

Data processing methods for GPS user devices control system

V. Belinska¹, V. Boicov², A. Kluga³

¹Department of Transport electronics and telematics, Riga Technical University, Lomonosov street 1, bloc V, LV-1019, Riga, LATVIA, E-mail: veronika_belinska@inbox.lv

²Department of Transport electronics and telematics, Riga Technical University, Lomonosov street 1, bloc V, LV-1019, Riga, LATVIA, E-mail: boicov@yahoo.com

³Department of Transport electronics and telematics, Riga Technical University, Lomonosov street 1, bloc V, LV-1019, Riga, LATVIA, E-mail: ansis.kluga@rtu.lv

This article describes the data processing methods for GPS user devices. Developed device control methods were applied for the equipments' testing with the Re-reference system and Spirent STR4500 simulator described in [1], [2].

Introduction

The essence of GPS data processing problem is that the data are received in the form of text file in the format of NMEA-0183 protocol. The volume of these data could be unlimited, because experiments are conducted in the different times, with the various GPS receivers, systems and scenarios too.

Data can be saved on a computer in the form of text file without a preprocessing. However, to summarize a great deal of devices' test results according to various conditions there are useful to modify them and to save in a special formed data bank.

I. The description of GPS user devices testing process

GPS user devices' testing starts with the research of these devices manufacturer's specifications, which involve the analysis of the GPS receiver parameters and possibilities. There is a need to select an imitation scenario and a model of used system [1] depending on possibilities of the tested devices. This is a very important part in the testing process, because some GPS receivers are adjusted to the large speed mode, for example, aviation GPSMAP 296, others, for example, Holux GR-213, works better within a car speed. There are other important features also, such as the Wide Area Augmentation System/ European Geostationary Navigation Overlay Service (WAAS/EGNOS) corrections utilization possibilities.

Then the GPS receiver connection to the computer through COM or USB port [1] follows. The special software is necessary on a computer to store data statistics. VisualGPS program can be used [2], it allows to visualize the National Marine Electronics Association (NMEA) received file content and to save their together in the text file.

Created together with the VisualGPS program NMEA data file contains a large amount of parameters: number of satellites, the measured receivers' antenna latitude,

longitude and height position and their changes in the time, dilution of precision (xDOP), signal to noise ratio (SNR). This information helps to evaluate the received signal quality and accuracy.

Figure 1 illustrates the window of VisualGPS program, where the received data summary from the Garmin eTrex receiver can be visually examined. Presented experiment lasted 24 hours using the Re-reference system the coordinates of its receiving antenna's were fixed with high precision.

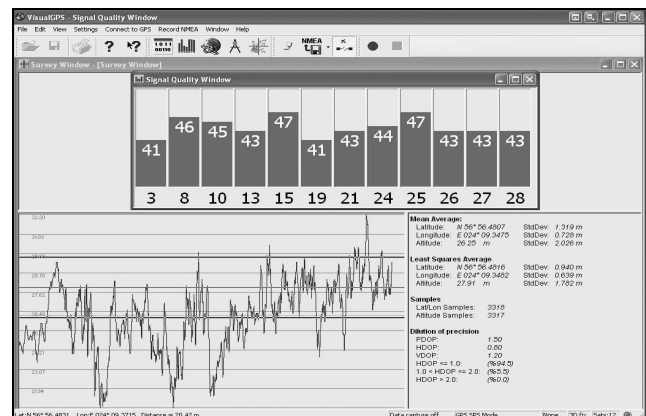


Fig. 1. Experiment result in the VisualGPS program

Data are stored in a text file in the NMEA format after the end of the experiment. Then the data were prepared for further research and saved in the database.

II. Preprocessing of data received from the GPS receivers

The protocol of NMEA-0183 data exchange describes the amount of different messages. Two tens can be selected from them that are used in the navigation equipment. All the NMEA-0183 commands and messages come off in the ASCII code. The NMEA standard message begins with five letters characters with \$ sign before, from which the first two are message source identifier, but others three – message format identifier. For example, all GPS NMEA messages have „GP” prefix. Messages, that aren't described in the NMEA specification, but are realized in

the GPS receivers in accordance with general rules, have the „P” prefix, which is added with the three characters unique for each company. For example, „PGRM” prefix (Fig.2.) is for the „own” NMEA Garmin messages, „PMGN” – Magellan.

```
$GPRMC,125352,A,5656.4803,N,02409.3465,E,0.0,183.4,190308,5.8,E,A,*1D
$GPRMB,A,0.00,L,,SIGULD,5708.612,N,02450.922,E,25.762,61.5,,V,A,*76
$GPGGA,125352,5656.4803,N,02409.3465,E,1.09,0.9,24.7,M,24.8,M,,*7B
$GPGSA,A,3,04,05,,13,14,20,23,30,31,32,,1.5,0.9,1.2,*39
$GPGSV,3,1,10,04,16,312,47,05,00,334,42,12,08,000,42,13,08,222,43,*7F
$GPGSV,3,2,10,14,06,049,38,20,81,252,47,23,45,213,46,30,08,032,38,*72
$GPGSV,3,3,10,31,39,079,49,32,14,093,41,*78
$GPGLL,5656.4803,N,02409.3465,E,125352,A,A,*41
$GPBOD,61.5,T,55.7,M,SIGULD,*42
$PGRME,6.0,M,6.3,M,8.7,M,*22
$PGRMZ,81.f,3,*22
$GPRTE,1,1,c,*37
```

Fig. 2. NMEA message packet of Garmin eTrex receiver

A current message’s checksum can be given in the message last field, it begins with the delimiter *, it can be used for each received message integrity and validity verification if necessary.

The complete aggregate of NMEA messages and commands is large enough [4]. Some NMEA messages can contain the identical data fields. There is a different messages amount and aggregate of various GPS receivers as well. Only a certain kind of information should be taken out from the NMEA file depending on the data processing results and purpose. This information will allow one to consider the GPS user device precision and its dependence, from the state of the satellite system

In order to obtain the information about the location the \$GPRMC and \$GPGGA type navigation messages can be used; an example is represented in the Figure 2. \$GPRMC (Recommended minimum data specifies GPS/Transit data) message doesn’t give a height information, therefore the \$GPGGA (Global positioning system fix data) type message is selected for the place estimation. This is the most popular and often used NMEA message with GPS data about the position, place determination time, data quality, number of used satellites, horizontal dilution of precision (HDOP), information about differential corrections and their age (Table 1).

Table 1: \$GPGGA message format

Field’s name	Example from Figure 2
Message ID	\$GPGGA
Coordinated Universal Time (UTC) position	125352
Latitude in form: ddmm.mmmm, where d - degree, m – minutes; N/S Indicator: North (N) or South (S)	5656.4803 N
Longitude in form: dddmm.mmmm, where d - degree, m – minutes; E/W Indicator: East (E) vai West (W)	02409.3465 E
GPS signal quality: 0 = Fix not available or invalid; 1 = GPS SPS Mode, fix valid; 2 = Differential GPS, SPS Mode, fix valid; 3 = GPS PPS Mode, fix valid	1
Number of satellites being tracked	09

(used)	
Horizontal dilution of position (HDOP)	0.9
Altitude, above mean sea level	24.7 M
Height of geoid (mean sea level) above WGS84 ellipsoid	24.8 M
Time in seconds since last DGPS update	-
DGPS station ID number	-
The checksum data	* 7B

The data preprocessing supposes the transformation of received data, in the result of which all the messages from the NMEA text file are set apart and saved in the separate files. This was done with the programs which are written in C++ language and compiled with Dev-C++, version 4.9.9.2 (Gnu GPL license). The aggregate of files is formed with the messages’ identifier names, for example, gpgga.txt (Fig. 3), gprmc.txt, gpgsv.txt, gpgsa.txt and other, placing the NMEA-0183 protocol files in the directory with gps.exe program and launching it.

```
$GPGGA,125352,5656.4803,N,02409.3465,E,1.09,0.9,24.7,M,24.8,M,,7B
$GPGGA,125354,5656.4803,N,02409.3465,E,1.10,0.9,24.6,M,24.8,M,,74
$GPGGA,125356,5656.4803,N,02409.3465,E,1.10,0.9,24.6,M,24.8,M,,76
$GPGGA,125358,5656.4803,N,02409.3466,E,1.10,0.9,24.6,M,24.8,M,,7B
$GPGGA,125400,5656.4803,N,02409.3466,E,1.10,0.8,24.6,M,24.8,M,,70
$GPGGA,125402,5656.4802,N,02409.3467,E,1.10,0.8,24.6,M,24.8,M,,72
$GPGGA,125404,5656.4802,N,02409.3467,E,1.10,0.8,24.5,M,24.8,M,,77
$GPGGA,125406,5656.4802,N,02409.3468,E,1.10,0.8,24.5,M,24.8,M,,7A
$GPGGA,125408,5656.4802,N,02409.3468,E,1.10,0.8,24.4,M,24.8,M,,75
$GPGGA,125410,5656.4801,N,02409.3469,E,1.10,0.8,24.4,M,24.8,M,,7E
$GPGGA,125412,5656.4801,N,02409.3470,E,1.10,0.9,24.4,M,24.8,M,,75
$GPGGA,125414,5656.4801,N,02409.3470,E,1.10,0.9,24.3,M,24.8,M,,74
$GPGGA,125416,5656.4800,N,02409.3471,E,1.10,0.8,24.3,M,24.8,M,,77
```

Fig. 3. Gpgga.txt file created by gps.exe

The gps.exe program allows also separating the fields from the totality of messages. These fields will be used for the further processing. The information about the position (time, latitude, longitude and height) (Fig. 4.) from the \$GPGGA message can be obtained. The angular coordinates are converted in the process of program action, and the coordinates in degrees are written into the text file. This message allows also knowing the number of used satellites.

```
125352,56.941338333333,24.155775,24.7
125354,56.941338333333,24.155775,24.6
125356,56.941338333333,24.155775,24.6
125358,56.941338333333,24.155776666667,24.6
125400,56.941338333333,24.155776666667,24.6
125402,56.941336666667,24.155778333333,24.6
125404,56.941336666667,24.155778333333,24.5
125406,56.941336666667,24.15578,24.5
125408,56.941336666667,24.15578,24.4
125410,56.941335,24.155781666667,24.4
125412,56.941335,24.155783333333,24.4
125414,56.941335,24.155783333333,24.3
125416,56.941333333333,24.155785,24.3
```

Fig. 4. File with the information about receiver position created by gps.exe

\$GPRMC contains the fields with the same \$GPGGA data about position without a height only and data about speed over ground, course over ground, date and magnetic variation.

\$GPGSA (GPS DOP and active satellites) message provides the information about DOP factors (PDOP (Position), HDOP (Horizontal) and VDOP (Vertical)).

The important data from \$GPGSV (Satellites in view) message can be received; it contains a few rows and describes each visible satellite elevation angle, azimuths in the degrees and signal level (SNR, dB).

III. GPS user devices received data processing possibilities

The data processing possibilities can be various depending on a research object and the desirable net result.

The errors that mainly have a random character follow the navigation values measuring, which is executed with the GPS user devices. The random errors are the consequences of various reasons, which act simultaneously. Therefore the random error can't be excluded from the result's particular sample. Random errors appear in the radio navigation measuring in case of radio waves distribution conditions inconstancy, chaotic or impulses noises action. It is possible to reduce these errors by choosing optimal equipment parameters, but it couldn't be prevented at all. Measuring errors change very slowly in many cases, for example, the delay errors created by ionosphere and the satellites motion deviation errors; they can be reduced by using a differential work mode.

It is necessary to estimate the accuracy because of above mentioned conditions. It is necessary to execute the estimation of results' statistical processing in the process of GPS equipments radio navigation measuring. Received data and exact place data are used to determinate errors. These data are obtained by other methods or set in a signal simulator scenario. To determine the radial errors it is necessary to do the errors' angular values transformation into linear values.

Then the various statistical characteristics can be find, for example, latitude and longitude estimation of expectation, root mean square (RMS) error, standard deviation, probability density function and other data using the aggregate of these radial errors. The measuring errors results are shown in [3].

Other NMEA data can be noted too, which are necessary for GPS receiver testing, the most important from them is a number of used satellites and its interlocation.

Figure 5 presents the graphs with the number of used satellites dependence from time different GPS receivers. The time interval is 18 hours (64800 seconds), from 12:53:32 to 07:04:02, it is divided into three parts: day, evening, night. The graphs show that the number of GPS receivers used in the night is bigger than in the day time and in the evening. It can be explained that satellites signal delay in the ionosphere is repeatedly less in the night, and therefore there is the largest exactness in the position coordinates determination [3].

Figure 5. a) shows the number of used satellites together with the number of visible satellites, it can be noted that the number of these satellites is different, the GPS receivers „see” more satellites than „use” for a place determination task (average of used satellites is 11, but of visible is 12).

It was noticed in the process of the experiments that not all the GPS receivers translate the information about used and visible satellites with NMEA protocol, for example, aviation GPSMAP 296 translates the information about the time, latitude, longitude, height, speed only, but all the other information is represented on its display.

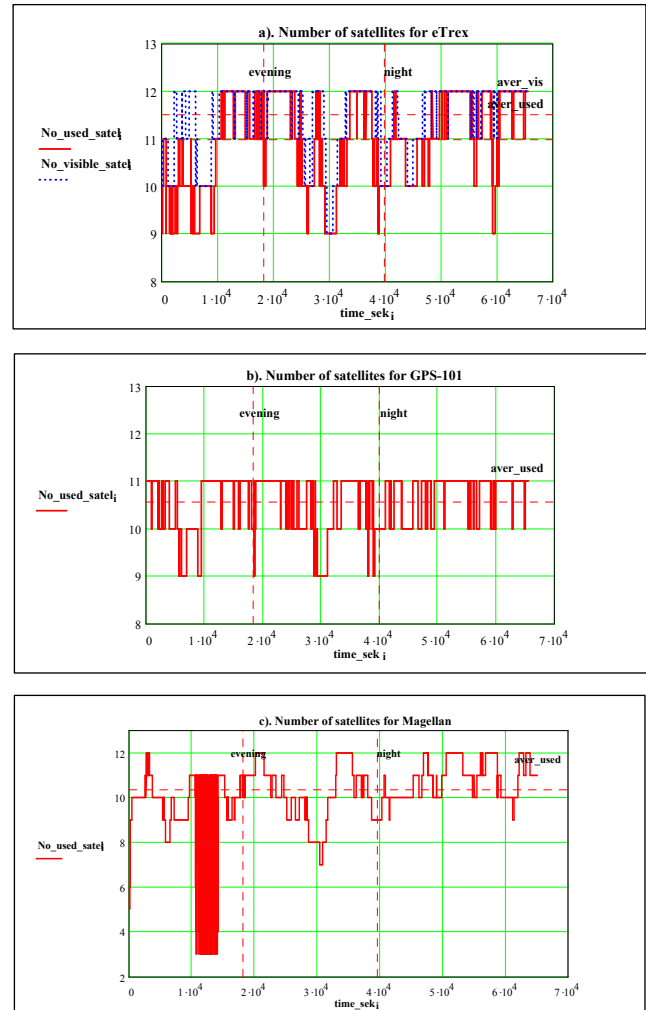


Fig. 5. Number of used satellites for GPS receivers: a). Garmin eTrex; b). Graymark GPS-101; c). Magellan eXplorist 300

The Magellan eXplorist 300 receiver showed the better result after accuracy characteristics. The Magellan receiver radial error increased [3], because of satellite signal instability, that lasted one hour (Fig. 6).

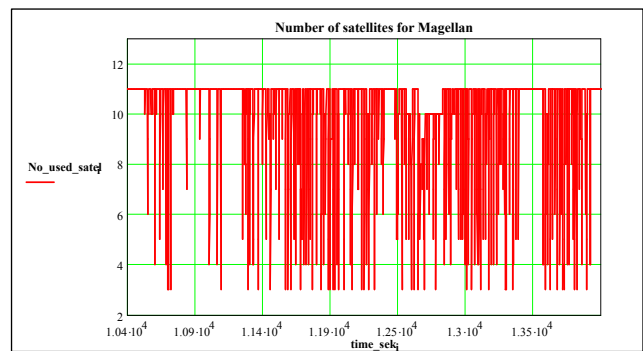


Fig. 6. The satellite signal instability of Magellan eXplorist 300 receiver

Other factors, which are important in the devices testing, exist also; it is the ratio of each GPS satellite signal to noise (SNR) and elevation angle (degrees). Figure 7 shows the graphic relevance of these factors. Data were obtained from the Garmin eTrex receiver NMEA file for the fourth satellite. It can be noted, that the signal to noise ratio is closely linked with a satellite elevation in a vertical plane.

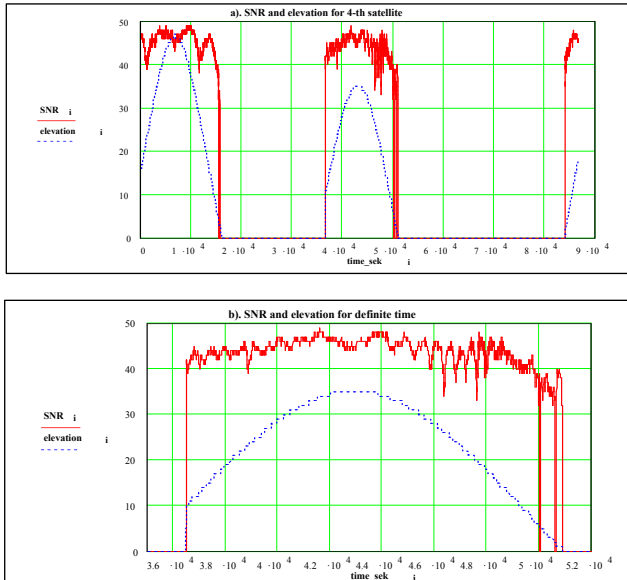


Fig. 7. The dependence graphs of the fourth satellite SNR and elevation in a vertical plane for the Garmin eTrex receiver

IV. Database use in the GPS user devices data processing

The volume of the executed GPS receivers' test experiment information in time of one day can exceed 1 GB. In addition it is necessary to do the information selections after various criteria very often with a view to research. The unique and correct decision of these problems can be the executed measuring information inserting into a database management system (DBMS), where could be all necessary information about experiment systems used in an experiment, GPS receivers, test time, duration and other important aspects. Construction of the similar information systems is described in [5], [6].

Data of the different experiments from the various NMEA files are kept in a specially created database „GPS_data”. Database as already was mentioned allows executing the data selection unlike a simple file format. It can take out from the database with the simple SQL query such experiment data, which conform to certain criterion, for example, when a number of the used satellites is over nine:

```
SELECT UTC_Time, Latitude, Longitude
FROM Experiment_data
WHERE No_used_satellites > 9
```

So, the data after preprocessing are systematized saved in the database with the Web interface, this software was specially written for GPS user devices precision research with the MySQL DBMS and PHP language.

GPS_data interface is formed in PHP and HTML language; it helps a user to manage the GPS user devices

information database „GPS_data”. It can see this interface with the simple browser, as also execute the certain actions with the database's data.

User interface gives all necessary information about GPS at large, as also about the executed experiments details: GPS receivers (Fig. 8), systems, experiment in an aggregate. User has a possibility to create the new experiment, to insert the necessary information and data into the database, to execute a search and data processing.

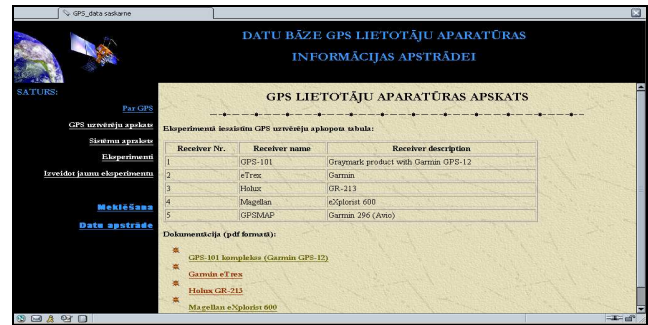


Fig. 8. The second page “GPS receivers’ description” of GPS_data interface

V. Conclusions

Data processing results, which are obtained in a test of receivers' process, are shown in this article. There is shown, that the test results aggregate need to save in the database not in the primary text files. Testing the GPS receivers there were defined the main parameters, after which it is necessary to form the access to the database: measuring realization time, used system, scenario, number of visible and used satellites and others.

References

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