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EXPERIMENTAL ANALYSIS OF NAVIGATIONAL PRECISION FOR DEDICATED GNSS RECEIVERS

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Abstract: In the paper experimental investigations related with analysis of navigational precision of three chosen GNSS receivers are shown. Used receivers allow for measurement of navigational signals in following modes of operations: receiving signals from single-frequency GPS system, dual-frequency GPS/GLONASS system, and receiving signals from GPS constellation with use of differential measurements. In the last mode the base station and mobile receiver were configured for transmitting/receiving differential corrections by pair of industry-grade radio modems. The most important features and configuration of navigational receivers for conducted experiment are presented. Afterward the features of computer program designed especially for simultaneous acquisition, analysis of quality parameters and archiving of navigational signals are shown. The results of conducted investigations are also shown. For each of the receivers quantity and quality parameters such as maximum and minimum numbers of visible satellites and DOP (dilution of precision) parameters achieved during the experiment are given.

Key words: GNSS Receivers, DGPS Measurements, GPS, GLONASS

1. INTRODUCTION

Global navigational satellite systems are nowadays used in different domains such as: communication, localization and tracking of vehicles (Cobano et al., 2010), precision agriculture (Perez-Ruiz et al., 2011) and unmanned aerial vehicles (Słowik, Gosiewski 2012). Also every new smartphone is now equipped in GNSS receiver – and their users use locationbased services (http://www.gsa.europa.eu). Accuracy of GNSS systems is also advancing. The receivers have more and more channels, which are used for increased precision of GNSS measurements by augmentations systems such as SBAS and EGNOS, also time of signal reacquisition is reduced. Nevertheless position measurements read by GNSS receivers are always effected by the errors. This is result of e.g. disturbances of navigational signal path (ionospheric, tropospheric, multipath effect) (Deng-feng et al., 2009). One of proposed solution for increasing quality of GNSS readings is to use the differential measurements. It required two GNSS receivers, configured for differential measurements and communication system which allow exchange the navigational corrections between them (Bakuła et al., 2009). Another solution are receivers which can obtain navigational signals from more than one GNSS system e.g. concurrent use of GPS and GLONASS. This approach was presented in the papers of Defraigne (2011), Kuzin (2007) and Kuter (2010).

In the paper the experimental research of three different type GNSS receivers was conducted. The measurements from receivers mentioned below were compared:

a) GPS receiver,
b) GPS mobile receiver and base station – working in differential mode (RTK-20),
c) GPS/GLONASS receiver.

The authors have shown features of used navigational receivers, described computer application created for simultaneous reading, archiving and analyzing of data. Afterward from obtained data, the quality parameters which characterize received navigational signals and results from experiment as imitation of traveled path were shown. Therefore mentioned parameters are PDOP (Position Dilution of Precision) and HDOP (Horizontal Dilution of Precision) (Specht, 2007).

$$PDOP = \frac{1}{\sigma}\sqrt{\sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2}\ , \tag{1}$$

$$HDOP = \frac{1}{\sigma}\sqrt{\sigma_x{}^2 + \sigma_y{}^2}\ , \tag{2}$$

$$VDOP = \frac{1}{\sigma}\sqrt{\sigma_z{}^2}\ , \tag{3}$$

where: σ – error of navigational parameter, σ_x, σ_y, σ_z – mean square errors of computed position in three directions (x, z, y).

2. EXPERIMENT SETUP

In described experiment the research was conducted on Bialystok University of Technology area. During investigations the three receivers were used at the same time, with the same weather conditions and with the same amount of visible satellites of GNSS systems. This solution was determined to reduce impact of signals propagation errors in the path from satellites to receivers, which will be the case if every of the receivers were investigated separately. For this purpose, special hardware configuration and frame for all of the receivers were made. Furthermore the

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base station was configured for differential measurements. The dedicated computer application was written which allow reading data frames in NMEA-0183 format simultaneously from three receivers. These application was used for acquisition of data on the mobile computer (through TTL-USB and USB ports).

2.1. Data Acquisition Software

Due to character of investigations – necessity of concurrent analysis of signals derived from three sources of navigational measurements, no commercially available applications which allow for simultaneously connection of three different types of receivers was found. That is a cause for developing of the dedicated computer application, which enable parallel read and processing of navigational data from three different receivers. The aforementioned program was developed in C# and Visual Studio IDE and enable concurrent backup, processing and signal analysis from three investigated GNSS receivers. That allow for recording navigational position and comparison of properties and quality characteristics of receivers in the same time. Beside measurement the application allow for reading and analysis of saved data. The chosen features of the application:

- concurrent use of three GNSS receivers, with reading and backup of data frames from GNSS receivers in NMEA-0183 format, their processing and saving as text files;
- NMEA-0183 data frame decomposition – in graphical form (in the form of charts of chosen characterics), and number representation of obtained measurements of geographical longitude and latitude, amount of currently visible satellites, quality parameters as PDOP, HDOP and VDOP;
- visualization of path travelled with use of OpenStreetMap online service as arbitrary chosen path in the form of finite set of real numbers which are geographical longitude and latitude.

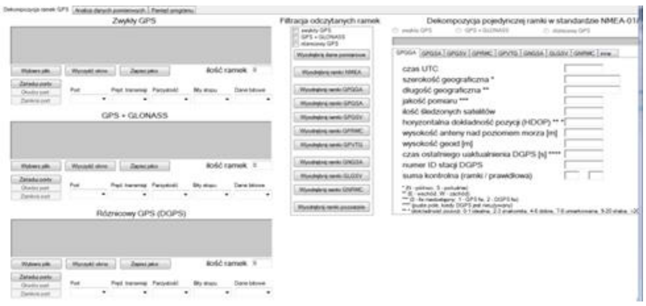

Fig. 1. Control panel of data acquisition and processing application (Mrozek, 2013)

2.2. GNSS Receivers

In the paper three different GNSS receivers were used. All of them was seen as serial devices with different COM numbers, given by operating system.

Main features of GPS Mouse Skytraq SJ-5210 (which contains SiRFStar III chipset) were described in (http://www.skytraq.com). The second receiver shown in Fig. 2. Is described in (https://www.maritex.com.pl). For differential measurements devices described in (http://www.novatel.com), showed below were used:

Fig. 2. On the left GPS Mouse Skytraq SJ-5210, on the right GNSSGMS G9 – picture of the receiver with USB-TTL interface in cover

Fig. 3. On the right - picture of base station Novatel FlexPak G2-V2-L1 with Novatel GPS-701-GG antenna, on the left mobile receiver GNSS Novatel OEMV-1DF mounted on dedicated power board with ANT-35C1GA-TW-N antenna

Receivers described above were connected to mobile computer by USB ports, which enable reading position and others parameters included in data frames of NMEA protocol.

Base station and mobile receiver were configured for receiving differential corrections by radio link (pair of industrial grade radio modems).

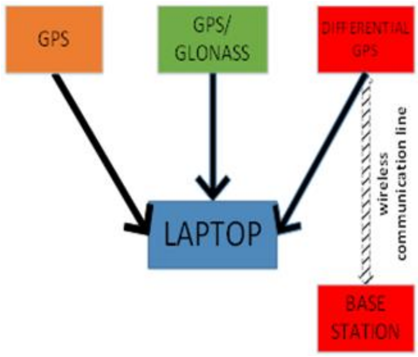

Fig. 4. Diagram of receivers communication during the experiment

3. CONDUCTED EXPERIMENT

As a part of experiment the concurrent reading, processing and saving navigational data from three different GNSS receivers (GPS, GPS+GLONASS and DGPS) during travelling by foot on determined path (Fig. 5). In the point indicated as start and end point of the path (red dot on the blue line near the middle of figure) the DGPS base station with radio modem configured for sending navigational corrections was located. The red arrow denote the direction of movement. The dotted line mean parts of the path in which impact of buildings on quality of measurements were observed. In this places the break of data link with navigational corrections occurred most frequently.

Fig. 5. The path on which the reading, processing and saving of navigational signals from GNSS receivers was made

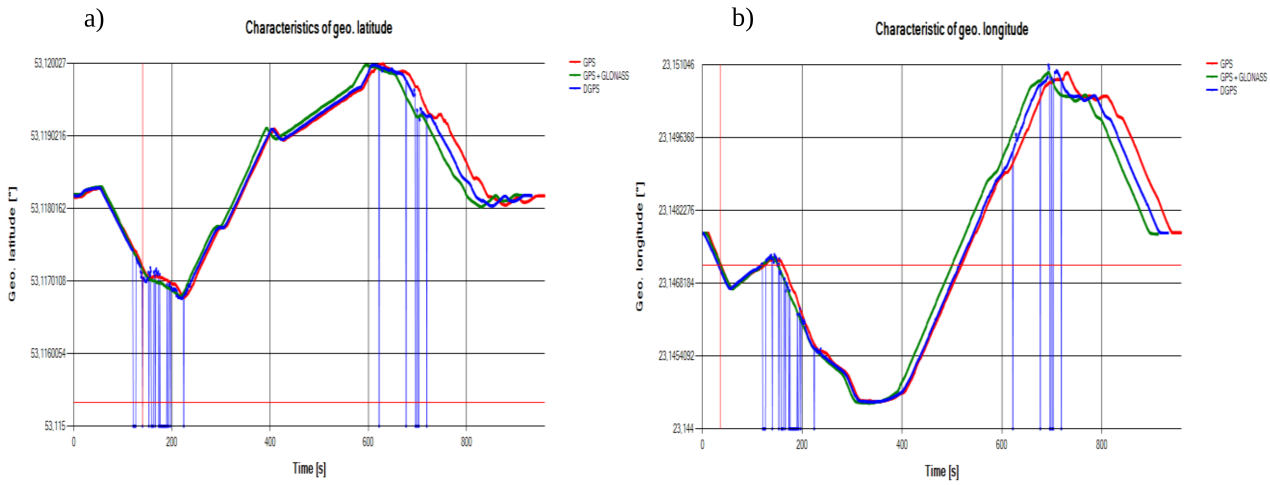

Fig. 6. The characteristic of geographical latitude (a) and longitude (b) changes – vertical lines indicate data frames when the connection between radio modems for DGPS measurements was broken

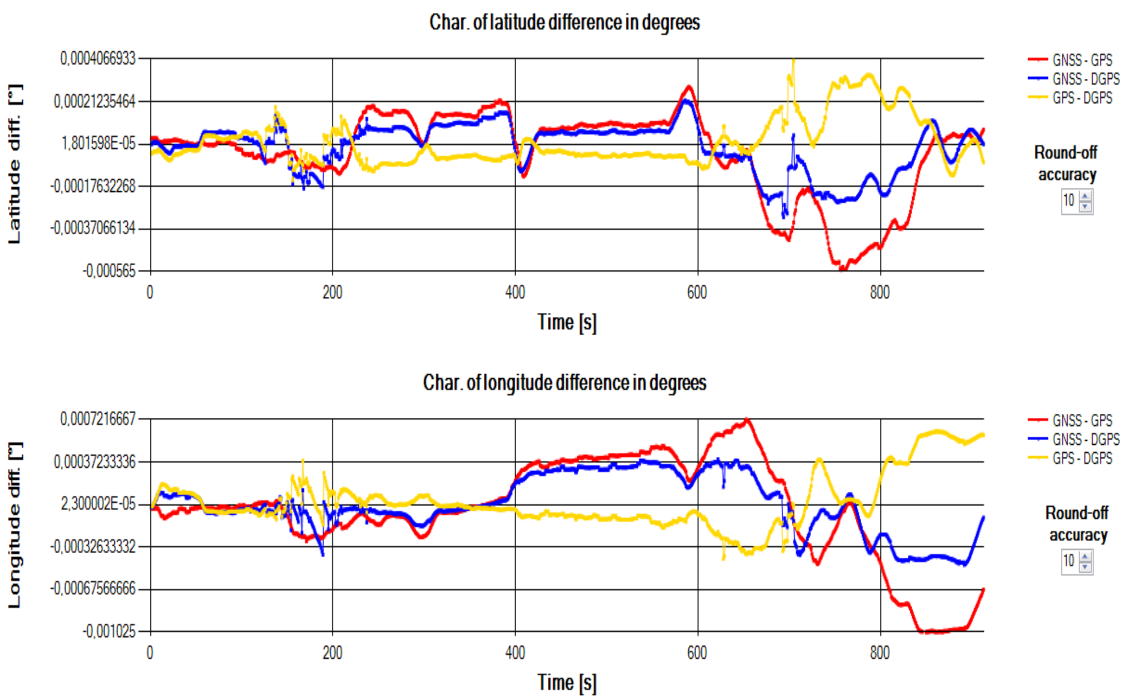

Fig. 7. Characteristic of changes of latitude and longitude in degrees

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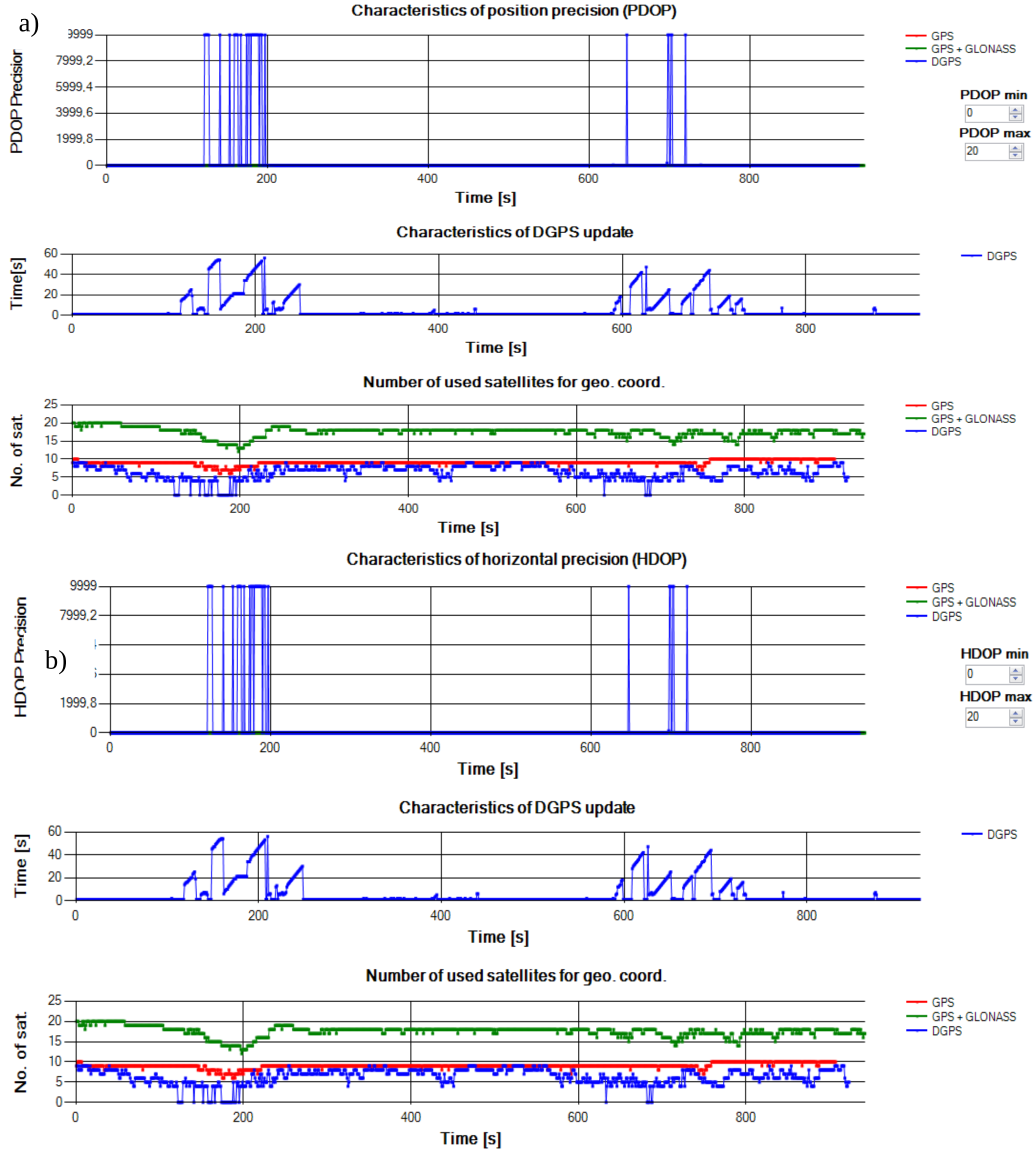

Fig. 8. The PDOP (a) and HDOP (b) characteristic of acquired navigational signals

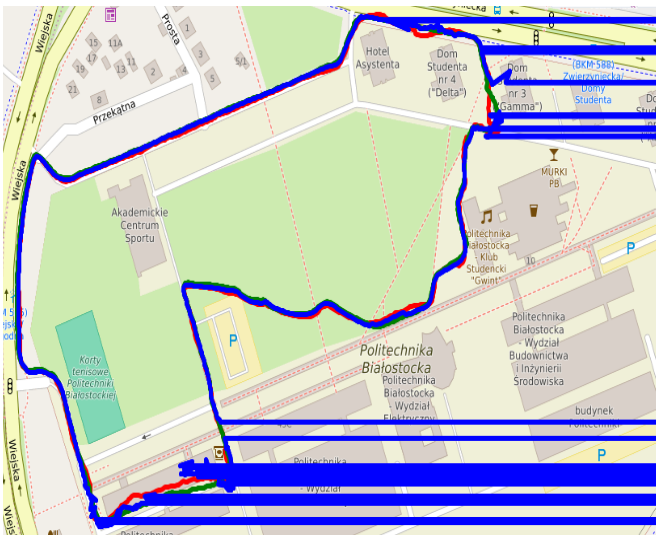

Fig. 9. Navigational signals received by three GNSS receivers ploted on the experiment map – horizontal lines indicates data frames when communication between radio modems for DGPS measurements was corrupted

4. EXPERIMENT RESULTS

Based on navigational data acquired during the experiment analysis od received signals were made. The most important parameters are described in tables 1-3.

Tab. 1. Number of used satellites

	GPS	GPS+GLONASS	DGPS
min. no of available satellites	6	12	0
max. no of available satellites	10	20	9

In the table above maximum and minimum number of visible satellites are shown. Number 0 for DGPS measurement indicates communication link break between radio modems which were sending navigational corrections from base station to mobile receiver.

Tab. 2. Values of DOP parameters

	GPS	GPS+GLONASS	DGPS
PDOP min	1.7	0.84	1.7
PDOP max	4	1.34	9999
HDOP min	0.9	0.54	0.9
HDOP max	2.1	0.9	9999
VDOP min	1.5	0.64	0
VDOP max	3.3	1.16	121.4

Values 9999 and 121.4 from Tab. 2 are unacceptable – they occurred in the moment of communication link break between radio modems of base station and mobile receiver.

Tab. 3. Changes of geographical lattitude and longitude

Changes of geographical latitude			
	GPS	GPS+GLONASS	DGPS
Δx min[°]	-0.000565	-0.0003151317	-0.000147205
Δx max[°]	0.0002783333	0.0002171683	0.0004066933
Changes of geographical longitude			
Δy min[°]	-0.001025	-0.00047172	-0.0004219867
Δy max[°]	0.0007216667	0.00039619	0.0006247

In the Tab. 3 the minimal and maximal scope of changes of geographical latitude and longitude is shown.

5. CONCLUSIONS

In the paper authors prepared and conducted experimental analysis and comparison of work and quality parameters of received navigational data for three different GNSS receivers. For investigations the following devices was chosen: one-frequency GPS, dual frequency GPS+GLONASS and one frequency differential GPS. These devices was mounted on dedicated frame for their simultaneous work. Due to lack of available software, the dedicated computer application for acquisition, processing and saving of received data frames was written. The experiment was conducted on Bialystok University of Technology Campus Area, where during the travel by foot the impact of building for quality of measurement was observed. Based on measurement and analysis of quality parameters, the best quality and availability of measurement were provided by dual frequency receiver which use the biggest number of satellites. In the case of DGPS receiver unacceptable values of PDOP and HDOP parameters occurred due to the break of communication link between base station and DGPS mobile receiver connected with entering area with high buildings. These moments were described in table 2 and on Fig. 6 and 9 by vertical and horizontal lines. In future works use of WiFi or circular communication is planned for sending navigational corrections between base station and mobile DGPS receiver.

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