Some Studies on the Quality of Gnss Determinations Under Specific Conditions

Gincho KOSTOV, Bulgaria

Key words: GPS, GLONASS, measurements, geodesy

SUMMARY

In order to study the overall quality of the GNSS determinations in various conditions (occupation time - up-to 2 min., up-to 5 min., up-to 10 min., up-to 15 min. and up-to 30 min.; cut-off angle - 0 degrees, 5 degrees, 15 degrees, 20 degrees and 25 degrees and field data collection – performed in night time), fast static geodetic measurements are done. Six spatial chords with lengths: up-to 5 km., from 5 up-to 10 km., from 10 up-to 15 km., from 15 up-to 20 km., from 20 up-to 25 km. and over 30 km were subject of quality assessment. The post-processing of the raw data was done with the firmware Geomax Geo Office, which calculated the quality criteria: $M_{3D}, Q_{xx}, Q_{yy}, Q_{zz}$, GDOP (max) and PDOP (max) - quality in position and height, elements of the co-variance matrix for the chord, number GDOP and number PDOP. The last were input in the application Vienna_Fuzzy (using the theory of Fuzzy logic), which calculated the rating value, corresponding to each measured chord for the relevant session. The night observations were compared to these, performed in day-time. According to the calculated results and today's Information Technologies, conclusions are given and proposals for future work are done.

РЕЗЮМЕ

За изследване на общото качество на GNSS определенията при различни условия (сеанси от – до 2 min., до 5 min., до 10 min., до 15 min. и до 30 min.; ъгъл над хоризонта – 0 градуса, 5 градуса, 15 градуса, 20 градуса, 25 градуса и време за измерване през нощта), бяха извършени бързи статични измервания. Предмет на оценка бяха шест пространствени хорди с дължини съответно – до 5 km., от 5 до 10 km., от 15 до 20 km., от 20 до 25 km. и над 30 km. Последващата обработка на геодезическите спътникови измервания беше извършена чрез софтуер Geomax Geo Office, който е изчислил критериите за качество: $M_{3D}, Q_{xx}, Q_{yy}, Q_{zz}$, GDOP (max) è PDOP (max) - качество по положение и височина, елементите на ковариационната матрица на хордата, числото GDOP и числото PDOP. Последните са третирани като входни данни в програмата Vienna_Fuzzy (използваща теорията на Fuzzy logic), която е изчислила рейтинга за всяка измерена хорда за съответния сеанс. Нощните наблюдения бяха сравнени с тези, извършени през деня. Предвид на изчисленията, получените резултати и даденостите на днешните Информационни Технологии, са направени изводи и препоръки за бъдеща работа.

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1. INTRODUCTION

The latest Information Technologies make possible the reception of the signals from more than one system (e.g. GPS and GLONASS) in the geodetic satellite receivers. The future use of GALILEO also (which system should become available for civil use in the next years) is supposed to make another step ahead for the overall improvement of the GNSS determinations.
Fast static method for determination of coordinates of points is from the most precise ones, see http://facility.unavco.org/. It can be used when high accuracy is required.
It is know that the day time is preferred for performing of the satellite measurements, due to organizational reasons [Wellenhof et al., 2002].
According to the literature [Valev et al., 1995], GPS measurements should be conducted in open areas, with cut-off angle minimum of 15 degrees. Lowering this angle, may result to noisier observations.
In this paper a study is performed aiming to determine the eventual differences in the overall quality of measured spatial chords, when using: various occupation time, changing the cut-off angle value. The geodetic measurements are done during the night and compared with the day-time observations. In [Valev et al., 1995] and [Wellenhof et al., 2002] is noted that GPS measurements performed in night time are characterized with better propagation of the radio signals and mitigated effect of the ionosphere.
The results from the satellite measurements are assessed with the mathematical instrument of Fuzzy logic - the application Vienna_Fuzzy [Kostov, 2005].

2. FUZZY LOGIC – THEORETICAL FOUNDATIONS

The so called *fuzzy multitude* consists of values of a given variable "X" and the relevant values of the characteristic (membership) function $\chi(X)$, abbreviated as MF. Its values are in the closed interval [0,1], indicating its degree of "membership". When $\chi(X) = 0$, there is no membership, and for $\chi(X)$=1 there is full membership. The idea of the fuzzy variables is linguistic – "small", "big", "very big", etc. Example: the number 0.1 can be treated as small, 0.6 as big and 0.99 as very big. Using the values of the membership – the so called *rating* it can be assessed the quality of a given system. The general principle of a fuzzy controller is:

Input>Fuzzification>Inference>Defuzzification

In the beginning exact values of the variables are entered, which are then fuzzified, this means with the relevant MF they get their value for the degree of membership. When performing the inference, the weights and the relevant operator ("and", "or") are applied. The last part -

defuzzification is used to obtain an exact value - the rating. A number of methods exist to perform this final part of the calculation, but the most appropriate and commonly used one is the centroid method of defuzzification.

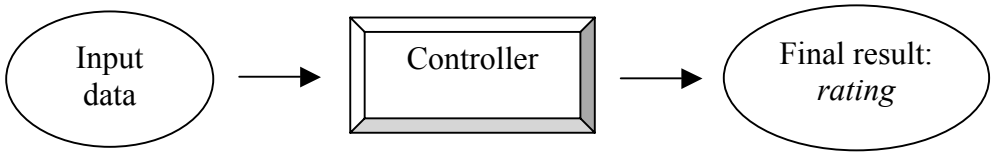

Figure 1. Graphical example of the system

For example, if GDOP or PDOP (see chapter 6) are small numbers, then the spatial chord is well determined.
Generally, using Fuzzy logic one can assess a given system, which consists of both very small or large values. The assessment is done using the so called "*rules*", defined by the user.
For instance, if „a" and "b" are small numbers, then the system is *good (well)* determined. Here with „a" and "b" are denoted the relevant input variables.
The general structure of a rule is: input variables, resulting MF, weight, logical operator ("and (1)", "or (2)"). For example, if the user defines "a" and "b" as input variables, the rules may look in the following way:

a	b	resulting MF	weight	logical operator
-1	0	1	0.30	2
1	1	2	0.50	2
0	1	2	0.88	1

Figure 2. Example and description for three rules in numerical format

When the calculation is performed, a value for the rating in the interval [0,1] will be produced. This value tells what the quality of the assessed system is. In our particular case, if the rating is 0.22, the system is not well determined, but if the value is 0.80 the chord has good quality.

3. APPLYING FUZZY LOGIC FOR ASSESSMENT OF THE OVERALL QUALITY OF MEASURED SPATIAL CHORDS

A number of publications exist, describing the applications of Fuzzy logic in geodesy [Haberler, 2003], [Kostov, 2005], [Wieser, 2001].
Another possible usage of Fuzzy logic and Vienna_Fuzzy in space geodesy will be given in this paper – for assessment of the overall quality of measured spatial chords, using GNSS technology and equipment. The chords are determined using various session time (up-to 2

min., up-to 5 min., up-to 10 min., up-to 15 min. and up-to 30 min.) and changed cut-off angle (0 degrees, 5 degrees, 15 degrees, 20 degrees and 25 degrees) in the firmware. The data collection was done during night time to mitigate the influence of the ionosphere.
Some publications about the choice of the value for the cut-off angle are published on the Web: [Krishnamurthy, 2009], [Park et al., 1996], [Schön et al., 2005] and others. One different study on the influence of the cut-off angle is given in the paper.
To eliminate the subjective factor from overall assessment of the quality of measured chords, Fuzzy logic was used. As input data in the last are used the following variables: $M_{3D}, Q_{xx}, Q_{yy}, Q_{zz}$, GDOP (max) and PDOP (max), described in details in chapter 6.

4. SOURCES OF ERRORS, INFLUENCING THE OVERALL QUALITY OF THE SATELLITE DETERMINATIONS

When performing GPS measurements, several factors concerning the quality of the geodetic determinations should be taken into account. According to [Minchev et al., 2005], the main sources of errors in satellite determinations and data processing are: errors from synchronizing of clocks in satellites and receiver, satellite orbit, troposphere refraction, ionosphere refraction, variations in the phase center of the antenna, multipath.
Detailed information about the various sources of errors in GPS measurements can be found also in [Wellenhof et al., 2002].
A parameter, which affects the overall quality of the geodetic satellite measurements, as it will be shown in this paper, is the cut-off angle. It is known, that satellites near the horizon are noisier. A detailed study for the influence of the value of cut-off angle is given in chapter 7.

5. PERFORMED GEODETIC MEASUREMENTS, SUBJECT OF QUALITY ASSESSMENT

In order to investigate the quality of real geodetic measurements, using contemporary GNSS equipment with implemented Q-lock technology in fast static mode, experiments are done.
In this paper subject of study are six spatial chords, with lengths as follows:
– up-to 5 km.;
– from 5 up-to 10 km.;
– from 10 up-to 15 km.;
– from 15 up-to 20 km.;
– from 20 up-to 25 km.;
– over 30 km.
The record rate of the satellite signals was set to 15 sec.
Measurements are done with occupation time of up-to: 2 min., 5 min., 10 min., 15 min. and 30 min.
The sites were situated on open areas, without interference sources around.
In the post-processing firmware, the cut-off angle was changed to 0 degrees, 5 degrees, 15 degrees, 20 degrees and 25 degrees, as stated in chapter 3.

6. USED CRITERIA FOR ASSESSMENT OF THE OVERALL QUALITY OF THE MEASURED SPATIAL CHORDS

In this paper the following quality criteria are used:
– quality in position and height M_{3D};
– elements of the co-variance matrix of the chord Q_{xx}, Q_{yy} and Q_{zz};
– number GDOP(max);
– number PDOP(max).
The numbers GDOP and PDOP are part from DOP factor for accuracy, described in [Wellenhof et al., 2002].

7. NUMERICAL RESULTS – NIGHT OBSERVATIONS

The raw data from the satellite observations was imported in the firmware for post-processing. The mentioned in the previous chapter quality criteria were calculated for each measured chord, for the relevant session.
Based on the data – the parameters, described in chapter 6, the rating value for the chords, subject of assessment was calculated for each session. It should be noted, that in this particular case, the bigger the rating value, the better the overall quality of the chord. The numerical results for the rating are given in the tables below:

Table 1. Chord up-to 5 km.

Occupation time 2 min.		**Occupation time 5 min.**		**Occupation time 10 min.**		**Occupation time 15 min.**		**Occupation time 30 min.**	
Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating
0	0.80	0	0.51	0	0.80	0	0.80	0	0.80
5	0.80	5	0.51	5	0.80	5	0.80	5	0.80
15	0.62	15	0.61	15	0.70	15	0.80	15	0.78
20	0.62	20	0.61	20	0.66	20	0.72	20	0.67
25	0.20	25	0.20	25	0.20	25	0.20	25	0.20

Table 2. Chord from 5 up-to 10 km.

Occupation time 2 min.		Occupation time 5 min.		Occupation time 10 min.		Occupation time 15 min.		Occupation time 30 min.	
Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating
0	0.51	0	0.50	0	0.80	0	0.80	0	0.80
5	0.51	5	0.50	5	0.80	5	0.80	5	0.80
15	0.55	15	0.58	15	0.63	15	0.49	15	0.53
20	0.62	20	0.57	20	0.54	20	0.31	20	0.41
25	0.20	25	0.51	25	0.20	25	0.20	25	0.20

Table 3. Chord from 10 up-to 15 km.

Occupation time 2 min.		Occupation time 5 min.		Occupation time 10 min.		Occupation time 15 min.		Occupation time 30 min.	
Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating
0	0.80	0	0.64	0	0.80	0	0.80	0	0.80
5	0.80	5	0.64	5	0.80	5	0.80	5	0.80
15	0.56	15	0.56	15	0.76	15	0.61	15	0.54
20	0.46	20	0.35	20	0.51	20	0.52	20	0.41
25	0.50	25	0.36	25	0.20	25	0.20	25	0.20

Table 4. Chord from 15 up-to 20 km.

Occupation time 2 min.		Occupation time 5 min.		Occupation time 10 min.		Occupation time 15 min.		Occupation time 30 min.	
Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating
0	0.80	0	0.80	0	0.71	0	0.78	0	0.80
5	0.80	5	0.80	5	0.71	5	0.78	5	0.80
15	0.77	15	0.69	15	0.67	15	0.73	15	0.72
20	0.52	20	0.65	20	0.67	20	0.71	20	0.61
25	0.20	25	0.20	25	0.20	25	0.20	25	0.20

Table 5. Chord from 20 up-to 25 km.

Occupation time 2 min.		Occupation time 5 min.		Occupation time 10 min.		Occupation time 15 min.		Occupation time 30 min.	
Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating
0	0.80	0	0.80	0	0.80	0	0.64	0	0.50
5	0.80	5	0.80	5	0.50	5	0.64	5	0.50
15	0.80	15	0.80	15	0.50	15	0.74	15	0.54
20	0.50	20	0.45	20	0.50	20	0.63	20	0.48
25	0.36	25	0.20	25	0.50	25	0.20	25	0.52

Table 6. Chord over 30 km.

Occupation time 2 min.		Occupation time 5 min.		Occupation time 10 min.		Occupation time 15 min.		Occupation time 30 min.	
Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating	Cut-off angle [degrees]	Rating
0	0.80	0	0.80	0	0.51	0	0.62	0	0.80
5	0.80	5	0.80	5	0.51	5	0.62	5	0.80
15	0.80	15	0.62	15	0.62	15	0.65	15	0.74
20	0.49	20	0.20	20	0.41	20	0.65	20	0.66
25	0.20	25	0.20	25	0.20	25	0.20	25	0.20

8. COMPARISON BETWEEN DAY AND NIGHT OBSERVATIONS

A case-study was performed aiming to assess and compare the overall quality of the measurements, conducted in day and night time using same geodetic control points for each chord. According to the results and conclusions in a previous experiment [Kostov, 2009], the comparison of the results from the geodetic measurements in this chapter is given for 10 min. occupation time. The table below summarizes the results from the satellite observations – the rating values of three spatial chords. The overall assessment is calculated, taking in mind the quality criteria given in chapter 6.

Length of the chord	Rating	
	Day	Night
from 0 to 5 km.	0.50	0.50
from 5 to 10 km.	0.20	0.80
from 10 to 15 km.	0.20	0.80

Table 7. Comparison - day and night observations

It can be clearly seen, that except the first chord, where equal rating values are calculated, the other results indicate obvious much better quality for the measurements, conducted in the night.

9. RESULTS AND REMARKS

In this paper a study, using measurements from GPS and GLONASS satellite systems was done.

Taking in mind the calculated values of the rating it can be noted:
The overall quality assessment - the rating for the chord with length of up-to 5 km. indicate that very good results are obtained using cut-off angle of 0 or 5 degrees. Not a significant difference in the rating is calculated for occupation time of 5 minutes with cut-off angle of 15 and 20 degrees.
The results for the chord with length from 5 up-to 10 km. show good quality for occupation time of 2 and 5 min., using cut-off angle of 15 and 20 degrees. The overall quality for 10 min. and more session time is high for 0 degrees in comparison to 15 degrees cut-off.
The chord - length from 10 up-to 15 km. is characterized with good quality, based on the results for cut-off angle of 0 or 5 degrees. If the value of the angle is increased, the rating gets lower values. Similar are the results for the chord, which length is from 15 up-to 20 km.
The next analyzed chord - length from 20 up-to 25 km has the following specifics. High quality results are obtained for 2 and 5 min. session time. If the chord is measured for 10 min. occupation time, rating is high when the cut-off angle is set to 0 degrees. For all other cut-off values are calculated same results for the rating – 0.50. The quality for angle 15 degrees and session time of 15 min. is improved - 0.74 in comparison to 0.64, which is achieved for 0 and 5 degrees, respectively. Similar conclusion can be done for 30 min. occupation time.
The results for the chord, which length is over 30 km. are the following. If the occupation time is set to 2 min., the rating is high for cut-off angle of: 0, 5 and 15 degrees. Comparable results are valid for 5 min. session time with slightly decrease of the rating for 15 degrees. A small increase in the quality is observed for 10 min. occupation and 15 degrees cut-off in comparison to 0 and 5 degrees. There are similar values for the overall quality for 15 and 30 min. session time and cut-off angle of 0, 5 and 15 degrees. If the last is increased, the quality gets worse.

A value for example of about 15 degrees cut-off angle can be denoted as a limit for obtaining high quality results. Increasing the cut-off angle generally leads to decrease of the rating of the system.
In most of the results very high quality is observed when the cut-off angle is either 0 or 5 degrees. There are several exceptions with a minor difference in the rating.

According to the used Information Technologies, also the GNSS equipment it should be noted that even in low elevation angles when necessary some satellites are not used in the calculations.

Based on the calculated rating values shown in table 7, night measurements are preferable. Their overall quality is at least equal (e.g. for the chord with length from 0 to 5 km.) to the day observations. The quality of the chords from 5 to 10 km. and from 10 to 15 km. is much better for the measurements performed in night time in comparison to the day-time observations.

10. CONCLUSIONS

From the experiments and calculations done in this study, it can be summarized:

If planning to conduct productive GNSS measurements and well determined spatial chords with high overall quality are of essence, then fast static geodetic surveys during night time should be used in order to get high rating values.

According to the results, derived with the used GNSS equipment based on the specifics of the satellite measurements a cut-off angle of either 0 or 5 degrees should be used to produce results with high rating and good overall quality.

REFERENCES

1. Haberler, M., 2003, A Fuzzy System for the Assessment of Landslide Monitoring Data, VGI, 1/2003, pp 92-98, Wien
2. Kostov, G., 2005, Assessment of the Quality of Geodetic Networks Using Fuzzy Logic, pp 2-7, Vienna University of Technology
3. Kostov, G., 2009, Using of Fuzzy logic for some studies over GNSS determination in fast static mode, UACEG, pp 3-7, Sofia (in Bulgarian), (in print)
4. Krishnamurthy, Y.V.N., 2009, The National Land Records Modernization Programme, Department of Land Resources, Ministry of Rural Development , Government of India, pp 119-120, Delhi
5. Minchev, M., Iv. Zdravcev, Iv. Georgiev, 2005, Foundations of the application of GPS in geodesy, pp 112-118, Sofia UACEG (in Bulgarian)
6. Park, C., Ilsun Kim, Jang Gyu Lee, Gyu–In Jee, Choon Shik Kim, 1996, A satellite selection criterion incorporating the effect of elevation angle in GPS positioning, Control Engineering Practice, Volume 4, Issue 12, pp 1741-1746, Seoul, Elsevier Science Ltd.
7. Schön, S., Andreas Wieser and Klaus Macheiner, 2005, Accurate Tropospheric Correction for Local GPS Monitoring Networks With Large Height Differences, ION GNSS 18th International Technical Meeting of the Satellite Division, 13-16 September 2005, pp 251, Long Beach, CA
8. Valev, G. M. Minchev, 1995, Instruction for determination of coordinates with GPS, pp 12-15, "Cartography" Ltd., Sofia (in Bulgarian)
9. Wellenhof, B., Herbert Lichtenegger, James Collins, 2002, GPS Theory and practice, Springer-Verlag/Wien, pp183, Austria (in Bulgarian)
10. Wieser, A. Robust and fuzzy techniques for parameter estimation and quality assessment in GPS, July 2001, Dissertation Technische Universität Graz, ISBN 3-8265-9807-5. ISSN 1618-6303, pp 49-80, Shaker Verlag, Graz

WEB:

11. ftp://igscb.jpl.nasa.gov/igscb/resource/pubs/wksp_3.pdf
12. http://facility.unavco.org/

Used software:
1. Geomax Geo Office;
2. Vienna_Fuzzy.

BIOGRAPHICAL NOTES

Dr. M. Sc. Gincho 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 7 publications in the area of geodesy. 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.

CONTACTS

Dr. M. Sc. Gincho Kostov
"GEO ZEMIA" Ltd.
41 "Solun" str. ap.9
Sofia
BULGARIA
Tel. +359-896-77-87-32
Fax + N/A
Email: geozemia@geozemia.com
Web site: www.geozemia.com