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APPLICATION OF LASER SCANNING IN THE BASIC GEODETIC WORKS DURING THE RECONSTRUCTION OF THE THERMAL SPA GUBER COMPLEX

Abstract

Laser scanning is one of the most modern technologies used for the mass collection of spatial data in the form of coordinates of points in space. Given that laser scanning is often used during the restoration of buildings and building facades, the paper describes the application of mobile laser scanning in the example of the reconstruction of the Banje Guber complex. In the practical part of the work, the cloud of points obtained by scanning the Banja Guber complex was processed and the computer software used for data processing was presented. A 3D model of the terrain and the classic geodetic situation of the Banja Guber complex was created.

Keywords: mobile laser scanning, point cloud, control points, 3D model of the terrain.

ПРИМЈЕНА ЛАСЕРСКОГ СКЕНИРАЊА КОД ОСНОВНИХ ГЕОДЕТСКИХ РАДОВА ПРИ РЕКОНСТРУКЦИЈИ КОМПЛЕКСА БАЊЕ ГУБЕР

Сажетак

Ласерско скенирање представља једну од најмодернијих технологија која се користи за масовно прикупљање просторних података у форми координата тачака у простору. С обзиром да се ласерско скенирање често користи приликом рестаурације објеката и фасада објеката, у раду је описана примјена мобилног ласерског скенирања на примјеру реконструкције комплекса Бање Губер. У практичном дијелу рада је обрађиван облак тачака добијен скенирањем комплекса Бање Губер и представљени су кориштени рачунарски софтвери за обраду података. Израђен је 3Д модел терена те класична геодетска ситуација комплекса Бање Губер.

Кључне ријечи: мобилно ласерско скенирање, облак тачака, оријентационе тачке, 3Д модел терена.

1. INTRODUCTION

LiDAR (Light Detection and Ranging) technology is based on the collection of three different sets of data. The position of the sensor is determined using GNSS (Global Navigation Satellite System), using phase measurements in the relative kinematics mode, while the orientation is determined using the IMU (Inertial Measurement Unit). The last component is a laser scanner that sends an infrared beam towards the ground that is reflected to the sensor. The time elapsed from the transmission to the reception of the signal, along with the knowledge of the sensor's position and orientation, enables the precise calculation of three-dimensional coordinates on the ground [1]. Scanning takes place by measuring the distance and angle to a certain point in the recording area. The result of this recording method is a set of three-dimensional X, Y, and Z coordinates of points called a point cloud. One of the main advantages is the collection, processing and delivery of data in digital format [2]. The point cloud is most often saved in ASCII (American Standard Code for Information Interchange) format. The point cloud can be loaded into several specialized software tools and GIS (Geographic Information System) applications (PointTools, MicroSurvey CAD [3], MicroStation, ArcGIS).

Based on the platform used as a base for the laser scanner, laser scanning is divided into TLS (Terrestrial Laser Scanning) and ALS (Airborne Laser Scanning). Terrestrial recording methods use classic tripods or mobile MLS (Mobile Laser Scanning) vehicles as a platform. For the method of aerial photography, an aircraft (plane) is used, with a laser scanner attached to it [4].

In mobile laser scanning, a laser point or line is projected onto the object from a hand-held device and a measuring sensor that measures the distance to the surface. The data is collected in a local coordinate system, and therefore the position of the scanner must be determined for accurate data collection. The position of the scanner can be determined using reference points on the surface to be scanned or by an external means of determination. External determination often takes the form of a laser tracker (to ensure sensor position) with an integrated camera (to determine scanner orientation) or a multi-camera photogrammetry solution [5]. Both techniques tend to use infrared light-emitting diodes attached to the scanner, which the camera sees through filters that provide resistance to ambient lighting. Mobile laser scanning does not use a static point from which to shoot, but a mobile base. Road or railway tracks are often recorded with a mobile laser scanner attached to a car or a train car.

Today, we are witnessing the constant development of spa tourism [6]–[8]. By using natural resources in combination with architectural, construction and medical achievements in Bosnia and Herzegovina, it is possible to attract a large number of tourists. The development of the economy of each country can be significantly influenced by raising the quality level of tourist and tourism-like content. The starting point of this work is a laser scan of the Banje Guber complex. Before scanning, it is necessary to properly mark and record orientation points using classic terrestrial recording methods. The starting point of every architectural or construction project is the geodetic basis, that is, a quality "geodetic situation" for design. Given that during the development of spa tourism, the positions of the thermal springs must also be taken into account and that the surrounding terrain of Banja Guber is extremely steep, inaccessible and overgrown with tall forest, the creation of a detailed geodetic situation will be done based on laser scanning with a mobile laser scanner. The geodetic survey will be created in the form of a 2D plan with written elevations of characteristic points and drawn contour lines, as well as in the form of a 3D view overlaid with a point cloud.

Although the spa has a large number of hot springs and mineral waters, as well as untouched nature, the construction of a spa-climate treatment centre is in the process of being put to rest. The construction of this complex started in 2010, and it is planned to be completed by 2011. In the meantime, the spa was privatized, but due to disputes over the company, the construction of the spa and hotel facilities did not continue. Considering the potential it possesses, it was crucial to record the current state to create an action plan for the restoration of this natural wealth (Figure 1).

Figure 1. Conceptual solution of the Banje Guber complex [9]

2. MATERIALS AND METHODS

2.1. THE STUDY AREA

Banja Guber is a medicinal spa in Republika Srpska (Figure 2). It is located in the municipality of Srebrenica, at 560 m above sea level. The municipality of Srebrenica occupies an area of 527 km^2, and together with the area of Osat, covers the central marginal area of the eastern part of the Republika Srpska. Part of the eastern and the entire southern part of the municipality lies in the bend of the Drina and is an integral part of the wider, colorful geographical mosaic of Podrinje. Its eastern part descends to the Drina, which is also the border with the Republic of Serbia. The urban area of the city of Srebrenica extends on the northern slopes of the Zeleni Jadar area, around the narrow valley plain of the Crvena Rijeka and the Ćićevačko Potok, a component of Križevica.

At the beginning of the 19th century, doctor Hans Duler was the first to point out that the Srebrenica springs have healing properties, while the first scientific analysis of the water was made by the Viennese chemist Prof. Dr Ernest Ludwig. From 1886 to 1888, he analyzed the majority of about a hundred mineral sources in Bosnia and Herzegovina. He also analyzed five of the 48 mineral springs in the vicinity of Srebrenica and declared them "the pearl of all springs on Earth", and proposed their exploitation, which began in 1889. Until 1901, the Viennese firm "H. Maoni" filled and exported 2 818 199 bottles of Guber water to the world [10].

In terms of chemical properties, Guber water is similar to Levico in Italy [11], Val Sinestra in Switzerland and La Bourboule in France. Compared to them, Guber water has a more complete representation of minerals and less arsenic and is used in its natural composition without any dilution. Guber water, from the Crni Guber spring, was declared a cure for hypochromic anaemia in 1956 and has since been sold in pharmacies bottled in 400-millilitre plastic bottles.

In the surroundings of Banja Guber, there are deciduous and coniferous forests, as well as a walking path. There are also five healing springs in the spa, the Guber picnic spot, was a favourite picnic spot of the residents of Srebrenica, as well as the guests of the spa. The name Guber was born after it was established that the springs in this area achieve healing of skin diseases, especially leprosy.

Centuries ago, this location was known for its healing springs, and the best evidence is the fact that the Romans still had a bath in this area, while the Austro-Hungarians during the occupation of Bosnia and Herzegovina examined these healing springs in detail, which turned out to be of exceptional quality, so bottled water and sold it in Europe. In the second half of the 17th century, the famous Turkish travel writer Evlija Čelebija wrote about the mineral and medicinal water in the area of today's Banja Guber. The people who lived in this area at that time did not believe in the medicinal properties of these waters and believed that they caused some diseases. At the beginning of the 19th century, doctor Hans Duler drew attention to the medicinal waters in this area. Dr Ludwig examined the local waters in 1887 and claimed that some of the springs were more precious than all others in Austria-Hungary.

Figure 2. Banja Guber used to be (left)[12], remains of Banja Guber (right)

There are a large number of springs in the spa, however, due to low investment in scientific research, only a part of them has been examined. Some of the well-known springs are: Crni Guber (Figure 3), Mali Guber, Sinus Voda, Očna Voda and Ljepotica Spring.

Figure 3. Spring Crni Guber

A large number of scientific analyses were carried out in the area of Crni Guber, while the first detailed analysis in this area was carried out in 1894 when it was declared one of the best natural springs in Europe. Every-day consumption of the healing water from Crni Guber has to be under medical control [11]. The Mali Guber spring contains large amounts of calcium and magnesium. The water is clear, colourless and sour. It contains the most iron, as well as arsenic. The source popularly called Sinus water reduces sinus pain in the forehead area [11]. South-east of Crni Guber, there is Očna Voda. This spring has a small capacity, but it contains more mineral ingredients than all other springs in this area. Očna Voda helps with diseases of the eyes and mucous membranes, as well as conjunctivitis [11]. The spring is popularly called Ljepotica because it contains a certain number of minerals that reduce skin problems [13].

2.2. INPUT DATA

At the very beginning, it is necessary to collect data on the existing geodetic base to be able to calculate the necessary transformation set for the recording area. Due to the lack of transformation parameters verified by the Republic Administration for Geodetic and Property Legal Affairs, for the area of the Srebrenica municipality, the transformation parameters were determined for the wider area of the Srebrenica municipality, based on the coordinates of known points of the geodetic network. There are nine trigonometric grid points in the area (Table 1), and based on their WGS84 and national coordinate system coordinates, a transformation set was calculated for the subject area. The coordinates of the trigonometric points were taken from the horizontal transformation on the territory of the Republic of Srpska.

Table 1. Coordinates of the trig points used

Point mark	DKS			WGS84		
	E[m]	N[m]	H[m]	X[m]	Y[m]	Z[m]
T277	6602326.87	4892222.53	448.94	4326015.60	1512784.72	4421792.65
T280	6607392.49	4892278.70	301.16	4324256.48	1517536.39	4421672.22
T20	6609968.78	4892121.20	383.67	4323590.33	1520029.94	4421585.82
T353	6602391.11	4887804.02	600.45	4329025.09	1513832.39	4418727.41
T310	6607156.55	4888830.52	600.46	4326819.07	1518126.17	4419409.43
T295	6613035.65	4886105.19	519.11	4326683.70	1524261.66	4417326.61
T163	6603195.70	4883224.14	578.18	4331784.85	1515574.38	4415414.59
T59	6608819.05	4882750.44	939.47	4330541.81	1521088.85	4415261.69
T360	6613447.61	4881524.88	883.02	4329829.77	1525723.59	4414285.15

When creating the report and determining the parameters, certain points were excluded from the set because they showed greater deviations, and as final trigonometry for creating the trigonometric set, T20, T310, T353 and T360 were retained for creating the transformation set. Table 2 presents the calculated transformation parameters. The points may show greater deviations due to measurement errors, systematic errors or the influence of external factors. Excluding points with larger deviations from the data set helps ensure greater accuracy of the analysis or model. The final decision on which points to retain depends on the need for reliable data and its importance in the analysis.

Table 2. Transformation parameters and RMS (Root Mean Square)

Number	Parameter	Value	RMS
1	Translation dX	-1068.3925 m	77.1478 m
2	Translation dY	120.2115 m	69.4919 m
3	Translation dZ	71.1233 m	68.8484 m
4	Rotation about X	2.26627 "	1.92049 "
5	Rotation about Y	-22.06708 "	2.84151 "
6	Rotation about Z	-2.76142 "	2.12772 "
7	Scale	-16.5176 ppm	8.0619 ppm

For the laser images to be georeferenced, i.e. oriented, it was necessary to mark signals measuring 30 x 30 (square) on the ground. The marking was done with white paint (white paint for roads, is extremely important because of the reflection) and the signals were placed approximately every 150 m. Signal no. 1 is placed on the left side of the road, signal number 2 on the right side, and signal no. 3 on the left and so alternately. The end of the route was signalled according to the same principle (left-right), with the fact that the signal was not placed at the very beginning and end of the route, but was terminated 10 m from the beginning, that is, the end. Then the signal was recorded, ie. measurement. It was measured with a GNSS receiver Leica1230GG three times for 30 seconds with a change in the height of the instrument. The signal was measured at the ends (edges) of the square, and when measuring each signal, it was also photographed.

After the geodetic survey, the Rinex data for the survey period were downloaded (the virtual station was downloaded from the website of the Republic Administration for Geodetic and Property Legal Affairs based on the nearest permanent stations of the Republic of Srpska) [14]. The coordinates of the recorded points were transformed into the ECEF (Earth-Centered, Earth-Fixed) system for the orientation of the recordings. The ECEF coordinate system, also known as the geocentric coordinate system, is a three-dimensional coordinate system used in geodesy, navigation, and astronomy to describe the position of objects on or near the Earth. In the ECEF system, the coordinate origin is set at the centre of the Earth, so the coordinates of all objects are expressed relative to that centre. Using ECEF coordinates, it is possible to precisely determine the position of an object in three-dimensional space. This coordinate system is often used in GPS (Global Positioning System) navigation as well as in other applications where it is necessary to precisely determine the position of objects on the surface or near the Earth. The terrain was scanned using the mobile laser scanning method. The Riegl VUX-1 UAV scanning device was fixed on the vehicle (Figure 4).

Figure 4. Riegl VUX-1 UAV scanner

The maximum range of this device is 920 m, the minimum range is 3 m, the accuracy/precision is 10 mm/5 mm, the maximum effective measurement speed is 500,000 points/second, the maximum scanning speed is 200 points/second, and the recording angle is 330° [15].

The scan was performed on 23.12.2022. year. Data acquisition was performed, i.e. The LiDAR device scanned the terrain by emitting laser beams and measuring the time it took for those beams to reflect to the sensor. This data is recorded and stored.

2.3. METHODS

2.3.1. ORIENTATION OF IMAGES

Given that the area in question included several LiDAR images, it was necessary to perform data processing. It involves georeferencing different shots to create a unique point cloud. After that, the recorded material was exported to .las files. Most laser recording devices have software for processing recorded material and exporting data. Also, there are software specialized for processing, such as TerraScan, CloudCompare, Lastools, Pix4D and many others. This software offers various functions and capabilities for the analysis and visualization of LiDAR data.

LAS (LiDAR Data Exchange Standard) is a file format [16] that is often used to store and exchange data obtained using LiDAR technology. The LAS format is particularly popular in geodesy, cartography, geoinformatics and other areas where data accuracy is important. This format is used to store three-dimensional points that represent measured distances to the surface of terrain or objects. These points often form a "point cloud" that describes the actual terrain. Each point in the .las file can be classified to indicate whether it represents land, buildings, vegetation, or other objects. This is useful for data analysis and interpretation. The LAS format can also contain RGB (red, green, blue) colours for each point, which allows the visualization of point clouds in colour. These files often contain geographic information, including coordinates and elevations of points. This enables georeferencing point clouds in real-world situations. Also, each point can have information about the intensity of reflected light, which can be useful for determining surface characteristics.

Based on such data, there is the possibility of various applications such as DTM (Digital Terrain Model), terrain analysis, urban planning, detection of changes in the landscape and many other geospatial analyses. There are multiple versions of the LAS format, from LAS 1.0 to LAS 1.4, which support different features and capabilities.

Based on the coordinates of the recorded orientation points, the transformation parameters and the recorded material, the orientation of the recordings was made. Each point in the point cloud has three-dimensional spatial coordinates (width, length and height) that correspond to a specific point on the Earth's surface from which the laser pulse was reflected in the form of .las files. Given that the MicroSurveyCAD program was used for the vectorization of the obtained point clouds, it was necessary to convert the .las files into .pci files before the vectorization. The conversion was done in the aforementioned Pix4D software.

2.3.2. MICROSURVEYCAD MICROSURVEYCAD MAPPING, MODELLING AND CLASSIFICATION PROCESS

MicroSurveyCAD is a CAD (Computer-Aided Design) focused platform for surveyors and engineers, designed to maximize efficiency and value by supporting a variety of workflows and data formats in a single program [3]. In AutoCAD, a model was created in which all symbols for plotting were entered in the corresponding Layers, as well as the Layers themselves, in which plotting will be done. Then we load a point cloud based on which we want to plot the recorded area. To plot objects and detailed geodetic situations in the MicroSurveyCAD program, a smaller point size (1 or 2) is recommended, while a larger size can only be used for easier identification of higher objects. As for the colour of the points, monochrome and RGB scales are offered, so that all the points can be the same colour, or for the colours to be graduated depending on the height of the recorded point. Often, point clouds are placed in files that require advanced graphics and computer RAM, and it is difficult to vectorize them on computers with lower performance, in those cases, it is possible to cut a certain part of the point cloud.

After setting the point cloud display, point cloud vectorization is performed (Figure 5). Given that the existing condition of the buildings is of key importance for the reconstruction of Banja Guber, the breaking points of the buildings were taken and by connecting these points with a line, the contour of the building was obtained (Figure 5).

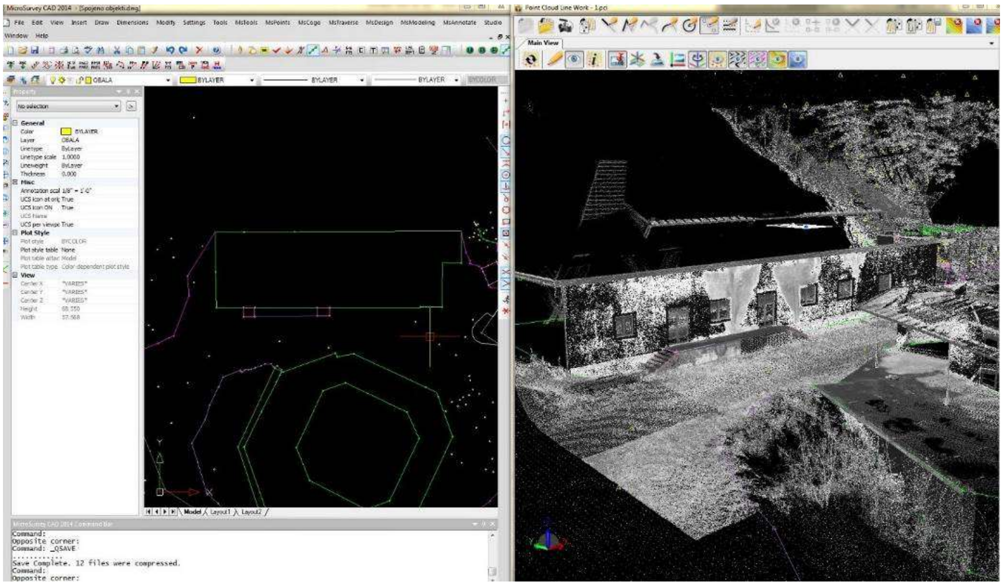

Figure 5. A vectorized object (left) and its appearance in a point cloud (right)

For the objects, all the characteristic breaking points were taken as if it was recorded using one of the classic terrestrial recording methods (contours, stairs, terraces, balconies, foundations, number of floors, etc.). In addition, the characteristic points of the terrain were chosen on the same principle. These points are used to draw TINs and countour lines. In addition, the upper and lower scarp, the edge of the road, and the water mirror were drawn from line elements. From the point elements, information was collected about springs, flags, substations, traffic signs, manholes and drains.

3. NUMERICAL RESEARCH

3.1. PREPARATION OF DETAILED GEODETIC SITUATION

After data preparation, marking and recording of orientation points, laser recording, processing, georeferencing and conversion of data into .pci format, it is necessary to perform vectorization, i.e. modelling of the recorded terrain. The following images show photos of the facility with different display options (Figure 6, Figure 7 and Figure 8).

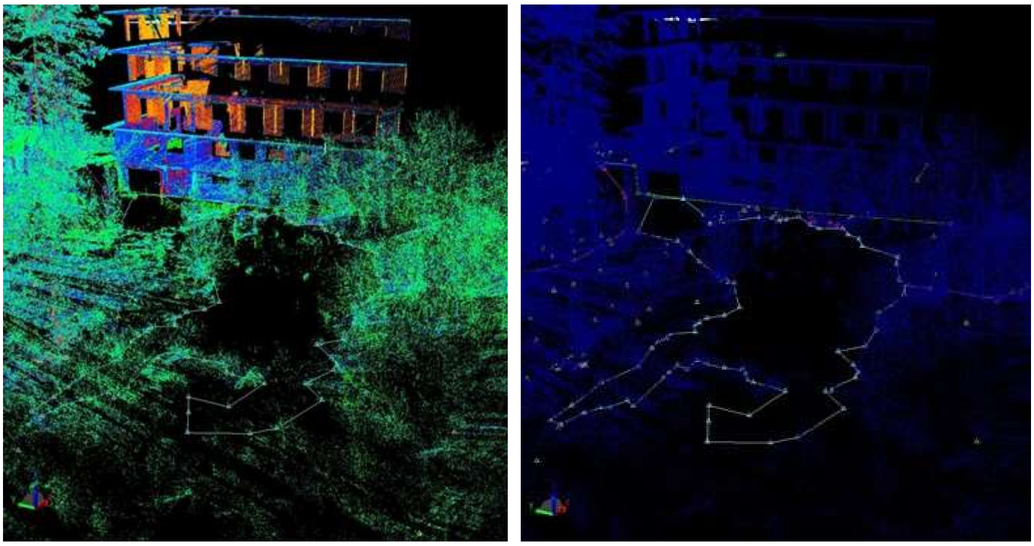

Figure 6. Captured object, Color map rainbow option (left), Elevation mapping option (right)

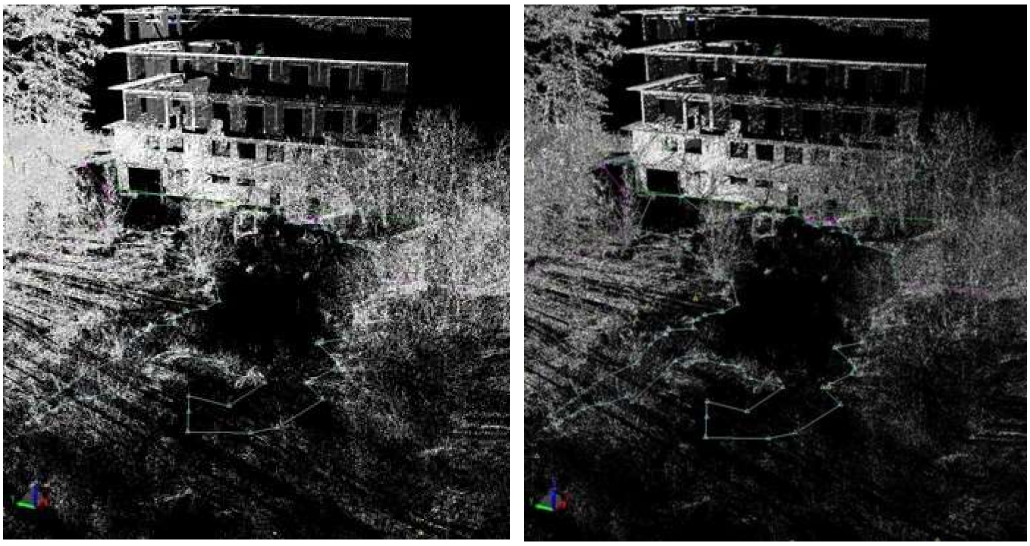

Figure 7. Captured object, Grayscale option (left), Multi Grayscale option (right)

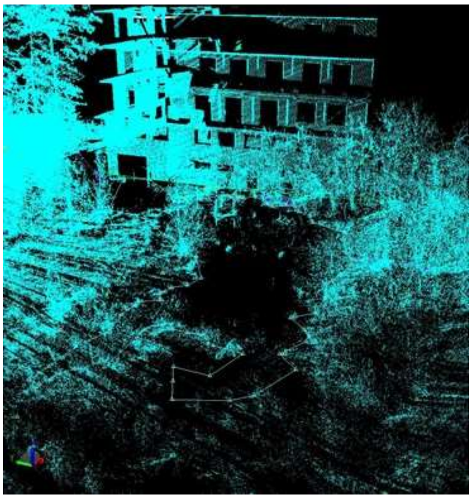

Figure 8. Captured object, One colour option

Since there is not a large range of heights on the ground, the Multi Grayscale option was chosen for further work and plotting. Selecting Multi Grayscale for visualization suggests using shades of gray to display data. The goal is to emphasize the differences in the data. It is important to ensure clarity and contrast so that data can be easily interpreted. This approach allows accurate information to be conveyed without the need for complex colors.

Figure 9 shows a comparison of a part of the video of the recorded location and the obtained cloud of points in MicroSurveyCAD.

Figure 9. Actual situation (left), captured point cloud (right)

Given that the largest and most healing source is Crni Guber, it is shown according to the same principle (Figure 10).

Figure 10. Actual situation on source Crni Guber (left), captured point cloud (right)

3.2. 2D GEODETIC SITUATION

To create a 2D situation, the elevations of the points were written, their distribution was carried out, and the corresponding hatches were assigned to the objects according to their purpose. All of the above was done in AutoCAD, as it would have been done with data obtained by classical recording methods. The cadastral base containing the borders of the existing parcels and their numbers were copied onto the obtained data so that a cadastral-topographic plan with written elevations of the points was obtained. At the end, a description and a legend were added to the sketch (Figure 11).

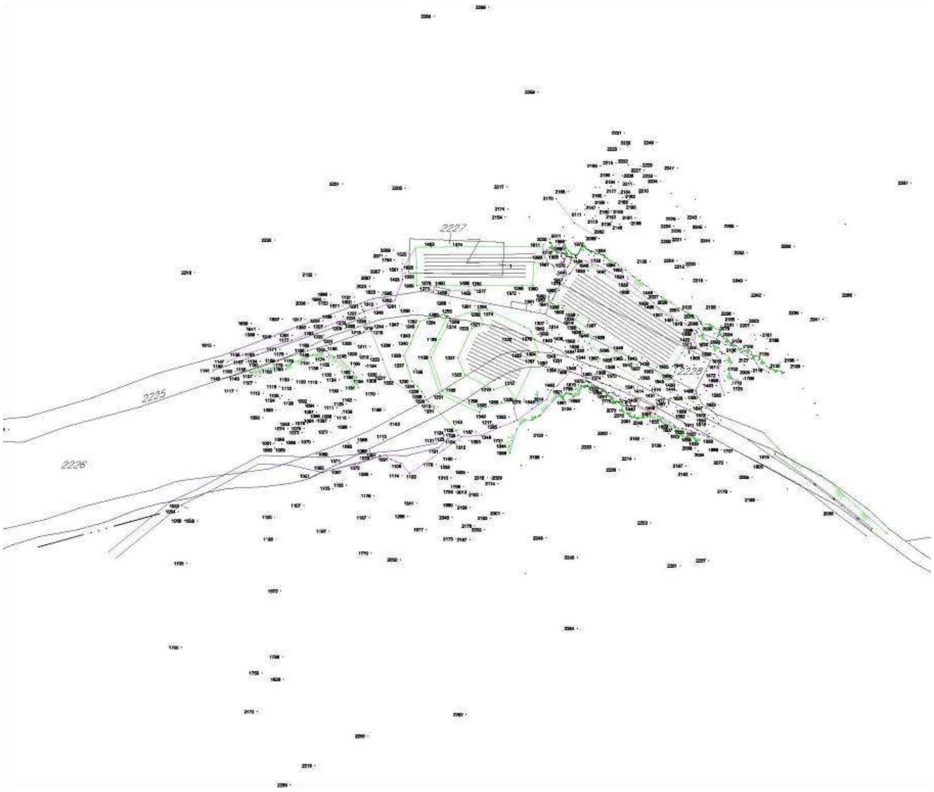

Figure 11. The 2D situation of objects near the source Crni Guber

3.3. 3D GEODETIC SITUATION

To create a 3D situation, a TIN model (Figure 12) was created, based on which the contour lines of the area in question were extracted. It was mentioned in the program add-on for AutoCAD called Survey.

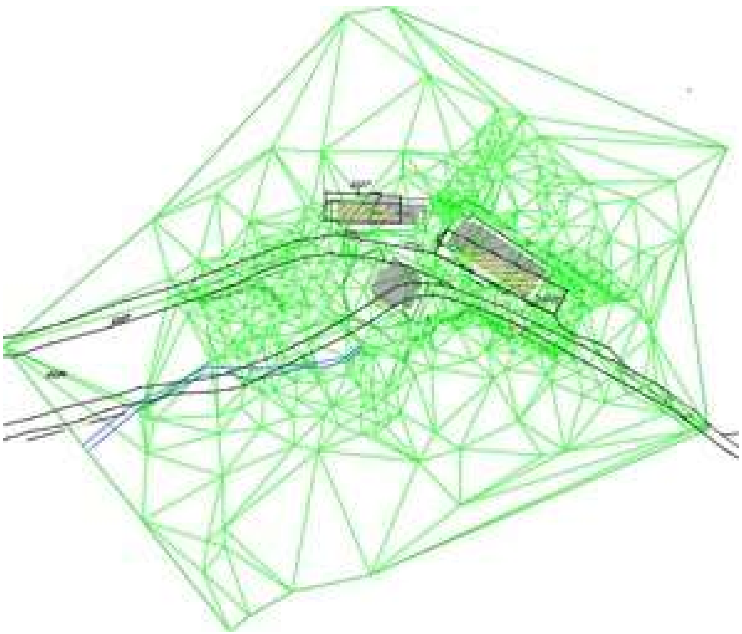

Figure 12. TIN model of the location near the source Crni Guber

It is interesting to check the recorded details and plotted contour lines by opening the drawings and clouds again in MicroSurveyCAD. Figure 13 shows how the obtained contour lines from the 3D situation follow the contours of the terrain. The layout of 3D situations is given in Figure 14.

Figure 13. Point cloud and contour lines

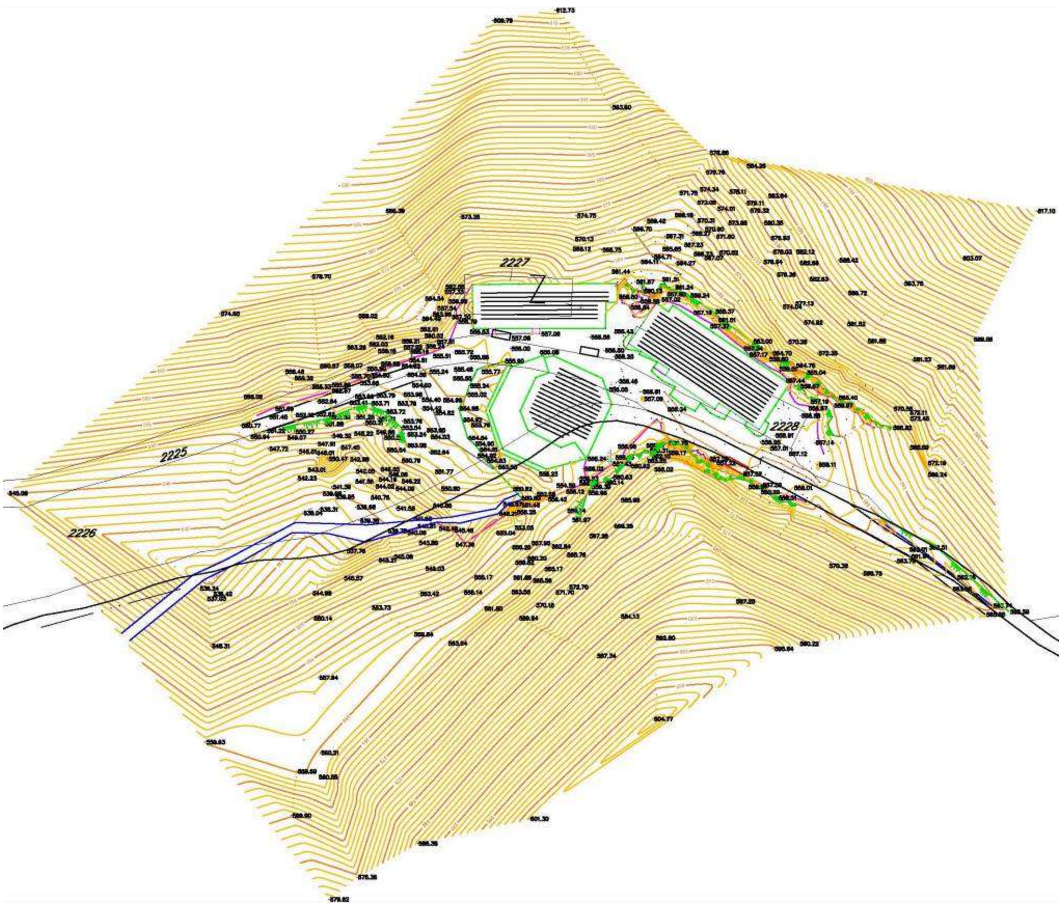

Figure 14. The 3D situation of objects near the source Crni Guber

4. CONCLUSION

Laser scanning can be successfully used to design and restore objects so that it can largely replace classical recording methods. The volume and quality of data obtained by laser scanning in the process of object restoration are superior to the volume and quality of data obtained by classical recording methods and can replace them in most situations.

What does not belong to the positive side of the laser scanning method is the high cost of the scanning equipment and the scanning process itself. Also, given the large amount of data involved, data processing often requires additional financial, hardware, personnel and time capacities.

In this paper, with the help of mobile laser scanning, a faithful representation of the current state of the facilities of the Banja Guber complex and part of the steep and inaccessible terrain surrounding was obtained. Some of the details captured in this way would be very difficult to capture with traditional recording methods. The resulting point cloud can be reloaded and vectorized for more detail as needed. It could be said that the point cloud contains all the essential information about the state of the terrain on the day of the shooting.

The advantages of this method far outweigh its disadvantages, so it is necessary to consider it and use it more and more often to reduce the danger for workers in the field and damage to equipment in risky situations, and to monitor world trends in the matter of geodesy and the creation of three-dimensional representations of objects (BIM models) and the cities themselves.

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