation – Finland, Technodigit 3D Reshaper 2017 – France, VirtualGrid VRMesh 9.5 – USA, GeoPlus VisionLidar 2018 Canada, Certainty 3D TopoDOT for Microstation – USA, DreamT&S PointShape Advanced for AutoCAD/Microstation – South Korea, Undet for SketchUp V2.1, and Undet for AutoCAD V2.4 – Lithuania [15].

The third group includes: Autodesk AutoCAD Civil 3D 2018 – USA, Bentley Pointools, Descartes for Microstation – USA, MicroSurvey CAD 2017 – Canada, Credo 3D Scan 1.4 – Belarus, “IndoorSoft” IndorCAD 2018 Russia [15].

The analysis showed that in the field of data processing, the studies studied are aimed at considering the stages of calibration and data equalization, classification issues and the automated search for
elements by reflection intensity, principles of data preprocessing, as well as a typical data processing process description without a detailed consideration of work algorithms in a particular program.

Based on the analytical review results, several conclusions can be made:
- The practice of using laser scanning is extensive, including a study that provides a methodology for monitoring linear objects (power lines) to search for deformations of supports, which is closest to the topic of this study. However, the aforementioned work [9] is mainly aimed at analyzing the possibility of using PTL laser scanning for monitoring and a methodology description for this work. While this article details the data processing algorithm in SP “Credo 3D Scan” for the wires’ deflection detection indicating the shortcomings and the ways to improve it;
- to optimize the work with a three-dimensional data array, there are algorithms for the automated objects search. However, such functionality is far from being implemented in all software products (SP), intended for processing three-dimensional data, and in those SP, where the automated search is provided, it is carried out without solving the related tasks that could be performed in parallel (for example, an automated wire search AR with their dimensions’ simultaneous measurement).

3. Laser scan data processing in “Credo 3D Scan”
Processing scan data involves:
- import of point clouds, photos from each station from the scanner memory;
- registration (adjustment) of scans and obtaining a common point cloud;
- performing the general necessary actions (creating a digital elevation model, creating a digital terrain model, creating a three-dimensional model);
- the applied actions’ performance (calculation of volumes, construction of sections, profiles, AR dimensions measurement, etc.).

The above-mentioned actions can be performed in various specialized programs, the order and process of their implementation depends on the following functional features.

In the program “Credo 3D Scan” the data processing was performed in the following sequence:
1. Setting up a project (choosing a coordinate system, specifying measurement units, choosing a geoid model, etc. by pressing the commands “File-Project Properties”);
2. Import laser scanning points (command: “File-Import-Select point cloud file” in the format LAZ, LAS);
3. Studying and evaluating the quality of the source point cloud (checking the import layer, viewing point structure information with the Point Cloud-Point Structure command, estimating the point cloud density, removing noise - it is possible both manually and by the “Point Cloud-Noise Filter below the relief” command);
4. Visualization optimization (if necessary, it is possible to increase the points size, for a clearer image of the contours of the situation with the command “Point Cloud-Calculate Normal”, adjust the lighting);
5. Search for the isolated points (“Point Cloud-Filter of isolated points”);
6. Highlighting the relief (in automatic mode, the classification of points of the ground surface from the points of buildings, structures with the division into layers “Relief - Select relief”);
7. Highlighting ground control points for building a model (“Point Cloud – Thinning”);
8. The control points change into the embossed ones (“Point cloud - Cloud points - into model”);
9. Building a relief matrix (creating a DEM-model “Relief-Point Cloud in DEM”, filling in a relief matrix to exclude the empty fragments corresponding to the buildings and structures that appeared in step 6 - “DEM Interpolation”);
10. Creating a terrain model (transforming a DEM model into a terrain model “Relief-Terrain model - Selecting the DEM model created in steps 6-9 - Apply”. After this stage, the situation elevations are calculated from the transformed DEM model);
11. Drawing a situation (“Situation-Create a linear object”, “Situation - Create a site object” with the parameters of the vectorized object).
It should be noted that the program solved the automatic recognition problem of PTL supports and wires according to the set parameters by pressing the commands “Situation - PTL Recognition”, which speeds up the search for wires among an array of other objects [16-18]. However, there is no command to calculate the numerical value of the wire deflection, that is why it is necessary to measure the distance from the points corresponding to the ground surface to the lower point of each wire manually. Of course, when monitoring on a citywide scale, the scanning method cannot be called effective. The task of the geodata operative collection is generally solved, while the process of their processing requires optimization [19].

To do this, the “PTL Recognition” function needs to be improved » by adding functionality for the automated deflection determination with visualization of a given value for each wire in the form of an inscription both in a three-dimensional model and in plan using a conventional symbol.

In addition, it should be borne in mind that the wires do not always pass above the ground surface, often they cross the linear objects and are parallel to the area ones. In this regard, the following concepts are distinguished:

• AR size at intersections - the smallest distance from the line wires vertically to the surface of highways and railways, rivers, communication wires when they intersect with an air route;

• AR size when approaching, the smallest permissible distance from the wires of air routes to various objects when passing through a line parallel to these objects (for example, buildings, structures, etc.).

Thus, the determination of the wires’ deflection magnitude is performed relative to the corresponding object surface.

The program provides for the recognition of linear and site objects by a point cloud (“Situation - Recognize LTO by point cloud”, “Situation - recognize STO by point cloud”). However, the function is performed manually – it is necessary to specify a line segment on each recognized object’s line, and then select the corresponding symbol that will be reflected in the plan. This command does not exclude viewing the entire array, it only speeds up the process of rendering the situation, but not recognizing the object. In this regard, to optimize the AR size determination at the intersections and rendezvous, it is necessary to develop algorithms for the automatic recognition of highways and railways, rivers, buildings and structures [20, 21].

After the introduction of such algorithms, in the automatic recognition command window, along with the recognition parameters of the corresponding objects, we suggest adding the line “Dimension and inscriptions of dimensions at intersections” and “Measurement and inscription of dimensions at rendezvous”.

Summary
Measuring the air routes deflection is an existing task when monitoring their condition, facing electric grid companies. To solve it, AR mapping with laser scanning technology that guarantees the speed, quality and reliability of data acquisition, is used. The study showed that such criteria are applicable for the field stage, while on the cameral criterion “speed” depends on the selected software, each of which has a different functionality. When processing the air routes laser reflections data in order to measure the AR size above ground (wire deflection) in the program “Credo 3D Scan” it is necessary to add the commands for calculating the deflection with the display of such parameters’ values in a three-dimensional view and plan; automate the search for highways, railways, rivers, buildings and structures with the addition of a line about the calculation and display of the dimensions in the AR search criteria at intersections and rendezvous. These changes will improve and speed up the data processing while monitoring the AR status, thereby optimizing the process of assessing their condition and timely identification of unacceptable wire deflection, which will increase the engineering infrastructure operation safety degree for the population.

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