Combination Of 3d Terrestrial Laser Scanning And GNSS Technologies For Measurement Of Hard /Impossible/ To Access Objects Of Cadastre In The Process Of Data Acquisition For The Required Update Of The Cadastral Plan

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Key words: laser scanning, GNSS, measurements, update, cadastral plan

SUMMARY

In this paper is discussed the possible joint application of 3D terrestrial laser scanning and GNSS technologies, which gives the geodesists the opportunity for productive and also precise way for gathering of the required spatial cadastral information in the field. The combination of these technologies for some specific objects in the surveying practice offers the possibility to save time in the field, gain overall efficiency and avoid making errors in the later on created documentation.

The paper explores the implementation of the technological procedures both in the field and in the office, which are necessary for the creation of the required documentation for the update of the cadastral plan. The surveying job consists of: preparation for and conducting of geodetic measurements /applying the above mentioned technologies/, data processing and analysis of the overall quality of the created 3D digital model. The last was used further on for data extraction of the relevant cadastral information as: contour points, inaccessible edges of the object, control points, etc.

A thorough analysis of the factors, which led to the decision for usage of these contemporary surveying methods was done in the paper. The technical requirements of the applied instruments were also taken into account.

Assessment of the accuracy of the performed geodetic measurements was done. In the paper are included the necessary graphical examples, which show the specifics of the carried work.

Conclusions and recommendations for future work are also given in the paper.

РЕЗЮМЕ

В този материал е разгледано възможното съвместно приложение на 3D наземно лазерно сканиране и GNSS технологиите, което дава на геодезистите възможност за продуктивен и също така прецизен начин за събиране на необходимата пространствена кадастрална информация на полето. Комбинацията на тези технологии за някои специфични обекти

от геодезическата практика предлага възможността да се спести време на полето, постигайки обща ефикасност и избягване на грешки в създадената документация.

Статията изследва изпълнението на технологичните процедури както на полето, така и в офиса (на компютъра), които са необходими са създаване на изискваната документация за попълване на даден кадастрален план.

Работата на геодезиста се състои от: подготовка и извършване на геодезически измервания /прилагане на двете цитирани технологии/, обработка на данните и оценка общото качество на така създадения 3D цифров модел. Последния е използван по-нататък за извличане на съответните кадастрални данни като: чупки на обекта, недостъпни ръбове, контролни точки и т.н.

В материала е извършен обстоен анализ на факторите, които са довели до вземане на решение за използване на тези съвременни технологии.

Под внимание са взети техническите изисквания на използваните инструменти. Направена е оценка на точността на извършените геодезически измервания.

В статията са включени необходимите графични примери, които показват спецификата на извършената работа.

В материала също така са дадени заключения и препоръки за бъдеща работа.

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1. INTRODUCTION

Both technologies - 3D terrestrial laser scanning and GNSS positioning are one of the most accurate (under certain conditions) and also productive for performing of geodetic measurements. There is a lot of printed and online literature for both of them - [Milev, 2012], [Minchev et al., 2005], [https://tinyurl.com/ybk3xxab], etc.

This paper studies two objects /hard to access, inaccessible/, which were measured and should be added on the existing cadastral plan.

Because of the fact, that scanner creates each scan in its own coordinate system and the existing cadastral plans are in certain official coordinate system, the coordinates of the measured object have to be transformed into the relevant system of the plan. This fact involved the application of surveying equipment which has the technical ability to deliver spatial data to be used for georeferencing.

Reasons, which led to the application of 3D terrestrial laser scanning:
- inaccessible /hard to access/ cadastral objects;
- elimination of the human factor for errors in the process of data acquisition;
- the information (3D coordinates of the edges of the cadastral object) was easy to be extracted from Trimble RealWorks;
- unsurpassed productivity.

Below are listed the most important facts, which led to the decision to be chosen the usage of GNSS equipment:
- enormous productivity in the field;
- very high quality of the final results.

This paper focuses on the details and the technical implementation of the applied combination of 3D terrestrial laser scanning and GNSS positioning. The work contains and is not limited to the following key aspects:
- performing of productive geodetic measurements, applying two technologies for fast data acquisition and producing high quality results;
- creation of accurate and thorough 3D digital model of hard to access objects, using LIDAR and later on the required final digital model in specialised format *.cad;

- delivery of only the necessary edges of the object for further use in other geodetic software;
- elimination of any possibilities for human mistakes;

2. EXAMPLES FOR APPLICATIONS OF 3D TERRESTRIAL LASER SCANNING FOR MEASUREMENTS OF OBJECTS OF CADASTRE

In the Internet there is a lot of information about the applications of 3D terrestrial laser scanning in the area of surveying, cadastre, etc. Some of the links for the publications, concerning various topics from cadastre are given below:
- development and updating of the base map [https://tinyurl.com/yaycdt9d];
- conservation of cultural heritage buildings [https://tinyurl.com/y9zeuurn];
- 3D city models [https://tinyurl.com/y7pcwx47];
- obtain 3D deliverables [https://tinyurl.com/y8dwkk5l];
- cadastral modelling [http://tinyurl.com/gqk9d4t];
- 3D cadastre [http://tinyurl.com/hjv785u];
- creation of documentation [http://tinyurl.com/yc4sd7ad].

One other application will be discussed in this paper, which combines the usage of both 3D terrestrial laser scanning and GNSS technologies. For the completion of the final task – update of the cadastral plan in the geodetic activities were also used several software products: Geomax Geo Office [http://tinyurl.com/h9s4aop], GNSSTransformations [https://tinyurl.com/y83qp2l2], Trimble RealWorks [http://tinyurl.com/pdckrlr] and Mkad [http://tinyurl.com/hapgj9l]. The listed software is given as it was technologically used in the process of update of the cadastral plan.

The aim of the created final digital (*.cad) product was submission of all the data from the performed geodetic measurements and the required graphical part in the relevant municipality to update the cadastral plan.

3. NECESSITY FOR USAGE OF 3D TERRESTRIAL LASER SCANNING IN THIS SPECIFIC CASE

In chapter 2 were listed some of the already known possible applications of 3D terrestrial laser scanning in the area of surveying. Here, in this chapter it will be focused on the reasons why use the LIDAR technology in our case.

3D laser scanning was chosen to be applied for the task update of the cadastral plan as most suitable technology for measurements - in our case of impossible to access edges of buildings. The reflectorless classical method for geodetic measurements was technically not the appropriate solution for safe and reliable completion of the survey process, due to the high risk of e.g. “erroneous” measurements to “other” point.

One of the major benefits from the usage of laser scanning for this task was the ability of the equipment to measure all visible details of the object. Taking in mind this, the geodesist could be sure, that all edges of the cadastral object would be measured. Also, nothing will be missed, and data will be reliable. Due to the nature of the 3D terrestrial laser scanning technology, the risks of existence of "missing or incorrect cadastral details" or "erroneous points" were ignored.

In this specific case, the following facts were of significant importance for the decision of the technology to be used and correct completion of the survey procedure:
- elimination of possibilities for operator's errors;
- field work, compared with the classical instruments was optimised;
- performed reliable contactless measurements for inaccessible edges of the objects;
- photo realistic information available after data processing;
- possible to explore the scan in the office within Trimble RealWorks.

4. NECESSITY FOR USAGE OF GNSS TECHNOLOGY FOR PERFORMING OF GEODETIC MEASUREMENTS TO UPDATE THE CADASTRAL PLAN

In the literature, e.g. [Minchev et al., 2005] there is a lot of information for GPS measurements in RTK mode and especially for their productivity, accuracy and reliability in the field work.

The important aim of the satellite technology was to coordinate (precisely and fast) in RTK mode control points, where the artificial targets of the scanner's equipment were placed on.

Based on the described productivity of GNSS measurements, also the specifics of the objects (require usage of LIDAR, see previous chapter) a decision to apply satellite technology in RTK mode was taken.

There are a number of services for precise GNSS positioning, like: [http://tinyurl.com/gsuc6pw], [https://tinyurl.com/y7wzpgsp], [https://tinyurl.com/y9u74vgm] and [https://tinyurl.com/ya3m7tgw]. According to various factors - network coverage, accuracy, etc., GNSS network was not involved in the measurements. Autonomous own reference station was used for our task.

5. PREPARATION FOR COMBINATION OF THE TECHNOLOGIES IN THE FIELD

Below are given the requirements, which should be carefully checked priory performing of the relevant measurements and to be fulfilled for both of the technologies in case of field activities for our purpose.

5.1 3D terrestrial laser scanning

In this specific case of major importance for delivery of quality final results from the measurements, also to ensure the safety of the equipment were the following environmental

conditions:
- it is preferable measurements to be performed in clear /not dusty/ environment;
- to avoid certain weather conditions, e.g. rain, snow, etc.

Full information for operational requirements of the scanner could be found at [http://tinyurl.com/pnqqabg].

5.1.1 Advantages /of significant importance for our case/

- the scanner acquires every detail of the object (useful in case of existence of many contour points);
- no need to keep records with the code of each point /the classical method requires/;
- high accuracy achieved;
- very high productivity obtained in the field.

5.1.2 Disadvantages /technical requirements/

- prior check must be done to ensure the direct visibility between the scanner and the object;
- if more than one station will be used, their position and the geometry of the artificial targets must be very carefully chosen on the terrain.

5.2 GNSS technology

The region of the object was studied prior the start of the geodetic measurements in order to be chosen suitable for the satellite technology reference network point for positioning the base receiver. The equipment was prepared to be performed GNSS measurements in RTK mode using the chosen suitable for the case network point and own autonomous reference station. Going through these steps, the productivity and accuracy of the geodetic measurements were guaranteed. Some of the advantages and disadvantage of GNSS technology explicitly for our task are listed below:

5.2.1 Advantages

- very high open field productivity;
- it was possible to be achieved high 3D accuracy of the geodetic measurements.

5.2.2 Disadvantage

- the control points next to the object should be with possibility for open sky.

6. PRACTICAL IMPLEMENTATION OF THE COMBINATION OF THE TECHNOLOGIES ON THE TERRAIN

In this chapter will be given detailed information for the practical steps of the applied procedure as well as its advantages and disadvantages.

6.1 Field measurements using 3D terrestrial laser scanner

Before the start of the 3D laser scanning the necessary control points were created and stabilised on appropriate stable places on the ground. According to the practice, in some of the cases it was difficult to choose suitable area on the ground to materialize control points on it. The artificial targets were placed over each control point, the last later on used for georeferencing, see chapter 7.2.

The scanner was positioned on appropriate place near the object, observing the following requirements as:
- angle of incidence of the laser;
- direct visibility between the scanner and the positioned artificial targets;
- visibility scanner-targets in-between two adjacent stations.

The relevant settings for outdoor scan and point distance parameter were applied in the firmware of the scanner in order to be achieved: the necessary quality of the scans and productivity of the field work.

6.2 Performing of GNSS measurements

After completion of 3D terrestrial laser scanning measurements, the next technological step was to apply GNSS technology and acquire the necessary spatial information for georeferencing of the point cloud.

GNSS equipment was prepared (see chapter 5.2) and installed on already chosen geodetic network point. Base station with rover were used in this procedure. The choice of this equipment was necessary, due to the reliability and accuracy requirements of the task (not everywhere in the region there was a network coverage).

After the operational start of the GNSS equipment, the control points - already created and stabilized, were measured using the rover. Their coordinates were recorded in the relevant coordinate system and used further, see chapter 7.

6.3 Analysis of the applied procedure

The described field procedure was a combination of two technologies, which have their advantages and disadvantages. Below are given the most important of them according to the particularity of our aim.

6.3.1 Advantages

- no need to store additional records in the field. Process was simplified;
- field crew requires only one high-qualified geodesist (another one was not always necessary – depends on the terrain conditions);
- in case of presence of leaves, branches, etc., the measurements with 3D terrestrial laser scanner were technically reliable;
- extremely high field productivity;
- high accuracy achieved for the point determination, see chapter 7.

6.3.2 Disadvantage /technological requirement/

- two types of instruments have to be carried in the field.

7. PROCESSING OF THE RAW DATA FROM 3D TERRESTRIAL LASER SCANNING AND GNSS MEASUREMENTS

The recorded raw data from these technologies was processed using the relevant geodetic software. The procedure is described in details below for each technology separately.

7.1 Input of the raw data from GNSS measurements in Geomax Geo Office

Geomax Geo Office was used to prepare the necessary information, which later on was input in Trimble RealWorks for performing of the step georeferencing of the point cloud. Fig. 1 shows the applied control points and also the quality achieved of the GNSS measurements.

Point Id	Point Class	Date/Time	Posn. Qlty
110025	Reference	07/20/2017 15:01:53	0.0000
110024	Measured	07/20/2017 15:03:45	0.0097
110001	Measured	07/20/2017 15:06:12	0.0070
110002	Measured	07/20/2017 15:07:30	0.0077
110003	Measured	07/20/2017 15:07:51	0.0061
110004	Measured	07/20/2017 15:08:12	0.0072
110005	Measured	07/20/2017 15:08:39	0.0072

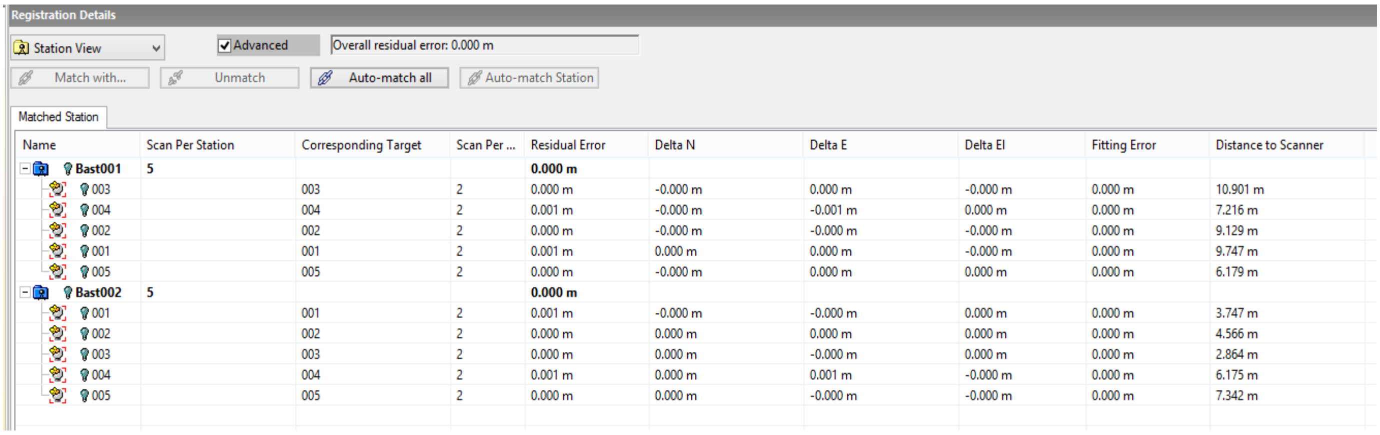
Fig. 1 List of the measured points and quality assessment

The information, listed in fig. 1 was converted in the appropriate format and imported in Trimble RealWorks, using GNSSTransformations [https://tinyurl.com/y83qp2l2].

7.2 Processing of the raw geodetic measurements from the 3D terrestrial laser scanning

The created scans were imported and registered in Trimble RealWorks. The option "Auto-extract Targets and Register" was used. The quality assessment of the registration is given in the fig. 2. From the results, given in fig. 4 it could be seen the existence of “overall residual error: 0.000 m” and same value for all spheres, included in the registration process. The data, shown in fig. 2 and fig. 4 proves the obtained high overall quality of the terrestrial laser scanning even in hard terrain conditions – impossible to access objects of cadastre.

The coordinates of the control points, measured by GNSS equipment, see chapter 7.1 were imported in the required format in Trimble RealWorks. In “Georeferencing tool” menu option the data from RTK measurements was used for georeferencing of the created point cloud. Screenshot with the results of this technological step from Trimble RealWorks environment for one of the objects of measurements is given in fig. 3.



Name	Scan Per Station	Corresponding Target	Scan Per ...	Residual Error	Delta N	Delta E	Delta El	Fitting Error	Distance to Scanner
Bast001	**5**			**0.000 m**					
003		003	2	0.000 m	-0.000 m	0.000 m	-0.000 m	0.000 m	10.901 m
004		004	2	0.001 m	-0.000 m	-0.001 m	0.000 m	0.000 m	7.216 m
002		002	2	0.000 m	-0.000 m	-0.000 m	-0.000 m	0.000 m	9.129 m
001		001	2	0.001 m	0.000 m	0.000 m	-0.000 m	0.000 m	9.747 m
005		005	2	0.000 m	-0.000 m	0.000 m	0.000 m	0.000 m	6.179 m
Bast002	**5**			**0.000 m**					
001		001	2	0.001 m	-0.000 m	-0.000 m	0.000 m	0.000 m	3.747 m
002		002	2	0.000 m	0.000 m	0.000 m	0.000 m	0.000 m	4.566 m
003		003	2	0.000 m	0.000 m	-0.000 m	0.000 m	0.000 m	2.864 m
004		004	2	0.001 m	0.000 m	0.001 m	-0.000 m	0.000 m	6.175 m
005		005	2	0.000 m	0.000 m	-0.000 m	-0.000 m	0.000 m	7.342 m

Fig. 2 Registration of the scans. Quality assessment results

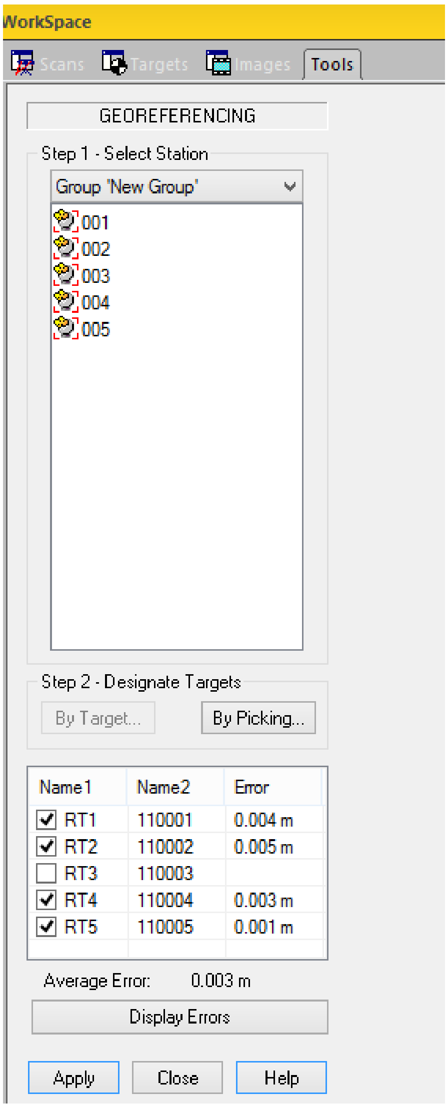


Fig. 3 Georeferencing of the point cloud. Result for the average error

Registration Details

Station View | Advanced | Overall residual error: 0.000 m

Match with... | Unmatch | Auto-match all | Auto-match Station

Matched Station

Name	Scan Per Station	Corresponding Target	Scan Per ...	Residual Error	Delta N	Delta E	Delta El	Fitting Error	Distance to Scanner
Sud001	**4**			**0.000 m**					
004		004	2	0.000 m	-0.000 m	-0.000 m	-0.000 m	0.001 m	8.283 m
002		002	2	0.000 m	0.000 m	0.000 m	-0.000 m	0.000 m	7.343 m
001		001	2	0.000 m	-0.000 m	-0.000 m	0.000 m	0.000 m	6.086 m
003		003	2	0.000 m	0.000 m	0.000 m	0.000 m	0.000 m	3.237 m
Sud002	**5**			**0.000 m**					
001		001	2	0.000 m	0.000 m	0.000 m	-0.000 m	0.000 m	4.658 m
002		002	2	0.000 m	-0.000 m	-0.000 m	0.000 m	0.000 m	3.862 m
003		003	2	0.000 m	-0.000 m	-0.000 m	-0.000 m	0.000 m	7.992 m
Target8		--	--	--	--	--	--	0.000 m	2.373 m
004		004	2	0.000 m	0.000 m	0.000 m	0.000 m	0.000 m	1.833 m

Fig. 4 Results from the registration of the scans - another object

The necessary terrain points of the cadastral object were extracted and exported in text format for further use and finalizing the office procedure - creation of the required final digital model in *.cad.

8. GRAPHICAL EXAMPLES OF THE OBJECTS, SUBJECT OF UPDATE OF THE CADASTRAL PLAN

In this chapter are given several screenshots, taken from Trimble RealWorks, which illustrate the “thick” environment around each object and the presence of various natural material like: leaves, branches, etc. The last excluded the possibility for application of other surveying equipment.

Fig. 5 below shows object “A”, with hard to access front part and inaccessible rear part. This object was surrounded by green area and the grapes leaves were situated around the building. There was neither possibility for safe and stable positioning of the geodetic equipment next to the object, neither for stabilizing of control points. The laser scanner and rover operated on the street.

Fig. 5 Contactless measurements for impossible to access object "A"

The edges of the building were acquired by the laser scanner using two positions of the scanner, as shown on fig. 6. It should be noted, that the direct access to the object was not safe and not possible due to the existence of tall green plants.

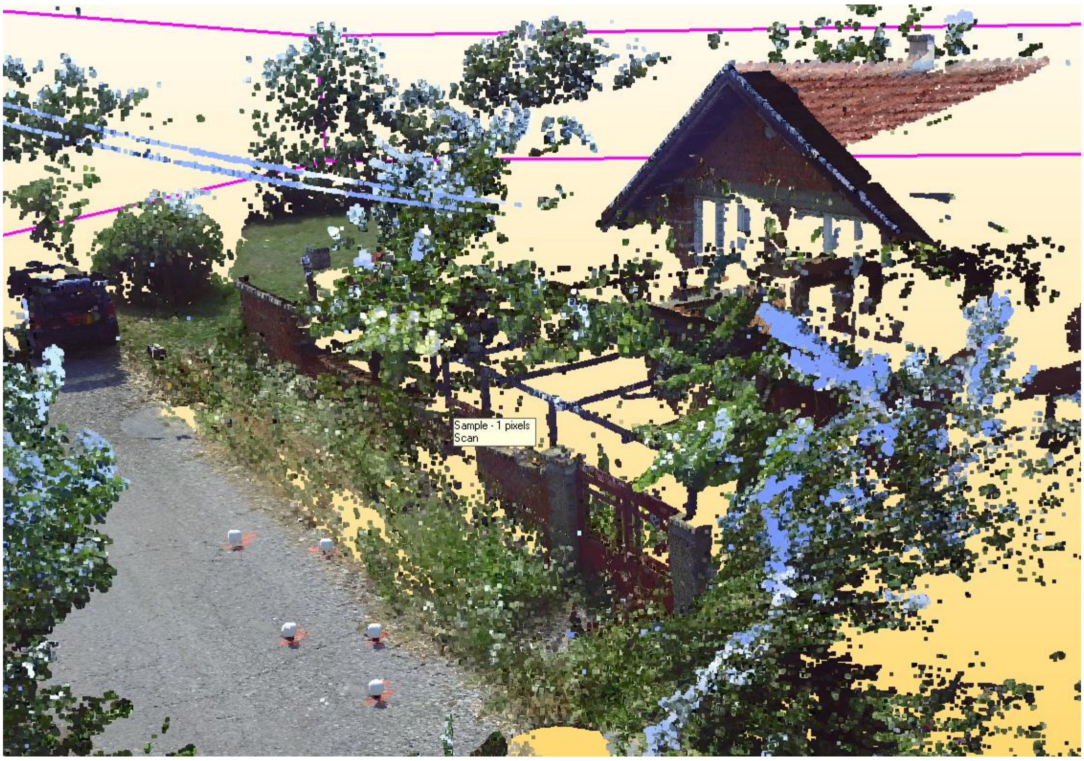


Fig. 6 The second station of the scanner for the inaccessible rear part of object “A”

From fig. 7 it could be seen the view from above to object “B”, which was hard to access. The point cloud contains a number of missing parts, due to the existence of huge quantity of natural material on the terrain and in the space around the object.

Fig. 7 View from above - object “B”

The graphical examples, given in figures NN 5, 6 and 7 show the difficult situation on the terrain, which existed during the performing of the geodetic measurements. The application of 3D terrestrial laser scanning made possible the measurements for these objects in the hard terrain conditions around them, because of the availability of enormous amount of precisely measured spatial information and photo realistic data.

9. CONCLUSION. RECOMMENDATIONS. FUTURE WORK

The focus of this paper was the combination of 3D Terrestrial Laser Scanning and GNSS Technologies with certain aim – update of the cadastral plan with objects, which were hard /impossible/ to access for the survey crew and other surveying equipment.

In this material were discussed the advantages and disadvantages of both technologies. Attention was concentrated on the reasons, which led to the decision to apply the combination of them. In the paper were also noted the main benefits for the geodesist, see chapters 3 and 6.3.

Described as it was – one possible combination of these technologies could be of significant importance for the geodesist in the terms of: time saving, minimization of the personnel in the field, productivity, accuracy achieved, etc.

For the completion of the task – update of the cadastral plan was involved precise and reliable information from 3D terrestrial laser scanning and GNSS measurements in RTK mode.

The results given in chapter 7 show, that there was no compromise with the overall accuracy of the data for the described hard terrain conditions. As it could be seen from fig. 2 and fig. 4 with the usage of artificial spheres for registration of the relevant scans, it was achieved extremely high accuracy in the processing of the laser scanning data, i.e. overall residual error of 0.000 m. The same results were calculated for the both objects – "A" and "B".

The information, listed in fig. 1 shows excellent quality results for the position quality parameter (column N 4) of the performed GNSS measurements – in the range of (6 mm, 9 mm). In the last step of the quality assessment of this procedure – georeferencing of the point cloud it was produced average error of 3 mm as shown in fig. 3. This value for the quality control satisfies the requirements for accuracy by all means.

It should be noted, that by application of the combination of 3D Terrestrial Laser Scanning and GNSS Technologies were achieved simultaneously two important technical moments – accuracy in the final results from the geodetic measurements and very high productivity in the field.

For the current task were used two contemporary technologies, which could acquire a large amount of 3D information in a short time span - of significant importance in the field.

The final product was created and prepared for further use in the relevant municipality, see chapter 7.2. It contained digital model in *.cad [https://tinyurl.com/yc6xeb48] with the necessary data for the object, together with printed graphical material.

Based on the accuracy achieved it could be stated, that the applied for our specific case technology for performing of geodetic measurements and their processing completely met the normative requirements for quality control of the survey job, stated in the relevant regulation documents.

According to the information in chapter 7 - e.g. registration report from Trimble RealWorks, also the results from RTK measurements, it could be highly recommended the usage of the proposed combined application of 3D Terrestrial Laser Scanning and GNSS Technologies. The described procedure could be of significant benefit for the geodesist, especially under specific circumstances in the surveying practice – for measurements of hard or impossible to access objects of cadastre.

Future work. The proposed application of combination of 3D Terrestrial Laser Scanning and GNSS Technologies could be more productive, if better accuracy was available from GNSS permanent networks and the necessary coverage existed in some regions by the mobile operators.

REFERENCES

Kostov, G. 2015, "Application of 3D Terrestrial Laser Scanning for Creation of Project Documentation for Cadastral Objects". XXV INTERNATIONAL SYMPOSIUM ON "MODERN TECHNOLOGIES, EDUCATION AND PROFESSIONAL PRACTICE IN GEODESY AND RELATED FIELDS", Sofia, 05 - 06 November 2015

Milev, G. 2012, Laser and Radar Scanning. Magazine, pp 5-6, 3-12, Sofia, "GKZ" Issue 2012 (In Bulgarian)

Minchev, M., Iv. Zdravcev, Iv. Georgiev, 2005, Foundations of the application of GPS in geodesy, pp 123, Sofia, UACEG (in Bulgarian)

WEB

http://tinyurl.com/gqk9d4t
http://tinyurl.com/gsuc6pw - (in Bulgarian)
http://tinyurl.com/hjv785u
http://tinyurl.com/pnqqabg
https://tinyurl.com/y7pcwx47
https://tinyurl.com/y7wzpgsp - (in Bulgarian)
https://tinyurl.com/y8dwkk5l
https://tinyurl.com/y9u74vgm
https://tinyurl.com/ya3m7tgw
https://tinyurl.com/ybk3xxab
http://tinyurl.com/yc4sd7ad - (in Bulgarian)
https://tinyurl.com/yc6xeb48

USED SOFTWARE

1. Geomax Geo Office (http://tinyurl.com/h9s4aop);
2. GNSSTransformations [https://tinyurl.com/y83qp2l2];
3. Mkad (http://tinyurl.com/hapgj9l - in Bulgarian);
4. Trimble RealWorks (http://tinyurl.com/pdckrlr);

BIOGRAPHICAL NOTES

Gintcho Kostov works in "GEO ZEMIA" Ltd. since 2001. In TU Wien, Austria he completed and defended scientific project, entitled "Assessment of the Quality of Geodetic Networks Using Fuzzy Logic". Dr. Kostov holds the following licenses: for performing of activities in the area of geodesy, cadastre, investment design and privatization. He has the following certificates, issued by: Chambers of the Engineers in Investment Design, Union of Scientists in Bulgaria. He is a member of: Union of Surveyors and land Managers in Bulgaria, Chamber of

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