Study on the Overall Quality of the Planned fast Static GNSS Measurements, if Certain Values of the Parameters are Applied in the System, Using Fuzzy Logic

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Key words: geodesy, GNSS, measurements, quality, static.

SUMMARY

Assessment of the overall quality of the GNSS measurements is one important step, even if continuous modernization of the system is performed.

It is recommended, that before conducting of satellite measurements a survey plan to be created in order to get the most from the GNSS determinations.

The aim of this paper is to analyse the quality criteria as results from the post-processing of the planned satellite measurements of chords with various lengths. The author uses the conclusions from his previous experiments, which have strong relation with the current topic. In this specific case, several factors (e.g. practical aspects, parameters of GNSS system, safety) were taken into account.

The quality criteria, calculated by the GNSS post-processing software (applied with certain values of the parameters of the system) were used as input data in the specialized geodetic software, using methods of Fuzzy Logic - Vienna_fuzzy (for assessment of the overall quality of geodetic measurements, determinations and networks).

The final results from the application Vienna_fuzzy – i.e. the rating of each chord were analysed. Conclusions are done and proposals for future work are given.

АБСТРАКТ

Оценката на общото качество на GNSS измерванията е важен етап, дори когато системата е непрекъснато подобрявана и модернизирана.

Преди извършване на спътникови измервания се препоръчва създаване на план за наблюденията с цел да бъдат извършени възможно най-качествени GNSS определения.

Целта на тази статия е да се анализират критериите за качество, получени при post-processing на планираните спътникови измервания на хорди с различни дължини. Авторът използва заключения от негови предишни експерименти, които имат пряка връзка с темата на този материал. В този специфичен случай, няколко фактора (напр.

практически аспекти, параметри на GNSS системата, безопасност) бяха взети под внимание.

Критериите за качество, изчислени чрез софтуера за post-processing (с приложени конкретни специфични стойности на параметрите на системата) бяха използвани като входни данни в специализирания геодезически софтуер, използващ методите на Fuzzy Logic - Vienna_fuzzy (за оценка на общото качество на геодезическите измервания, определения и мрежи).

Крайните резултати от програмата Vienna_fuzzy – т.е. рейтинга на всяка хорда бяха анализирани. Направени са заключения и са дадени препоръки за бъдеща работа.

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1. INTRODUCTION

During the recent years satellite technologies and constellations continuously improve their technical parameters, see [http://en.wikipedia.org/wiki/GLONASS], [http://www.ewdn.com/2011/06/02/glonass-sets-goal-to-exceed-gps-accuracy-twofold-vice-pm-guarantees-free-service-worldwide/] and [http://www.pods.org/assets/file/PODS_UserConference_FutureofHigh-AccuracyGPS_2011.pdf].
As a result of the updates of the system, the user has the possibility to track additional satellites and obtain better overall quality.
Future modernizations of the GNSS technologies are planned, which will continue the work for a better system performance [http://www.ask.com/wiki/GLONASS#Renewed_efforts_and_modernization].
Despite of the improvement of the IT in the area of satellite determinations, it is recommended, that before conducting of GPS measurements a survey plan to be created and used. It is supposed, that in this way the geodesist should get the most from the satellite measurements.

Taking into account the modernized GNSS technologies and planning possibility, there are some topics to discuss, which should be answered with results, numbers and conclusions. Some of the main points to study might be:
– How much (in the terms of overall quality) will be the improvement of the GNSS determinations by the created survey schedule?
– Will there be a (significant) change in the values of the quality criteria between the *"worst"* and *"best"* time frames?
– Would the productivity be decreased?

This paper studies the results from the post-processing of the planned satellite measurements, if certain values of the parameters are applied in the system, using the methods of Fuzzy logic. The study tries to answer the above mentioned questions.

2. WAYS AND SOURCES TO PERFORM PLANNING OF GNSS MEASUREMENTS

If the survey work requires planning of GNSS measurements, the schedule could be created in various ways:
2.1 Classical – by using the option from the firmware, generally provided with the

equipment.

2.2 Cloud - nowadays, several web sites offer satellite prediction service, where the user can create schedule, e.g. [http://www.trimble.com/GNSSPlanningOnline/#/Settings], [http://www.navcomtech.com/Support/Tools/satellitepredictor/main.cfm], [http://asp.ashtech.com/wmp/]. It must be noted that this listing could be extended with other references, also the last link is in beta version at the period of writing this paper.

Useful information (session length, accuracy requirements, visibility diagram, etc.) and details how to manage planning of GPS measurements are discussed in: [http://maic.jmu.edu/sic/gps/planning.htm], [http://www.navleader.com/GGE2012_LectureNotes/21.Lecture110324_GGE2012_GPS04_Tutorial_byAhn_2pages.pdf], [http://www.navleader.com/GGE2012_LectureNotes/20.Lecture110322_GGE2012_GPS03_PlanningGPSsurvey_byAhn_2pages.pdf], [http://www.oregon.gov/ODOT/HWY/GEOMETRONICS/docs/presentations/2-10-11_Olsen_Armstrong-Part4_GNSS_Survey_Planning.pdf?ga=t], [http://www.isprs.org/proceedings/XXXVIII/4-W13/ID_10.pdf], [http://www.romdas.com/romdascd/info/faq/GPS%20Survey%20Planning.pdf?token=d3d4138d99e1556bdfb8cbbe8eb1260e99ffc63e|1328729771#PDFP] and [http://www.gpsworld.com/survey/satellite-gps-glonass-sbas-mission-planning-8635].

In this paper the classical way for prediction of satellite availability was used.

3. PRACTICAL ASPECTS AND PARAMETERS OF THE GNSS SYSTEM

The experiment here uses the methodology, described below:

3.1 Type of survey. Fast static method for GNSS determinations was involved. Permanent GNSS network was not used. The spatial chords, subject of study and quality assessment (see chapter 4) were chosen carefully, according to the following conditions:

3.1.1 Reference. One and the same reference point was used;

3.1.2 Lengths. Spatial distance between the reference and the rovers selected to be: up to 5 km, up to 10 km, up to 20 km, up to 30 km.

3.1.3 Rovers. The rover stations were placed on points from the existing geodetic network (in proximity to or on major roads), which have clear horizon.

3.2 Previous experiments. For this specific case and according to previous author's results and conclusions [Kostov, 2009], [Kostov, 2010], [Kostov, 2010] the necessary values of the parameters of the GNSS system were applied and used in order to get the most of the GNSS measurements.

3.3 Factors. For the practical implementation were taken into account the following key moments:

3.3.1 The safety, e.g. the measurements to be conducted during daylight;

3.3.2 The productivity, e.g. the length of the sessions set to a reasonable time;

3.3.3 The convenience, e.g. each rover placed on point with easy access by car.

4. CONDUCTED PLANNED GNSS MEASUREMENTS

In this study several spatial chords were measured - numbered and named as follows: RT 22 (Kaloianovec), GT 527 (Bogomilovo), RT 1829 (KEN), and GT 547 (Oriahovica).
The experiment was divided into four cycles of measurements.

The first cycle was performed in a time span, which provides *"best"* quality conditions in the terms of: high number of visible satellites and low GDOP numbers for the chords named Kaloianovec and Oriahovica. Within this cycle, *"worst"* conditions for satellite measurements were chosen, i.e. low number of predicted satellites and high GDOP numbers for chords named Bogomilovo and KEN.

The second cycle of the measurements was chosen as to provide *"worst"* quality parameters for the system, i.e.: low number of visible satellites and high GDOP values for the chords named Kaloianovec and Oriahovica. The cycle also consists of *"best"* quality conditions for chords named Bogomilovo and KEN.

The third and fourth cycles from the conducted GNSS measurements contain the geodetic determinations for the chord named Bogomilovo. The planned time-windows were chosen as to provide the *"best"* and *"worst"* values for: number of visible satellites and GDOP numbers.

The measurements were done using a pair of GNSS receivers in fast static mode, during the daylight. The analysis of the values of the quality criteria from the above mentioned cycles is given in chapter 7. The study is done, using Fuzzy logic's methodology and the specialized geodetic software "Vienna_fuzzy".

5. USED CRITERIA FOR OVERALL QUALITY ASSESSMENT OF THE CONDUCTED GEODETIC DETERMINATIONS

For this specific case, the following quality criteria were used:
5.1 Quality in position and height M_{3D};
5.2 Elements of the co-variance matrix Q_{xx}, Q_{yy} and Q_{zz};
5.3 Number GDOP(max);
5.4 Number PDOP(max);
5.5 Number GDOP (min);
5.6 Number PDOP(min).
As it is known, the numbers GDOP and PDOP are part from DOP factor for quality, described in [Wellenhof et al., 2002].

6. PROCESSING OF THE QUALITY CRITERIA, USING FUZZY LOGIC

Using the GNSS firmware, the raw data from the satellite measurements was post-processed as to be calculated the values of the quality criteria, mentioned in the previous chapter. Specific values for the post-processing parameters were used. The results were exported in *.prn format and the necessary data extracted in order to be used further.

The information, subject of assessment was structured and then entered in the specialized geodetic software Vienna_fuzzy, which window is given below in Fig. 1. Full description of the application can be found in [Kostov, 2007].

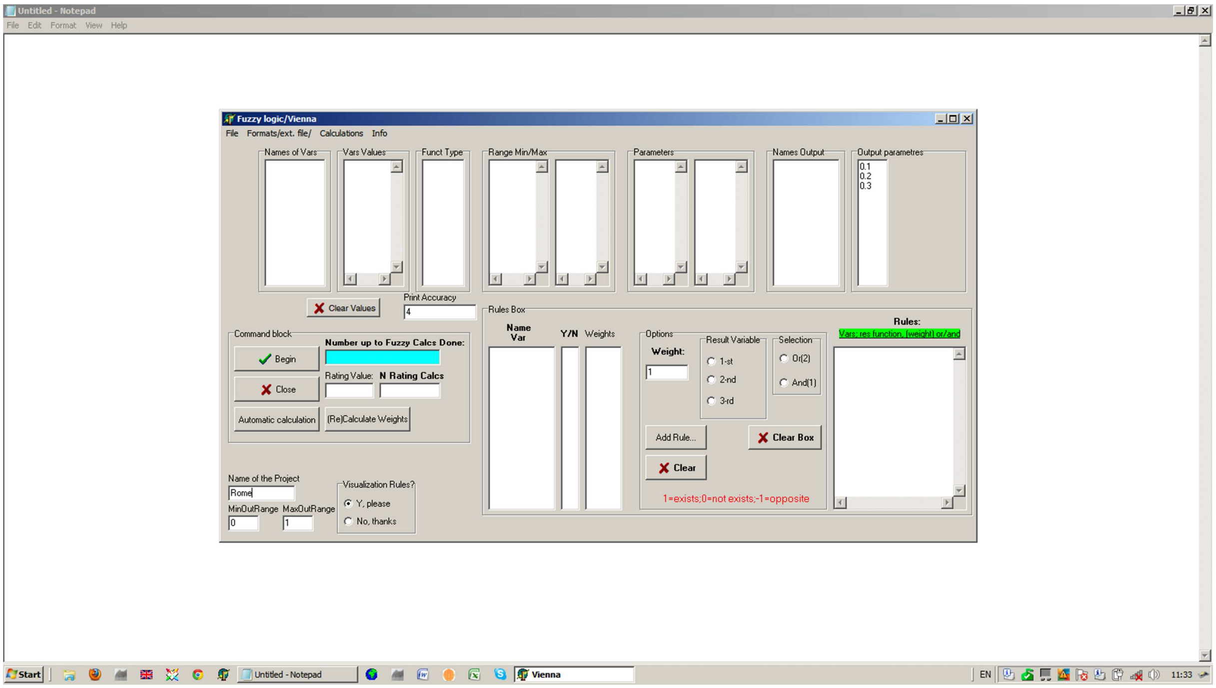

Fig. 1

The software Vienna_fuzzy, after performing the necessary computations returns a value, called *rating*. The last gives the user information about the overall quality of the system, under assessment, which in our case is each measured chord.

In this specific study, *the bigger the value of the rating, the better the overall quality* of the system.

7. ANALYSIS OF THE RESULTS

Based on the technical details, given in chapter 3, four spatial chords with various lengths were measured, using GNSS system. The results from the post-processing: M3D, Qxx, Qyy, Qzz, GDOP (min), GDOP (max), PDOP (min) and PDOP(max) are given below in tables NN

1, 2, and 3. It should be noted that a float solution was produced for the chord named Oriahovica (see table 1). Despite of the fact that the value of M3D quality criterion was within the accuracy requirements, the float solution was excluded. It must be stated, that even in the open field without obstructions, some of the visible satellites were thrown away by the controller's software.

In table 1 is given the information from the first cycle of GNSS measurements. The table consists of the results for "*the best time-window in the day*" for conducting of measurements for chords: Kaloianovec and Oriahovica. Table 1 also provides information for the results for "*the worst time-window in the day*" for chords: Bogomilovo and KEN. In the column "*from GNSS planning*" is given the data taken from the GNSS firmware, which was used to generate the schedule for conducting of the satellite measurements. The last row contains the final result from the analysis – the calculated rating value for each measured chord.

	remote station	Kaloianovec	Bogomilovo	KEN	Oriahovica
from GNSS planning	length [km]	**2.8**	**9.1**	**17.4**	**28.5**
	date and time	2.12.2012 14:26	2.12.2012 13:11	2.12.2012 12:26	2.12.2012 11:21
	number satellites	23	18	18	23
	GDOP	1	1.2	1.3	0.9
Criteria	M3D [m.]	0.00024	0.00069	0.0004	N/A
	Qxx	0.00000021	0.00000027	0.00000276	N/A
	Qyy	0.00000007	0.0000001	0.00000185	N/A
	Qzz	0.00000018	0.00000021	0.00000278	N/A
	GDOP (min)	1.2	1.4	1.4	N/A
	GDOP (max)	1.5	1.5	1.5	N/A
	PDOP (min)	1.1	1.3	1.3	N/A
	PDOP(max)	1.3	1.3	1.3	N/A
	rating	**0.78**	**0.53**	**0.52**	N/A

Table 1

Table 2 contains the data for the second cycle from the conducted GNSS measurements. It includes "*the best time-window in the day*" for chords: Bogomilovo and KEN, also results for "*the worst time-window in the day*" for conducting of geodetic measurements for chords: Kaloianovec and Oriahovica. The numerical results for the calculated rating values are given in the last row of table 2 below.

	remote station	Kaloianovec	Bogomilovo	KEN	Oriahovica
	length [km]	**2.8**	**9.1**	**17.4**	**28.5**
from GNSS planning	date and time	02/18/2012 16:27:04	02/18/2012 13:48:54	02/18/2012 10:47:03	02/18/2012 12:02:03
	number satellites	18	23	23	18
	GDOP	1.2	0.9	0.9	1.2
Criteria	M3D [m.]	0.00017	0.00036	0.00064	0.00045
	Qxx	0.00000016	0.00000022	0.0000052	0.00000273
	Qyy	0.00000009	0.00000008	0.00000299	0.0000019
	Qzz	0.00000018	0.00000017	0.00000453	0.00000286
	GDOP (min)	1.3	1.5	1.2	1.4
	GDOP (max)	1.6	1.6	1.8	1.5
	PDOP (min)	1.1	1.3	1.1	1.3
	PDOP(max)	1.4	1.4	1.5	1.3
	rating	**0.75**	**0.56**	**0.62**	**0.54**

Table 2

In table 3 are listed the results from the post-processing only for the chord named Bogomilovo, using both *"the best time-window in the day"* and "*the worst time-window in the day*". The planned geodetic measurements were conducted in a different day from first and second cycles (as noted in the table). The values of the calculated rating values for this chord are given in the last row of table 3.

It should be noted that under the term *"the worst time-window in the day"* should be understood a time-window when *minimum number of satellites* are visible (according to the planning software) and *maximum value* for GDOP was predicted. Within the term *"the best time-window in the day"* is denoted a period from the day, when *maximum satellites* are visible, along with *minimum value* for GDOP.

	remote station	Bogomilovo	Bogomilovo
	length [km]	**9.1**	**9.1**
from GNSS planning	date and time	02/19/2012 11:55:01	02/19/2012 10:56:08
	number satellites	18	23
	GDOP	1.2	0.9
Criteria	M3D [m.]	0.00076	0.00077
	Qxx	0.00000016	0.00000027
	Qyy	0.00000011	0.00000019
	Qzz	0.00000016	0.00000022
	GDOP (min)	1.4	1.3
	GDOP (max)	1.5	1.6
	PDOP (min)	1.3	1.1
	PDOP(max)	1.3	1.4
	rating	**0.56**	**0.63**

Table 3

The results from the processing of the data from first and second cycles, using Fuzzy logic are summarized in table 4 and table 5. They contain the necessary information for further analysis of the calculated rating values. In the last row of table 5 are given the differences in the rating values between first and second cycles.

first cycle				
remote stations	Kaloianovec	Bogomilovo	KEN	Oriahovica
lengths [km]	2.8	9.1	17.4	28.5
number satellites	23	18	18	23
GDOP	1	1.2	1.3	0.9
rating first cycle	**0.78**	**0.53**	**0.52**	**N/A**

Table 4

second cycle				
remote stations	Kaloianovec	Bogomilovo	KEN	Oriahovica
number satellites	18	23	23	18
GDOP	1.2	0.9	0.9	1.2
rating second cycle	**0.75**	**0.56**	**0.62**	**0.54**
differences in rating between first and second cycles	0.03	0.03	0.10	N/A

Table 5

The data, given in table 6 and table 7 summarizes the final results from the computations for third and fourth cycles, applying Fuzzy logic. The tables contain the information, required for the necessary analysis of the rating values. In the last row of table 7 is given the difference in the rating values between the *"best"* and *"worst"* time frames for the chord named Bogomilovo.

third cycle	
remote station	Bogomilovo
number satellites	18
GDOP	1.2
rating for "worst" time frame	0.56

Table 6

fourth cycle	
remote station	Bogomilovo
number satellites	23
GDOP	0.9
rating for "best" time frame	0.63
differences in rating between third and fourth cycles	0.07

Table 7

Based on the performed GNSS planning, according to the calculated final results i.e. the rating value for each cycle and chord, it could be summarized:

7.1 First and second cycles

7.1.1 Chord Kaloianovec

The difference in the rating values between these cycles of measurements for the chord is 0.03. According to the principles of Fuzzy logic it could be noted that the conducted geodetic determinations in the first and second cycles have similar overall quality.

7.1.2 Chord Bogomilovo

The difference in the rating between these cycles is 0.03. The conclusion for the results should be similar as in point 7.1.1.

7.1.3 Chord KEN

The final result from the analysis, concerning the chord, which length is over 15 km shows a difference of 0.10 between the rating values (from first and second cycles). It should be noted, that this value indicates slight, but not a quite significant change in the overall quality of the conducted geodetic measurements.

7.1.4 Chord Oriahovica

According to the results from the post-processing of the first cycle, the produced float solution for this chord was excluded.

7.2 Third and fourth cycles

The planned GNSS measurements for these cycles were exclusively conducted for a chord with length of up to 10 km, named Bogomilovo. This length was chosen for special analysis as such spatial distances are one of the common used in the geodetic practice. The calculated difference in the rating values between these cycles is 0.07, see table 7. Based on theory foundations of Fuzzy logic, it could be concluded that no (significant) difference exists in the overall quality of the geodetic measurements, conducted in third and fourth cycles.

8. CONCLUSIONS

According to the given results and analysis in chapter 7, it could be concluded that very small differences in the overall quality of each measured chord were observed between the relevant cycles (first and second; third and fourth).

The topics to discuss, given in chapter 1 could be answered in the following way:

– There is a quite small improvement in the overall quality of the measured chords between "*the worst time-window in the day*" and "*the best time-window in the day*" in the terms of the calculated rating values. Numerically, the difference in the rating is within the interval [0.03-0.1].

– The calculated values of the quality criteria for each chord and cycle vary. This was one of the main reasons to apply Fuzzy logic in order to produce objective results for the overall quality of the measured chords.

– It could be noted, that the productivity was decreased, as a strict schedule for conducting of the measurements was used.

For certain projects or when explicitly required, planning should be used in order to produce the maximum possible overall quality for the results from the GNSS measurements. According to the recent improvements of the IT in the GNSS, also based on the results in chapter 7 it has be noted that for geodetic applications, which do not require high level of accuracy, planning may not give significant change to the quality of the measurements. Also, as already stated it leads to a decrease of the expected productivity of the GNSS determinations.
Future work and experiments could include analysis at places with existing obstructions and their influence on the results of the geodetic measurements.

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BIOGRAPHICAL NOTES

Gintcho Kostov graduated in UACEG, Sofia in 1998. He works in “GEO ZEMIA” Ltd. since 2001. In TU Wien, Austria he completed and defended a scientific project, entitled “Assessment of the Quality of Geodetic Networks Using Fuzzy Logic”. 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: 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. He is a member (in part Geodesy) of the Councils of Experts in Municipalities: Stara Zagora and Opan.

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