Application of 3D Terrestrial Laser Scanning in The Process of Update or Correction of Errors in the Cadastral Map

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Key words: Laser Scanning, Cadastral Map, Update.

SUMMARY

3D terrestrial laser scanning has a number of possible applications in surveying. Another one is proposed in this paper, taking in mind the current trends for augmentation of the coverage of the cadastral maps in Bulgaria.

Currently in the country there are a number of created, approved and put into legal power cadastral maps. The last cover various territories, including those, containing buildings with more than one owner.

Due to various reasons it often happens, that existing cadastral information is created incorrectly or is missing at all on the map. These facts impose conducting of geodetic measurements for creation of the required digital information for update or correction of the cadastral map.

This paper studies the implementation of the specific field procedures, also the processing of the geodetic measurements (obtained by 3D terrestrial laser scanner) for delivery of the necessary data for the existing on the terrain, but missing or incorrectly situated on the map objects of cadastre.

Analysis of the technical difficulties and the advantages of the proposed method for this particular case are given in the paper, based on the requirements of the surveying equipment.
In the paper are also given graphical examples for illustration the specifics of the carried work. Assessment of the accuracy of the conducted geodetic measurements is done in the study.

Conclusions, recommendations and future proposals are given in the paper.

РЕЗЮМЕ

3D наземното лазерно сканиране има огромен брой приложения в областта на геодезията. Едно друго възможно е представено и предложено в този материал, имайки предвид текущите тенденции за покритие на територията на България с кадастрални карти.

Понастоящем в страната има немалък брой създадени, одобрени и влезли в сила кадастрални карти. Последните покриват различни територии, включително такива съдържащи в себе си сгради с повече от един собственик.

Поради редица причини често се случва, че съществуващата кадастрална информация е представена грешно или изобщо липсва на картата. Тези факти налагат извършване на геодезически измервания за създаване на необходимата цифрова информация с цел попълване или поправка на кадастралната карта.

Тази статия изследва извършването на специфичните дейности на полето, както и обработката на геодезическите измервания (получени чрез 3D наземно лазерно сканиране) за доставяне на необходимата информация за съществуващата на терена, но липсваща или грешно представена на кадастралната карта.

Анализ на техническите трудности и предимствата на предложения метод за този специфичен случай са представени в статията, базирайки се на изискванията на геодезическото оборудване.

В материала също така са дадени графични примери за илюстрация на спецификата на геодезическата дейност. В статията е извършена оценка на точността на проведените геодезически измервания.

Заключение, препоръки и предложения за бъдеща работа са включени в публикацията.

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1. INTRODUCTION

3D terrestrial laser scanning is amongst the methods for high-accurate and productive way for measurements and gathering of spatial information – 3D coordinates of the points, also the intensity of the returned laser signal in the scanner [Milev, 2012]. Other sources from the Internet could also be listed here: [http://tinyurl.com/pmz2hf6] and [http://tinyurl.com/pttjzxh].

Recently in Bulgaria for a number of regions there are created, approved and put into legal power cadastral maps. Due to various reasons mistakes are existing in the already created digital maps. The last are available online at https://kais.cadastre.bg.

The focus of this paper are the technical implementation and practical issues which could be met in the process of update/correction of the cadastral map.

This study describes one contemporary way for conducting of the measurements, which are required for the project, described in details in [Ordinance N RD-02-20-5, 2017]. The documentation of the project in digital and paper type must be submitted by the owner in the Agency of Geodesy, Cartography and Cadastre.

The issues which could require update/correction in the cadastral maps could be and are not limited to:
-missing objects of cadastre (buildings, schemes of the separated objects on the relevant floor of a building, etc.);
-incorrect contours of the existing objects on the cadastral map.

This paper focuses the attention on the following technical details:

- conducting of geodetic measurements /3D laser scanning/, using the LIDAR technology both in external and internal areas;
- creation of reliable and accurate 3D digital model;
- extraction of the required data in the 2D space (in 2005 Cadastral coordinate system);
- elimination of the possibility for any errors during the survey process and data handling;
- obtain productivity, also minimization of the crew activities in the field.

In this project were involved the following software applications: Trimble RealWorks [http://tinyurl.com/pdckrlr], AutoCAD (http://tinyurl.com/zc9mot3) and Mkad [http://kolma.bg/download.php]. The applications are listed in the order of their usage in the study.

The final product in this specific case consists of:

- base information in *.cad format, bought from the Agency of Geodesy, Cartography and Cadastre;
- the coordinates of the new-determined points;
- the data from the conducted geodetic measurements and their processing.

The digital project in *.cad format contains the required information for the update/correction of the cadastral map, according to the requirements of [Ordinance N RD-02-20-5, 2017].

2. POSSIBLE APPLICATIONS OF 3D TERRESTRIAL LASER SCANNING FOR CADASTRAL PURPOSES

A lot of possible applications involving the usage of the terrestrial laser scanning in the area of cadastre could be found on the Internet. Some of them are listed here:

- https://tinyurl.com/zgbs4nj
- http://tinyurl.com/z2jpaqj
- https://tinyurl.com/glxva27
- http://tinyurl.com/gqk9d4t
- http://tinyurl.com/hjv785u

One other application, which applies both contemporary and precise surveying equipment, also the latest GIS software is proposed here. The geodetic activities follow the normative requirements for update/correction of the put into legal power cadastral map in Bulgaria. The final aim of the procedure is creation and preparation of the necessary data in a productive way for the required update/correction of errors in the existing cadastral map.

The procedure in our case involves the usage of:

- up-to-date digital information from https://kais.cadastre.bg;
- contemporary surveying technology (3D terrestrial laser scanning);
- 3D panoramic photos;
- Trimble RealWorks - software for 3D Scanning Professionals;
- contemporary GIS software Mkad;
- latest *.cad format – ver. 4.03.

3. APPLICATION OF 3D TERRESTRIAL LASER SCANNING, ESPECIALLY FOR UPDATE/CORRECTION OF THE CADASTRAL MAP

As mentioned in the previous chapter there are a number of applications of 3D terrestrial laser scanning in surveying. Another one, especially for cadastral purposes in Bulgaria will be given in details here.

According to the current regulatory requirements [Ordinance N RD-02-20-5, 2017] in order to create a project for update or remove mistakes from the cadastral map, the licensed surveyor must perform geodetic measurements with the relevant accuracy. The last were completely met by the 3D

terrestrial laser scanner Trimble TX5. The necessity for conducting of geodetic measurements required the choice of the most appropriate technology and equipment for our specific case.

Here are listed some of the reasons, which imposed the usage of 3D terrestrial laser scanning:

- object was situated underground, where the usage of other surveying equipment would be unreasonable;
- short distances between the edges of the object and the surveying instrument (fig. 1 and fig. 2);
- low chance (almost impossible) to be produced error/s/ in the final results;
- object "sealed" as it is at the moment;
- easy data delivery;
- missing architectural plans.

Below are given the possible reasons, which led to the decision of excluding other surveying method:

- object under study was situated in high-density urban area;
- most of the objects, burdened with gross errors or are at all missing on the cadastral map are situated in such areas with existence of tall buildings;
- points from the national geodetic network were not existing;
- high productivity was required as the trade activities in the object were cancelled during the measurements;
- distances between the instrument and the objects were short.

The application of 3D laser scanning was motivated and chosen as a suitable and productive technology in our case, because of its ability to capture all visible information in the relevant range. In this way it was guaranteed, that all existing cadastral details, subject of the project will be captured. The human factor for errors was eliminated. The field work was optimised as the object was a trade place in urban area with a lot of people in its vicinity.

The usage of GNSS technology for georeferencing in our specific case was not possible due to the high density of both buildings and tall trees in the area of the object.

4. REQUIREMENTS, ADVANTAGES AND DISADVANTAGES OF THE USED TECHNOLOGY, EXPLICITLY IN OUR CASE

Below are listed some of the requirements, which should be followed and are of essence especially for the current project. For producing data with the required quality, several factors should be met before the start of the geodetic measurements:

- scanning against direct sunlight should be avoided;
- the relevant settings in the scanner should be set, according to the environment (outdoor and indoor);
- the direction of the light should also be carefully observed in the initial settings prior the scan;
- the area around the scanner should be kept clear.

The complete list of the requirements is given in [http://tinyurl.com/pnqqabg].

Also, here are listed some of the advantages and disadvantages of the laser scanning, with significant importance if conducting the measurements for update/correction of the cadastral map:

4.1 Advantages:

- possibility to capture all objects in 360 degrees in the horizontal plane within a short time period;
- no need to keep a record for the description of the points;
- high productivity was obtained;
- easy to measure the necessary control points from other objects.

4.2 Disadvantages:

- requirements for direct visibility between scanner-object;
- the position of the scanner must be carefully chosen.

In this specific case (urban area, trade place, a number of people in the vicinity of the object) the security of the survey equipment, also the situated on the ground artificial spheres was of high priority. In general, this required additional crew to be involved to assure the overall safety during the conducting of the measurements.

The described in details in this paper update of the cadastral map was required due to the existence of more than one owners in the building, subject of measurements.

5. PREPARATION AND 3D TERRESTRIAL LASER SCANNING OF THE OBJECT, SUBJECT OF UPDATE OF THE CADASTRAL MAP

The object (missing on the cadastral map), subject of measurements and the buildings nearby were examined in details. The stations were chosen very carefully in order to be fulfilled the following requirements:

- short distance between object and scanner;
- appropriate (short) distances between the stations;
- the visibility between the scanner and the artificial spheres;
- the safety of the spheres in the urban area;
- the distances between the scanner and each target;
- well chosen angle of incidence (in the relevant bounds).

The places for the stations of the scanner were chosen, according to the mutual position of the object and other cadastral details in its vicinity, which should be also captured, [Kostov, 2015].

The area and its nearby terrain were bounded in order to be guaranteed the safety of the equipment as noted in the previous chapter.

The necessary settings for outdoor/indoor scans were applied, the scan resolution was set as to

provide a balance between quality and productivity (of high priority in this specific case).

After the completion of the preparatory activities for the terrestrial laser scanning, the field work was continued, carefully observing the safety.

A set of stations of the scanner for both external and internal parts of the object was created and scans were performed. It was necessary to be assured, that all the cadastral details will be measured for the required digital model.

For control of the existing cadastral details redundant stations were created and the relevant measurements were done. In this way the completeness of the measured information was guaranteed.

6. TECHNICAL DIFFICULTIES, WHICH SHOULD BE TAKEN INTO ACCOUNT IN THE HIGH DENSITY URBAN AREA AND IN INTERNAL PLACES

The mentioned in chapter 4 advantages of the 3D terrestrial laser scanning in this specific case simplified the process and made the job productive.

As it is known this kind of surveying equipment has some parts, like the rotating mirror, which require some special care and attention from the point of safety in the field. Fig. 1 below clearly shows the potential danger from falling natural material (e.g. small branches or leaves) from the tree onto the scanner.

Fig. 1 The tall trees, situated next to the object

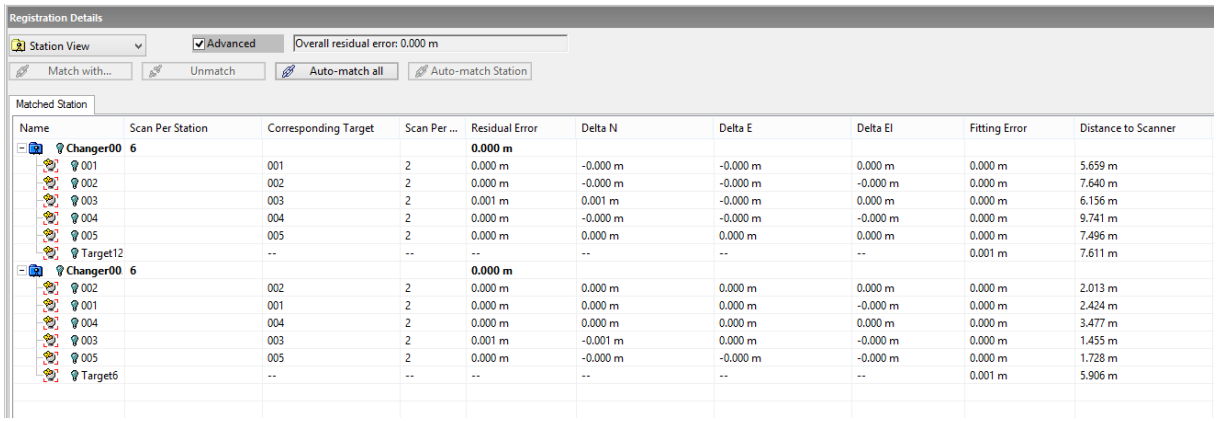
Another situation should be also observed in the field during the performing of the measurements. According to the technological possibilities of the scanner for creating 3D panoramic photos, the area around the scanner should be kept clear in order to be produced quality photos, required for the further geodetic activities, like recognition of the measured details of the object.

The surveyor should be also prepared for conducting of measurements in an extreme/dangerous environment – the equipment must contain accessory for well fixing of the tripod on a slippery floor.

7. PROCESSING OF THE INFORMATION. FINAL RESULTS FROM THE GEODETIC MEASUREMENTS. ANALYSIS

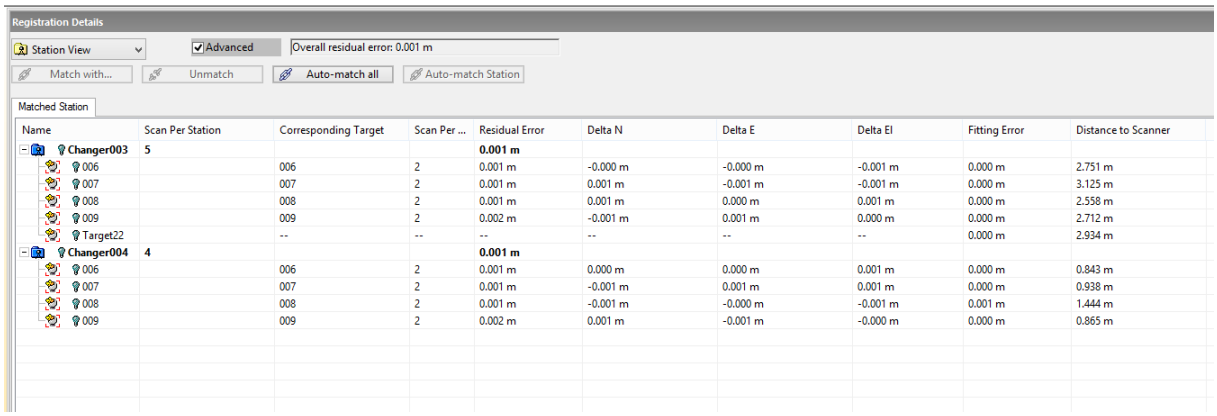
The scans were imported and processed in Trimble RealWorks. The stations were divided into external and internal (underground) ones. The first were used, as mentioned in chapter 5 for control purposes of the existing cadastre. The internal stations delivered information for the geometry and position of the object. The scans were registered, using the "Auto-extract Targets and Register" menu option. The fast, productive and precise registration process was possible due to the usage of the artificial targets, which were placed on suitable safe places on the ground (both outside and underground).

The results from the registration and its quality control are given in fig. 2 and fig. 3 below. The last include various information, including the achieved quality in the registration process – in our case the maximum overall residual error was 0.001 m. From the last column of fig. 3 it could be seen the short distances between the scanner and the targets. The values of the lengths indicate the specific underground environment (impossibility of placing the spheres elsewhere on the ground) where the laser scanner operated in.



Name	Scan Per Station	Corresponding Target	Scan Per ...	Residual Error	Delta N	Delta E	Delta El	Fitting Error	Distance to Scanner
Changer00	**6**			**0.000 m**					
001		001	2	0.000 m	-0.000 m	-0.000 m	0.000 m	0.000 m	5.659 m
002		002	2	0.000 m	-0.000 m	-0.000 m	-0.000 m	0.000 m	7.640 m
003		003	2	0.001 m	0.001 m	-0.000 m	0.000 m	0.000 m	6.156 m
004		004	2	0.000 m	-0.000 m	-0.000 m	-0.000 m	0.000 m	9.741 m
005		005	2	0.000 m	0.000 m	0.000 m	0.000 m	0.000 m	7.496 m
Target12		--	--	--	--	--	--	0.001 m	7.611 m
Changer00	**6**			**0.000 m**					
002		002	2	0.000 m	0.000 m	0.000 m	0.000 m	0.000 m	2.013 m
001		001	2	0.000 m	0.000 m	0.000 m	-0.000 m	0.000 m	2.424 m
004		004	2	0.000 m	0.000 m	0.000 m	0.000 m	0.000 m	3.477 m
003		003	2	0.001 m	-0.001 m	0.000 m	-0.000 m	0.000 m	1.455 m
005		005	2	0.000 m	-0.000 m	-0.000 m	-0.000 m	0.000 m	1.728 m
Target6		--	--	--	--	--	--	0.001 m	5.906 m

Fig. 2 Registration of the external stations



Name	Scan Per Station	Corresponding Target	Scan Per ...	Residual Error	Delta N	Delta E	Delta El	Fitting Error	Distance to Scanner
Changer003	**5**			**0.001 m**					
006		006	2	0.001 m	-0.000 m	-0.000 m	-0.001 m	0.000 m	2.751 m
007		007	2	0.001 m	0.001 m	-0.001 m	-0.001 m	0.000 m	3.125 m
008		008	2	0.001 m	0.001 m	0.000 m	0.001 m	0.000 m	2.558 m
009		009	2	0.002 m	-0.001 m	0.001 m	0.000 m	0.000 m	2.712 m
Target22		--	--	--	--	--	--	0.000 m	2.934 m
Changer004	**4**			**0.001 m**					
006		006	2	0.001 m	0.000 m	0.000 m	0.001 m	0.000 m	0.843 m
007		007	2	0.001 m	-0.001 m	0.001 m	0.001 m	0.000 m	0.938 m
008		008	2	0.001 m	-0.001 m	-0.000 m	-0.001 m	0.001 m	1.444 m
009		009	2	0.002 m	0.001 m	-0.001 m	-0.000 m	0.000 m	0.865 m

Fig. 3 Registration of the internal (underground) stations

Due to the unique situation – narrow entrance and steep stairs, the unity between the external and internal parts of the object was done using the software option "Cloud based registration". The results from the quality control are given in Fig. 4 below.

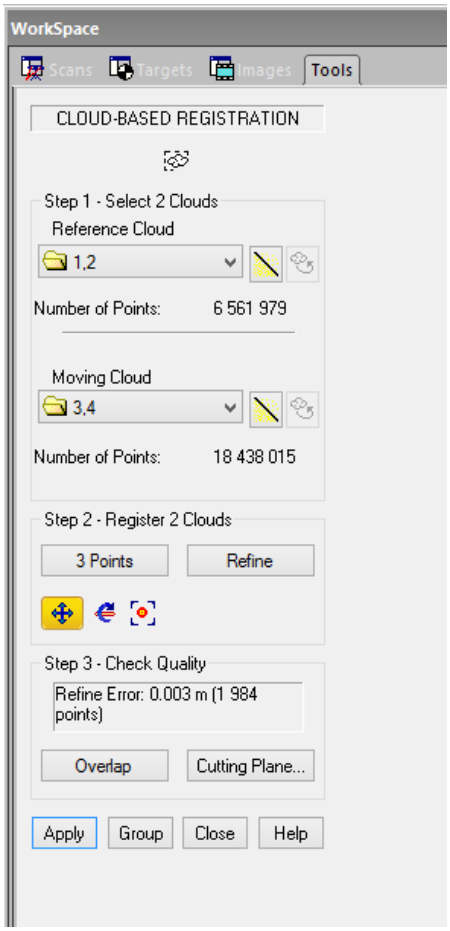


Fig. 4 Cloud based registration of the external and internal parts of the object

As seen on the screenshot from Trimble Realworks, a refine error of 0.03 m. of the cloud based registration was achieved. The last value completely satisfied the accuracy requirements for our purpose.

On fig. 5 is given a screenshot from the point cloud of the united model. It could be clearly seen the specific spatial geometry of the object, subject of update of the cadastral map.

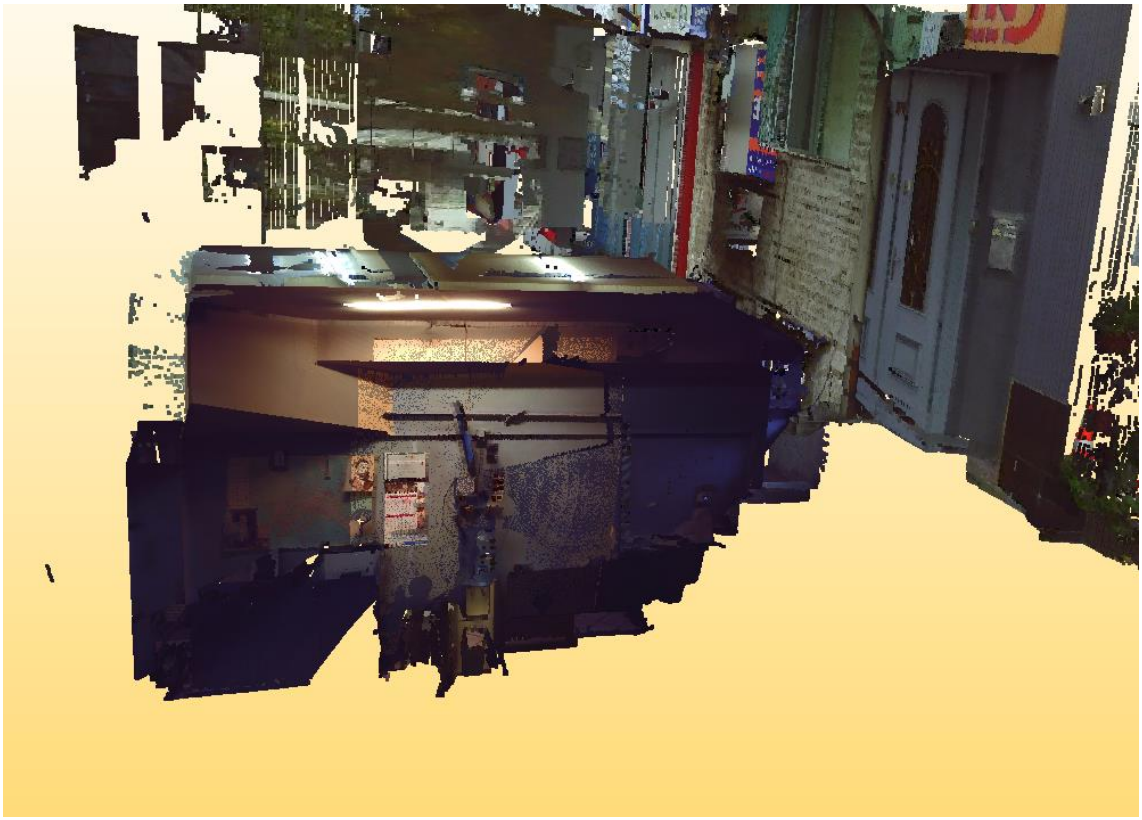


Fig. 5 The underground object

One part of the digital product – an extracted horizontal cross section (using the possibilities of Trimble Realworks) is given in fig. 6. In our case it was used to be obtained information for the position of the object in order to be created the digital model of the so called scheme of a separated object on the relevant floor of the building. In blue colour is denoted the point cloud and in green – the measured object. The nearby objects like stairs, walls, etc. could also be recognised.

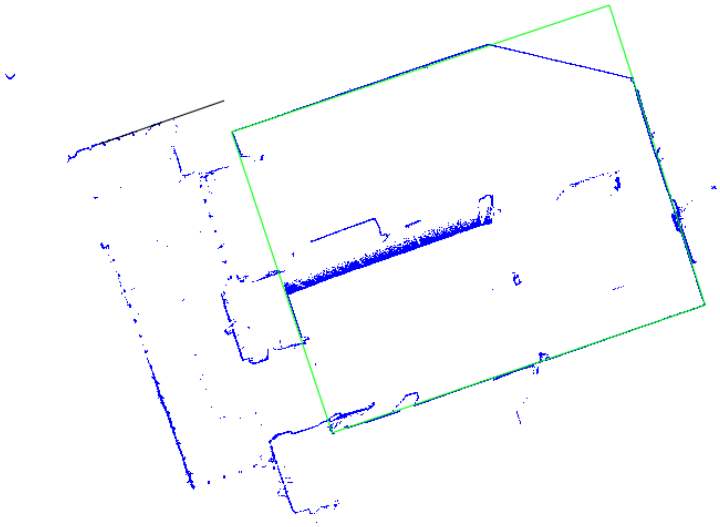


Fig. 6 Horizontal cutting plane with the contour of the object

The geometric information – the contour of the object, given in fig. 6 was used further on in the environment of Mkad (described in chapter 1) in order to be prepared the *.cad file, required for the update of the cadastral map.

8. CONCLUSION. RECOMMENDATIONS. OUTLOOK

The aim of this paper was to explore the benefits, disadvantages and issues which might appear in the application of 3D terrestrial laser scanning for the process of update/correction of errors of the put into legal power cadastral map. According to the requirements of [Ordinance N RD-02-20-5, 2017] in order to submit a project for update/correction of errors of the cadastral map geodetic measurements must be performed. Unfortunately, in the annex N 8 to article N 36 (2) of the above mentioned Ordinance the technology of laser scanning was nowhere mentioned, even though it satisfies completely the requirements for accuracy of the listed types of surveying methods for performing of geodetic measurements.

It should be noted, that the specific case described in this paper performs update of the cadastral map (the object was missing). If correction of the existing data on the map is required, the described in details geodetic activities, including the measurements (conducted using terrestrial laser scanner) should be mandatory performed.

The required update of the cadastral map was successfully completed, applying 3D terrestrial laser scanning, using the possibilities of the listed software and also following the technical details, given in chapter 5. The mentioned disadvantages in chapter 4 and the difficulties, described in chapter 6 did not reflect on the overall productivity and reliability of the conducted geodetic measurements.

As mentioned in chapter 1 3D terrestrial laser scanning eliminated the possibility for errors, which might occur (if using the conventional surveying methods). This fact makes the applied in our case technology a reliable one for geodetic activities in this specific case, taking in mind the nature of the object (situated underground). The used surveying equipment maximized the overall productivity. The last was of major importance in the field (high density urban area). As it was described in details in chapter 3, the application of other way for measurements was technically ill-founded. Last, but not least the IT, which was involved created a step forward to a more productive procedure, accurate and reliable final product based on the applied in our case 3D terrestrial laser scanning.

The quality assessment of the performed geodetic measurements, given in chapter 7 proved the high quality of the data for the purpose of update/correction of the cadastral map:

- residual error in the target-based registration - max. 0.02 m.;
- overall residual error for the target-based registration – max. 0.001 m.;
- refine error of the cloud based registration - 0.03 m.

According to the obtained high productivity in the field, also the mentioned results from the quality control, the applied technology for update/correction of the cadastral map was essential for the successful and reliable completion of the current task.

If analysed, the information in the listed results from processing of the raw data from 3D terrestrial laser scanning leads to the following conclusion - it could be strongly proposed an update of the requirements for the geodetic measurements /especially in the area of the subject of this paper/, taking in mind the technical possibilities of the nowadays surveying equipment in land surveying.

Outlook. It would be highly recommended the necessary update of the current normative documents and the explicit addition of 3D terrestrial laser scanning as excellent opportunity for geodetic activities in the area of cadastre.

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WEB

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http://tinyurl.com/hjv785u
https://kais.cadastre.bg - in Bulgarian

USED SOFTWARE

Autodesk AutoCAD (http://tinyurl.com/zc9mot3);
Mkad (http://kolma.bg/download.php - in Bulgarian);
Trimble RealWorks (http://tinyurl.com/pdckrlr).

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