Using of both Fast Static and RTK Modes for GNSS Determinations to Obtain Required high Accuracy and Productivity, According to the Current Possibilities of the IT

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Key words: Geodesy, GNSS, RTK, static, accuracy.

SUMMARY

Recently the Information Technology (IT) is in very fast development and provides users with flexibility and various ways to complete certain geodetic task. The existing permanent GNSS networks also facilitate the geodetic activities.

Before conducting geodetic measurements amongst all technical details, two should be very carefully considered – required accuracy and productivity. Taking in mind the last, a suitable technology should be chosen and used in order to meet the project's requirements. Another important step is to facilitate the practical use of the chosen technology.

This paper studies the possible ways for performing GNSS measurements and focuses on the usage of both fast static and RTK modes, implemented in contemporary IT. In this case exact values of the parameters are applied in the GNSS determinations. Quality assessment of the results from the geodetic measurements is done.

In order to make the practical usage of the results from the satellite measurements a flexible process, application GNSSTransformations (for conversion of the results from GPS and GLONASS geodetic measurements. Extraction and preparation for printing of the results.) was created and used.

Based on the results from the conducted GNSS measurements and used IT, conclusions and proposals for future work are done.

SUMMARY

В днешно време Информационната Технология (IT) търпи много бързо развитие и предоставя на ползвателите удобство и различни начини да се извърши определена геодезическа дейност. Съществуващите перманентни GNSS мрежи също улесняват геодезическите работи.

Преди извършване на геодезически измервания успоредно с всички технически детайли, два следва да бъдат много внимателно обмислени - изискваната точност и производителност. Като се има предвид последните, следва да се избере и приложи

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подходящ метод на работа с цел спазване изискванията на задачата. Друга важна стъпка е да бъде улеснено практическото използване на избраната технология.

Тази статия третира възможните начини за извършване на GNSS измервания и фокусира на използването и на двата - RTK и бърз статичен режими, приложени в съвременна IT. В този специфичен случай конкретни стойности на параметрите са приложени при GNSS определенията. Извършена е оценка на качеството на резултатите от геодезическите измервания.

С цел да се направи практическото използване на резултатите от спътниковите измервания удобен процес, беше създадена и използвана програмата GNSSTransformations (за конвертиране на резултатите от GPS и GLONASS геодезически измервания. Екстракт и подготовка за печат на резултатите).

На база на резултатите от извършените GNSS измервания и използваната IT са направени заключения и предложения за бъдеща работа.

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1. INTRODUCTION

Currently the IT in geodesy is developing with a very fast step. This means that the geodetic hard and software are changing rapidly in order to fit the new technologies, global trends and users' expectations, e.g.: http://solitech.bg/novini.html, http://www.leica-geosystems.com/en/Product-News_934.htm, http://www.geomax-positioning.com/geomax-ggo-version-20_424.htm, etc. In this way nowadays there is a possibility to complete various geodetic tasks with more productivity and without compromising the overall quality of the results from the measurements.

In Bulgaria, the permanent GNSS networks provide the end user with a set of various technical possibilities, see http://www.geonet.bg/services.html, http://www.naviteq.net/bg/1, http://www.smartnet.bg/ and http://www.geomedia.bg/index.php/article:293?PHPSESSID=773ef63cadd79f8931e48c1e36b0dd55.

On the other hand, the computer industry offers the clients (in our specific case the geodesists) various equipment, constructed in a way that it can handles the challenges of the user's environment and activities. Various operating systems exist, both free and paid, which provide users with list of functionalities, see http://en.wikipedia.org/wiki/Operating_system.

The firmware, included in the GNSS equipment is constructed to deliver the geodesists various functionalities and the necessary surveying modes - i.e. depending on the type and specifics of the object, also accuracy requirements the job could be completed in various ways.

As it is known, RTK mode for geodetic measurements is very fast and productive method for surveying [Minchev et al., 2005]. On the other hand fast static mode for satellite determinations is one of the most precise ones, see http://facility.unavco.org/. It can be used when high accuracy and no data link between the receivers are required.

According to the current possibilities of the IT, also based on the results from previous experiments, one proposal for practical implementation of both RTK and fast static modes for GNSS determinations will be described and studied in this paper. Quality assessment of the results from the conducted geodetic measurements is given.

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2. IT POSSIBILITIES NOWADAYS AND THEIR APPLICATION IN GNSS DETERMINATIONS

Currently, three most wide spread (and used) Operating Systems (OS) exist – divided into free and paid. Some useful information on this topic can be found at http://downloadpedia.org/Open_Source_Operating_Systems and http://answers.yahoo.com/question/index?qid=20100325093841AAkgs5U. On one hand, as it is known, Microsoft Windows is one of the most used *paid* OS. On the other hand OS Linux seems to be its serious rival (not only because it's free of charge), see http://en.wikipedia.org/wiki/Comparison_of_Windows_and_Linux.

The existence of free alternative of Microsoft Windows allows users to choose OS and use the best platform for her/his everyday activities. Further in this chapter some details of Linux (which are connected with the specifics of this paper) will be described. The last OS is free, open source and users can continuously add new improvements to it.

In geodesy significant numbers of applications (in our specific case in the GNSS data processing) are designed to run on Windows, e.g.
http://www.leica-geosystems.com/common/shared/downloads/inc/downloader.asp?id=12413 and http://solitech.bg/office-software.html. Other GNSS applications are constructed to run also on Linux platform, for example see http://www.bernese.unibe.ch/features.html#TEC.

Due to the fact that the software, which is designed for Windows does not run directly in Linux, the geodesists (who prefer to use the last OS for instance) are required to apply some necessary "fixes" i.e. to install a "layer" in the host, see http://www.thefreecountry.com/operating-systems/windows-clones.shtml and http://www.low-cost-computing.com/Windowsbe__Applications_on_Linux.shtml like Virtual box or Wine for instance, for free. Either of the last is required in order to run applications, designed for Windows. Applying this "layer" provides user with the functionality of using applications, designed to run under Windows.

As the hardware is under continuous improvement, it offers the user useful functionalities as netbook computer with Solid State Drive (SSD). In this particular case, the mentioned hardware combination does important work in the field performance. When "office" data processing in the field is necessary, it can be easily and safe done, because of the small size of the netbook computer and its independence from possible vibrations, shocks or movements. It should be noted that in our case – processing of GNSS data and graphics visualization, the usage of a *large enough screen* is strongly recommended, due to the specifics of the work.

3. MODES FOR GNSS DETERMINATIONS

It is known [Minchev et al., 2005] that in geodesy GPS determinations could be divided into the following methods:
- (fast) static and kinematic;

- RTK and post-processing.

For completeness of the information here it should be noted again, that on one hand RTK mode is fast and quite productive method for geodetic determinations, see [Minchev et al., 2005]. On the other hand fast static method is one of the most precise ones, see [http://facility.unavco.org/]. It is applied if the geodetic activities require high accuracy and no data link between the base and rover are needed.

In [Valev et al., 1995] is stated, that GPS measurements should be conducted in open areas, with cut-off angle minimum of 15 degrees. An experiment using GNSS equipment was done, which results show, that the cut-off angle could be lowered to either 0 or 5 degrees and to deliver very good results [Kostov, 2010]. According to the last, setting in the GNSS firmware with 5 degrees cut-off angle was used in this paper.

According to the literature [Wellenhof et al., 2002] it is known, that the day time is preferred for conducting of satellite measurements, taking in mind the required organization within the survey crew. In our specific case, GNSS determinations can be conducted either in day or night time, without compromising neither the working schedule nor quality of the results.

Here will be listed both the advantages and disadvantages of RTK and fast static modes, which have *strong relation* with the topic of this paper:

3.1 RTK mode – advantages:
3.1.1 Results are available immediately – no need for additional data processing afterwards;
3.1.2 The quality criterion for the results, i.e. M_{3D} (see chapter 6) is available in the moment.
3.2 RTK mode – disadvantages:
3.2.1 Dependence from the terrain and environment conditions e.g. forests, urban areas, hills, etc.;
3.2.2 Long baseline measurements are not preferable;
3.2.3 Unsure data link coverage, when specific terrain conditions exist.

3.3 Fast static mode – advantages:
3.3.1 Independence from the various environmental conditions between the stations, i.e. no data link required;
3.3.2 Very high overall accuracy is achieved;
3.4 Fast static mode – disadvantages:
3.4.1 Results available after the post-processing;
3.4.2 Some time required for gathering of raw data;
3.4.3 Clear horizon required for the stations.

Due to the above mentioned facts, treating RTK and fast static modes for satellite determinations, taking in mind the given information in chapter 2, one possible combined practical application of them both will be described and discussed in the next chapter.

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4. USAGE OF BOTH FAST STATIC AND RTK MODES IN THE GEODETIC PRACTICE

In order to use the advantages of the both modes, based on the nowadays GNSS status, see http://www.unoosa.org/pdf/publications/icg_ebook.pdf and the IT in geodesy, one their possible combined implementation could be done and respectively conducted in the practice.

This combination could be very useful if the geodetic activities are performed for instance in regions, where the network is demolished, has insufficient quality, usage of other survey method is inappropriate, etc.

Depending on the type of the geodetic activity (e.g. survey, stake-out), the necessary determinations are performed first either in RTK or fast static mode. When necessary, the firmware profile is changed. In our specific case, appropriate control points, which have easy access on roads or elsewhere are used as to be done the network connection in the used coordinate system. If field computations are necessary, then for the convenient and easy processing of the geodetic measurements, netbook computer with SSD, along with the software GNSSTransformations (see Fig. 1) are used.
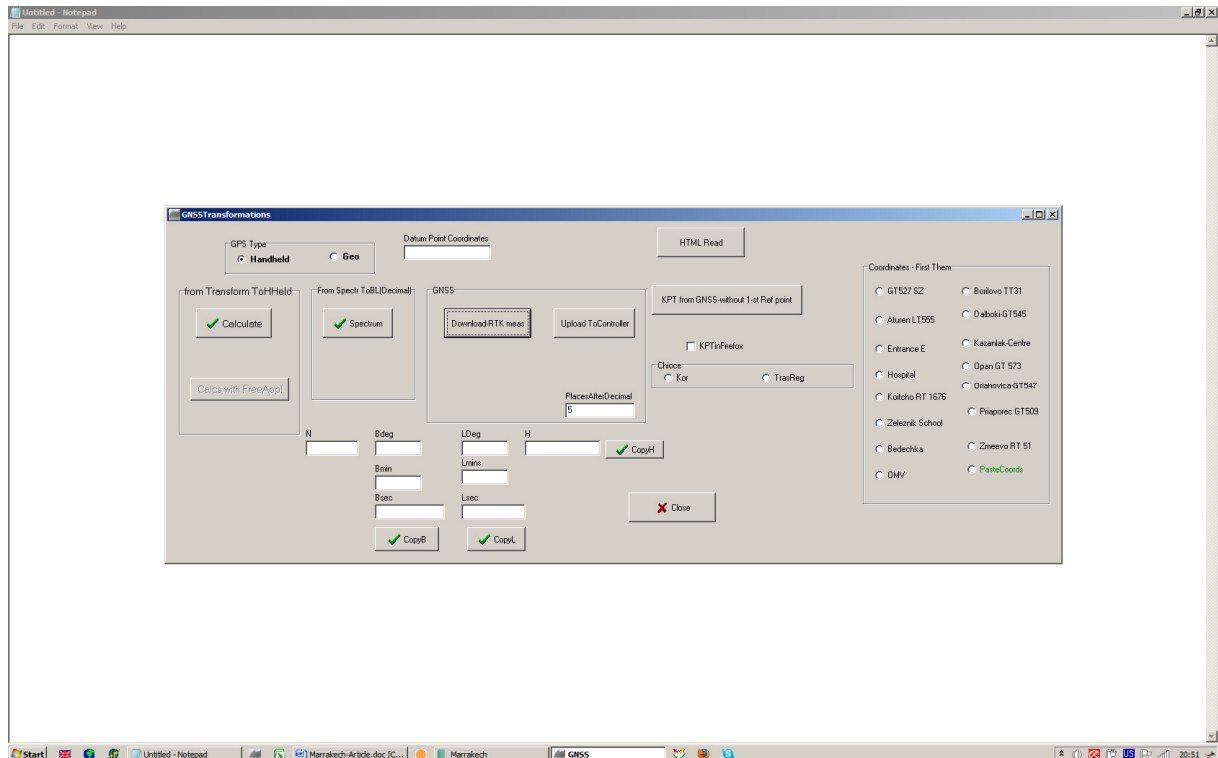

Fig. 1

In order to achieve the required *high accuracy of the results* and obtain the necessary *high productivity* from the described technology, specific parameters (explored and tested in previous experiments [Kostov, 2009] and [Kostov, 2010]) are applied in the GNSS system.

This paper could be treated as one *continuation* of the author's work and implementation of the above mentioned studies in the geodetic practice, if using both RTK and fast static modes.

Some examples for objects, where the described technology was used in the geodetic practice:
-surveying activities, including areas with specific or difficult terrain conditions - i.e. trees, hills, urban areas, etc., where RTK mode meets the disadvantage, described in point 3.2.1.
-geodetic activities in regions where network: does not exist (e.g. it is demolished) or does not have the necessary quality.

It must be noted that the described technology can not be applied in regions with strong urbanization or existence of active or passive disturbance sources, for instance.

5. SOURCES OF ERRORS IN THE GNSS MEASUREMENTS AND DATA PROCESSING, INFLUENCING THE OVERALL QUALITY OF THE RESULTS

There are several factors, which should be taken into account when performing GPS measurements. According to the literature [Minchev et al., 2005], the main sources of errors in satellite determinations and data processing are: errors from synchronizing of clocks/the time/ in satellites and receiver, satellite orbit, troposphere refraction, ionosphere refraction, variations in the phase centre of the antenna, multipath.
Explanations about the various sources of errors in satellite measurements can be found also in [Wellenhof et al., 2002].
Here is given only brief information, details can be found in the literature.

6. USED CRITERIA FOR OVERALL QUALITY ASSESSMENT OF THE PERFORMED GEODETIC DETERMINATIONS

In this paper the following quality criteria were used:
6.1 Quality in position and height M_{3D};

6.2 Elements of the co-variance matrix Q_{xx}, Q_{yy} and Q_{zz};

6.3 Number GDOP(max);

6.4 Number PDOP(max).
The numbers GDOP and PDOP are part from DOP factor for accuracy, described in details in [Wellenhof et al., 2002].

7. RESULTS. CONCLUSIONS

Based on the given in chapter 4 technology, a number of objects from the geodetic practice were completed, using the described (required) IT.

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Below is given the quality assessment from the post-processing of the raw data from fast static mode. It should be noted that when applying RTK mode (in our specific case), the value for M_{3D} criterion reached 0.0088 m., according to the print-out from the firmware.

7.1 Fast static mode - used according to chapter 4 and applied over baselines with various lengths:

Object "River". Length of the spatial chord 1100 m.

Point ID	M_{3D} [m.]	Qxx	Qyy	Qzz	GDOP (max)	PDOP (max)
777	*0.0004*	0.00000135	0.00000108	0.00000102	1.5	1.4

Table 1

Object "Ostra Mogila". Length of the spatial chord 5800 m.

Point ID	M_{3D} [m.]	Qxx	Qyy	Qzz	GDOP (max)	PDOP (max)
100	*0.0007*	0.00000211	0.00000046	0.00000090	2.0	1.8

Table 2

Object "Stake-out activities". Length of the spatial chord 11700 m.

Point ID	M_{3D} [m.]	Qxx	Qyy	Qzz	GDOP (max)	PDOP (max)
555	*0.0008*	0.00000189	0.00000038	0.00000088	1.8	1.6

Table 3

Object "Surveying activities near the boundary". Length of the spatial chord 30600 m.

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Point ID	M_{3D} [m.]	Qxx	Qyy	Qzz	GDOP (max)	PDOP (max)
110001	*0.0010*	0.00000646	0.00000319	0.00000602	1.7	1.4

Table 4

In the case – usage of fast static mode, the quality criterion M_{3D} was with the maximum value of 0.001 m. Taking in mind this, also the values of the DOP factors (which have their maximum of 2), it could be concluded that high quality results were derived.

These facts show that the coordinates can be transferred from the datum point to the object of the geodetic activities with very high quality using nowadays IT possibilities.

7.2 RTK mode, applied over spatial chords with various lengths

In order to explore and test the reliability and overall quality of RTK mode with the used IT, several "experiments" were conducted over baselines with lengths, starting from 3300 m. up to 9400 m. The results from the quality assessment are given below:

Object "Priaporec-SZBani" - spatial chord, length 3300 m.

Point ID	Qxx	Qyy	Qzz	M_{3D} [m.]
150100	0.00011064	0.00003138	0.00006143	*0.016*

Table 5

Object "Sarnevec" - spatial chord, length 3889 m.

Point ID	Qxx	Qyy	Qzz	M_{3D} [m.]
2222	0.00003238	0.0000169	0.00003462	*0.011*

Table 6

Object "Gradiste" - spatial chord, length 9000 m.

Point ID	Qxx	Qyy	Qzz	M_{3D} [m.]

150100	0.00006554	0.00002714	0.00004038	*0.021*

Table 7

Object "Badeste" - spatial chord, length 9400 m.

Point ID	Qxx	Qyy	Qzz	M_{3D} **[m.]**
1	0.00001945	0.00001554	0.0000143	*0.020*

Table 8

It can be clearly seen that the quality criterion M_{3D} has low values for these four objects – from 0.011 m. up to 0.021 m. According to these experiments, it could be concluded, that RTK mode could also be used for geodetic determinations of spatial chords with lengths of several thousand meters and to produce good quality results. It should be stated, that application of RTK mode in our specific case (within the conditions described in point 3.2) is not preferable and should be avoided.

Based on the above mentioned results, it could be summarized:

The IT in geodesy nowadays, especially the current GNSS status provides the geodesists with lots of flexibilities and possibility for deriving of high quality results.

The described and applied technology, along with the IT could be used with success in the practice (with the limitations, mentioned in chapter 4), when high: *accuracy and productivity* are essential or required for the objects of geodetic activities.

The application GNSSTransformations could be updated with the option as to perform some checks, according to the specifics of the technology.

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http://www.unoosa.org/pdf/publications/icg_ebook.pdf

Used Software:

1. Geomax Geo Office;
2. GNSSTransformations.

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BIOGRAPHICAL NOTES

Dr. M. Sc. Gintcho Kostov works in "GEO ZEMIA" Ltd. since 2001. From 1998 till 2001 he has been working in the predecessor of this company. He successfully defended his PhD thesis entitled "Contemporary Geodetic Networks – Principles in Constructing and ways of Adjustment", developed in UACEG, Sofia and received the PhD degree in 2008. In TU Wien, Austria he completed and defended a scientific project, entitled "Assessment of the Quality of Geodetic Networks Using Fuzzy Logic". He graduated in UACEG, Sofia in 1998. He has nine publications in the area of geodesy. He has teaching activities to the students from I-st and III-rd grade in UACEG, Sofia. Dr. Kostov holds the following licenses: for performing of activities in the area of geodesy, cadastre, constructing and privatization. He holds: certificate for intermediate level of knowledge in English language system PITMAN, diploma for membership in the Union in Scientists in Bulgaria, Chambers of the Engineers in Geodesy, Chambers of the Engineers in Investment Design, diploma for best presentation as a young scientist. He is a member of the Union of Surveyors and land Managers in Bulgaria, Union in Scientists in Bulgaria, Chamber of Engineers in Geodesy and Chamber of Engineers in Investment Design.

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