

USING MATLAB FOR GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS) SURVEYS

Miroslav TSVETKOV¹

Zhelazko NIKOLOV²

¹Assistant professor, Ph.D., Nikola Vaptsarov Naval Academy, Varna, Bulgaria

²Assistant professor, Ph.D., Nikola Vaptsarov Naval Academy, Varna, Bulgaria

Abstract: In this paper are represented a software tools for Global Navigation Satellite System Navstar surveys developed in MatLab. The different tools are suitable for preliminary calculations in respect to planning the GPS measurements and post processing. The tools can support researchers for choosing thebesttime or the best place to perform theGPS measurements. TheMatLabscripts suite can be used for calculations for visible constellation of navigational satellites, creating a map of elevation angles, different types of dilutions of precision, ionosphere maps and total electron contents processing, almanac processing, ephemeris and radioephemeris processing, pseudo range corrections and etc.All calculations are performed for a user-defined point and for a user-defined time moment or time period. The tools can be used for the other Global Navigation Satellite Systems like GALILEO.

Keywords: GNSS, MatLab, DOP, Ionosphere, Mapping, Planning, Survey

1. INTRODUCTION

The Global Navigation Satellite Systems (GNSS)NAVSTAR and GLONASS was originally designed primarily to provide highly accurate radionavigation capability to U.S. and Russians military forces respectively, while also providing an unencrypted signal of degraded accuracy to civilian users. As the system developed, civil usage expanded rapidly and the number of civilian users now greatly exceeds the number of military users. The timing, velocity, and positioning information provided by GNSSare being used for a growing number of new, innovative applications that could not have been foreseen by the original system designers. For example some innovative applications are:social networking, wreck diving, marketing, sky diving, photographic geocoding, weather prediction improvements, GNSS road pricing, tracking,heading information, using during flight from passengers, location-based games, emergency and location-based services, mobile satellite communications, precise time reference, archeology, geophysics and geology, mapping and geographic information systems, surveying etc. As a result of the increased interest of civilian users, new European global navigation satellite systems Galileo is developed.Because of widespread of

GNSS a different kinds of augmentation systems have been planned and developed for increasing the GNSS measurement accuracy. The space based augmentation systems are: U.S. –Wide Area Augmentation System (WAAS), European –European Geostationary Navigation Overlay Service(EGNOS), Indian –GPS-Aided GEO Augmented Navigation system(GAGAN), Japanese – MTSAT Satellite Based Augmentation System(MSAS) and Chinese–Satellite Navigation Augmentation System(SNAS).Another way to obtain more accurate GPS measurements is to plan the time and length of sessions.

2. THE MATHEMATICAL MODEL

One very important parameter with respect to accuracy of the GPS observations is dilution of precision (DOP). There are several types of DOP's. HDOP, VDOP, PDOP, and TDOP are respectively Horizontal, Vertical, Positional (3D), and Time Dilution of Precision. They follow mathematically from the positions of the available constellation of satellites.The idea is to use MatLab script to calculate all types of DOP's for the point in which will be carried out the measurements. The mathematical model of code pseudorangeobservation is used [2]. As a first step in computing DOP, consider the unit vectors from the receiver to satellite i (formulas 1 and 2).

$$\left(\frac{(x_i - x)}{R_i}, \frac{(y_i - y)}{R_i}, \frac{(z_i - z)}{R_i} \right), \quad (1)$$

$$\text{where } R_i = \sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2}, \quad (2)$$

and x_i, y_i, z_i denote the position of satellite i , and x, y, z denote the position of the receiver. Formulate the matrix, A, as:

$$A = \begin{pmatrix} \frac{(x_1 - x)}{R_1} & \frac{(y_1 - y)}{R_1} & \frac{(z_1 - z)}{R_1} & -1 \\ \frac{(x_2 - x)}{R_2} & \frac{(y_2 - y)}{R_2} & \frac{(z_2 - z)}{R_2} & -1 \\ \frac{(x_3 - x)}{R_3} & \frac{(y_3 - y)}{R_3} & \frac{(z_3 - z)}{R_3} & -1 \\ \frac{(x_4 - x)}{R_4} & \frac{(y_4 - y)}{R_4} & \frac{(z_4 - z)}{R_4} & -1 \end{pmatrix}, \quad (3)$$

The first three elements of each row of A are the components of a unit vector from the receiver to the indicated satellite. If the elements in the fourth column are c which denotes the speed of light then the time dilution factor is always 1. If the elements in the fourth column are -1 then the time dilution factor is calculated properly.Formulate the matrix, Q, as:

$$Q = (A^T A)^{-1}, \quad (4)$$

The elements of Q are designated as:

$$Q = \begin{pmatrix} q_{XX} & q_{XY} & q_{XZ} & q_{Xt} \\ q_{XY} & q_{YY} & q_{YZ} & q_{Yt} \\ q_{XZ} & q_{YZ} & q_{ZZ} & q_{Zt} \\ q_{Xt} & q_{Yt} & q_{Zt} & q_{tt} \end{pmatrix}, \quad (5)$$

However the elements of Q do not represent variances and covariances as they are defined in probability and statistics. Instead, they are strictly geometric terms. Therefore the elements of Q are used as dilution of precision. GDOP, PDOP and TDOP are given by:

$$\begin{aligned} GDOP &= \sqrt{q_{XX} + q_{YY} + q_{ZZ} + q_{tt}} \\ PDOP &= \sqrt{q_{XX} + q_{YY} + q_{ZZ}}, \\ TDOP &= \sqrt{q_{tt}} \end{aligned} \quad (6)$$

In (6) the DOP's and elements of co-factor matrix Q are represented in the Cartesian coordinate system (x, y, z) . The corresponding co-factor matrix for the local geographic components (n, e, u) is obtained as follows:

$$Q_{(n,e,u)} = RQR^T = \begin{pmatrix} q_{xx} & q_{xy} & q_{xh} \\ q_{xy} & q_{yy} & q_{yh} \\ q_{xh} & q_{yh} & q_{hh} \end{pmatrix}, \quad (7)$$

where R is rotation matrix, formulate as:

$$R = \begin{pmatrix} -\sin \varphi \cos \lambda & -\sin \varphi \sin \lambda & \cos \varphi & 0 \\ -\sin \lambda & \cos \lambda & 0 & 0 \\ \cos \varphi \cos \lambda & \cos \varphi \sin \lambda & \sin \varphi & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad (8)$$

Where φ is Latitude and λ is Longitude of the GPS receiver position.

As a result in addition two more DOP's are available. There are HDOP (Horizontal DOP) and VDOP (Vertical DOP). They are given by:

$$\begin{aligned} HDOP &= \sqrt{q_{xx} + q_{yy}} \\ VDOP &= \sqrt{q_{hh}} \\ HDOP &= \sqrt{EDOP^2 + NDOP^2} \end{aligned} \quad (9)$$

3. DATA SOURCE FOR THE SATELLITES AND THE DATA FORMAT

There are several institutions which are producing precise orbital (ephemeris) data to support different kind of applications. Precise ephemeris data is based on GPS data collected at a global GPS network coordinated by the International GPS Service for Geodynamics (IGS) [1]. At the present time, precise ephemeris data is available to users with some delay, which varies from 12 hours for the IGS ultra rapid orbit to about 12 days for the most precise IGS precise orbit. The corresponding accuracies for the two precise orbits are in the order of a few decimeters to 1 decimeter, respectively. Users can download the precise ephemeris data free of charge from the IGS center, at [3]. Users can download also a five day predicted ephemeris data.

To facilitate exchanging such precise orbital data, the U.S. National Geodetic Survey (NGS) developed the SP3 format, which later became the international standard [1]. The SP3 is an acronym for Standard Product #3, which was originally introduced as SP1. The SP3 file is an ASCII file that contains information about the precise orbital data and the associated satellite clock corrections. The line length of the SP3 files is restricted to 60 columns (characters). All times are referred to the GPS time system in the SP3 data standards.

A precise ephemeris file in the SP3 format consists of two sections: a header and data [1]. The header section is a 22-line section. The first line starts with the version symbols (#a) and contains information such as

the Gregorian date and time of day of the first epoch of the orbit, and the number of epochs in the ephemeris file. Line 2 starts with the symbols (##) and shows the GPS week number, the seconds of the week, the epoch interval, and the modified Julian day. Lines 3-7 start with the symbol (+) and show the total number of satellites (on line 3) as well as list the satellites by their respective identifiers (PRN number). Lines 8-12 start with the symbols (++) and show the accuracy exponents for the satellites shown on lines 3-7.

The data section of the precise ephemeris in the SP3 format starts at line 23, which contains the data and time of the first record (epoch). In fact, this is the same time shown in the first line of the header section. Subsequent lines contain the satellite coordinates and the satellite clock data for the current epoch. Each line is assigned for a particular satellite and starts with the character "P", which means a position line. The character "P" is followed by the satellite PRN number, the x, y, and z coordinates of the satellite in kilometers and the satellite clock correction in microseconds. In some cases, satellite velocity values and the rate of clock corrections are mixed with this information. To handle this, the position and clock correction record will be on one line, followed by a line containing the velocity and the rate of clock correction record for the same satellite. The line containing the velocity record starts with the letter "V". Subsequent epochs will have the same structure, and the file ends with the symbol "EOF".

4. USING MATLAB FOR GPS MISSION-PLANNING AND SURVEY

To help users in identifying the best observation periods, GPS manufacturers have developed mission-planning software packages, which predict the satellite visibility and geometry at any given location. Mission-planning software provides a number of plots to help in planning the GPS survey or mission.

Now with mathematical model of code pseudorange observation and five day space vehicles (SV) orbit predictions from NGS-SP3 files we can use MatLab as GPS mission planning and survey software.

On Figures from 1 to 10 are presented graphics generated from MatLab script implemented the idea.

The first plot is known as the satellite availability plot, which shows the total number of the visible satellites above the user-specified mask angle. Figure 1 shows the satellite availability of SV's of GNSS NAVSTAR for Constantza on April 1 2013, mask angle of 10° . Figure 2 shows the satellite availability of SV's of GNSS GLONASS for Constantza for the same time period and mask angle. The green points show the number of visible SV's with interval of 15 minutes.

Other important plots are the satellite geometry plots. The satellite geometry plots are normally represented by the different types of DOP plots.

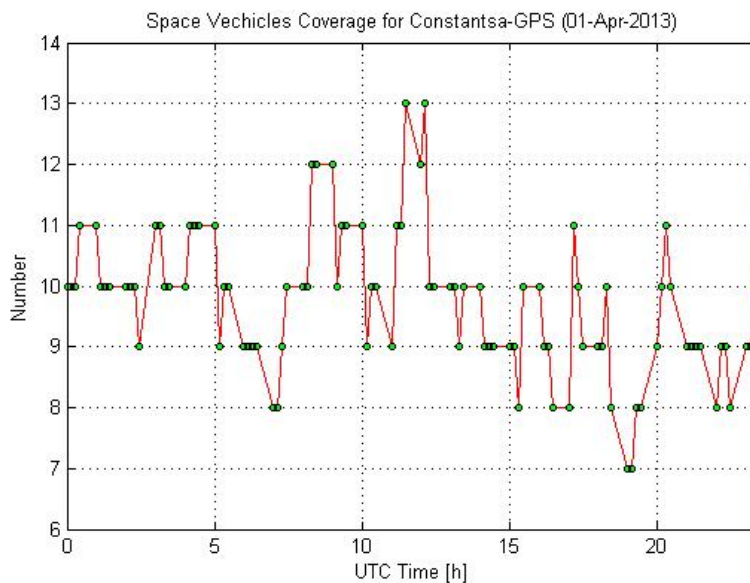


Fig. 1

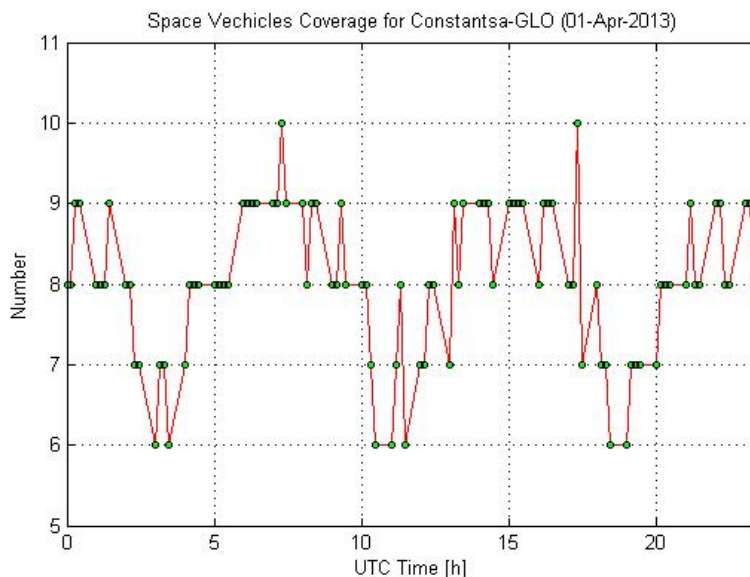


Fig. 2

Figures 3, 4 and 5 represent PDOP, HDOP, VDOP, NDOP and EDOP respectively for the satellite constellations shown in Figure 1.

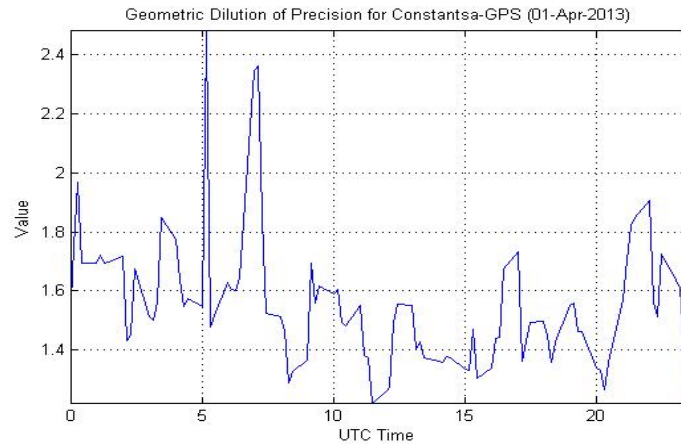


Fig. 3

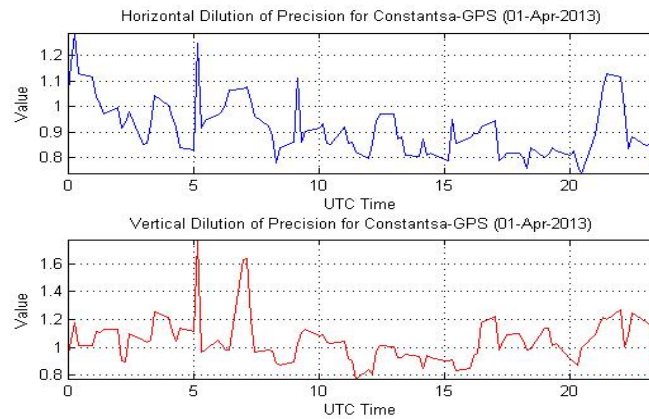


Fig. 4

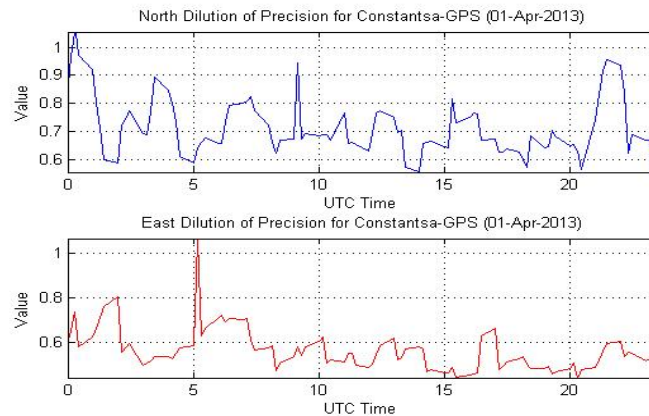


Fig. 5

The same plots are generated also for GNSS GLONASS.

5. CONCLUSION

In this brief article we have introduced the concept of the tool realized in MatLab for GPS mission planning and survey. This MatLab tool allows to researchers and GPS users to: decode and import the orbital data for space vehicles of two GNSS's – NAVSTAR and GLONASS; calculate different kinds of DOP values for each one GNSS separately and for combined usage; interpolate or extrapolate the orbital data with respect to research purposes; visualize the orbital and DOP data directly or after interpolation and extrapolation; save the output data in to text and binary files for archiving or post-processing; plan their surveys with respect to find a time period with the best DOP values;

References

- [1] Ahmed El-Rabbany "Introduction to GPS: The Global Positioning System", Artech House, London, 2002
- [2] B. Hofmann-Wellenhof, Herbert Lichtenegger, James Collins "GPS Theory and Practice", 4-th ed., Springer-Verlag, Wien, New York
- [3] <ftp://igscb.jpl.nasa.gov/igscb/product/>.