GPS SIMULATION PACKAGE FOR MATLAB

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Abstract

Position determination and navigation has become very important tool in various areas of human activities, ranging from travelling in wild nature to precise geodetic measurements. Global Positioning System (GPS) has brought a new dimension to position determination, it has permanent and global coverage.

GPS offers great possibilities for new innovations and new product implementation. Simulation is a vital step for new design – it can be carried out using GPS hardware simulators or great deal can be done more effectively using software simulation tools. Simulators can also forecast important conditions of the system such as satellite constellation and satellite visibility.

This paper describes simulation software package implemented in MATLAB that can perform various simulations and calculations related to GPS.

Introduction

Satellite navigation system was developed primarily for military purposes. The development and implementation of GPS was sponsored and controlled by the Department of Defence, USA. Soon possible applications for civil purposes were recognized. However, precise knowledge of one's position was considered as strategic information and thus the performance of civil part of the system was deliberately worsened. The so-called Selective Availability Service[1].

GPS system is usually divided into 3 segments:

1. *Satellite segment*
   Consists of at least 24 satellites[2] (21 operational plus 3 back-up satellites) that orbit in six orbiting planes with inclination 55° and in the height 20 200 km above Earth surface. This means that the orbit period is 11 hours 58 minutes.
2. *Control segment*
3. *User segment*

Satellites broadcast CDMA signals on two frequencies – called L_1 (1575.42 MHz) and L_2 (1227.6 MHz) where only L_1 signal can be received by civilian users.

A GPS receiver measures delay on the signal propagation path from a satellite to the receiver. The position of each satellite is calculated from parameters of its orbit that are broadcast in the signal from each satellite. A GPS receiver must receive signals from at least four satellites to be able to determine its position.

GPS position determination is effected by several errors (for more details see [1], [3]).

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[1] The SA worsening has been switched off as from 5th May 2001.
[2] There were 28 satellites in orbit at the time of the software design.

Software simulation package for GPS

A reliable simulation tool is a vital part of any engineering development and design work. Simulation makes development process not only faster but also cheaper and more effective. Also, in the area of GPS research it is very important to simulate and/or forecast some characteristics of the system. Last, but definitely not least, simulation software package developed at a university department can be used for seminars and student projects.

Requirements for the simulator can be summarized in these main points:

- Simulator must be modular so that further functions can be added using the existing package.
- Simulator must have standard interface that students know by the time they start working on projects.
- Intermediate calculation steps and data types should be viewed easily.
- Standard GPS data files can be imported into tabular structure and it is easy to handle such data records in further calculations.
- Extensive calculations can be entered in a simple and elegant way
- Documentation and help can be easily integrated into the simulator.

All of the above requirements had lead to a decision to implement the simulation package in MATLAB[3].

Features of GPS MATLAB simulator

This simulator was designed as the main scope of diploma thesis [3][4]. The main motivation for design of a compact and powerful simulation tool was to enable other students to make use of author's work, to create good basis that others can build upon[5].

The simulation tool programmed in MATLAB contains

- More than 80 well documented and thoroughly tested functions
- About 100 pages of documentation
- GPS data are read from standard GPS files that can be downloaded from many sites on the world wide web.

The GPS simulator can perform following operations and calculations

- Import of GPS data from standard files of type Rinex OBS, Rinex NAV, YUMA, SEM, NMEA.
  (Interfaces of functions had to be kept very simple, a complex data structure that store all satellite data was used[6] and thus only one parameter is transferred. It makes the simulator much more transparent.)
- Satellite position and velocity (including possibility to verify validity of ephemerides)
- Satellite visibility and elevation angles for given elevation mask
- Satellite visibility and elevation for horizontally variable elevation mask (useful for mountain regions and valleys as well as for urban areas).
- User position – also for any given (even horizontally variable) elevation mask
- RMS error of user position
- Ionospheric and tropospheric modelled delay

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[3] There are also commercial solutions for GPS simulators implemented in MATLAB – see [4].
[4] Supervised at the Department of Radioengineering, Faculty of Electrical Engineering, Czech Technical University
[5] Before that all students had to start „from scratch". The author believed that even though the results of such an endeavour are not obvious at first (and may not be appreciated), it is worth the effort and it can bring long-term benefits to the working group. The author believed that teamwork cooperation and good team management is very important even in the highly individual field of research.
[6] The structure is used in many functions in the whole simulator.

- DOP, PDOP, HDOP, VDOP
- Common satellite visibility for two receivers – for any given elevation masks
- Difference in ionospheric and tropospheric modelled delay for two receivers
- DGPS corrections
- GPS time
- Coordinate transformation
- CA code generation
- Animated satellite movement over Earth surface
- All-in-one functions that import data from standard files and calculate satellite visibility and/or receiver position

Most functions generate graphical output as well as numerical results.

The package also includes many general functions that were needed during calculations but could be used for many other purposes.

Examples – simulation outputs

Several graphical outputs are shown in this section for illustration. These outputs are based on data from a receiver from the reference station of the Department of Radioengineering, Faculty of Electrical Engineering, Czech Technical University in Prague recorded in GPS week 1138 day 1.
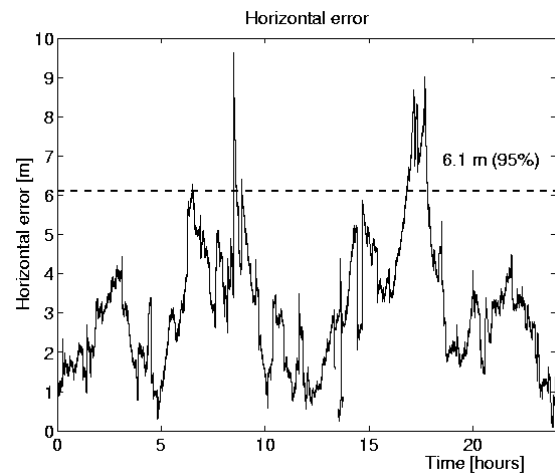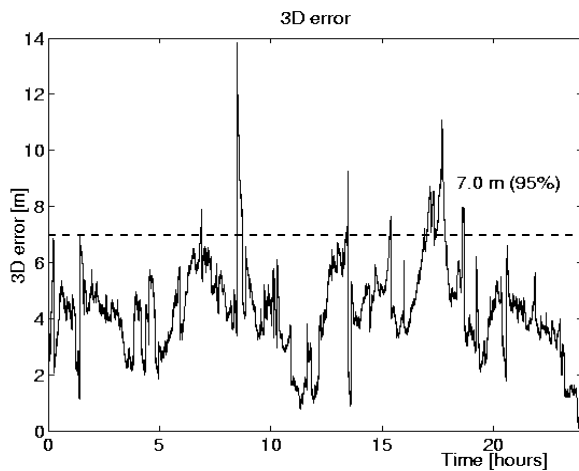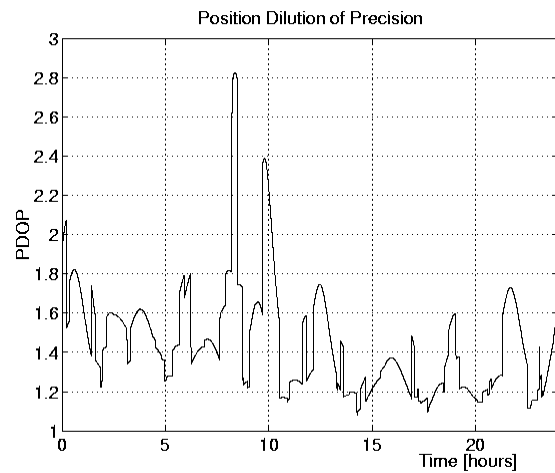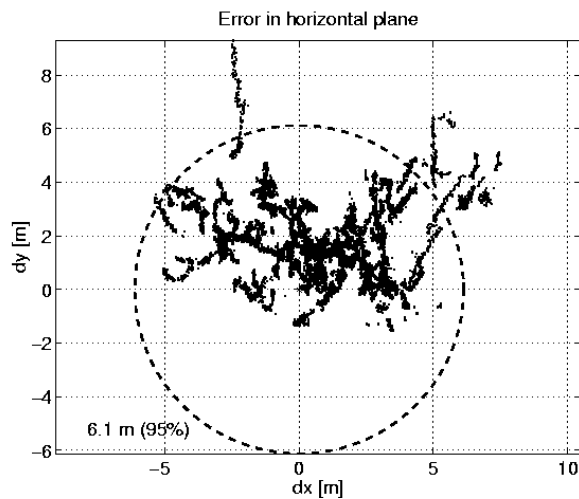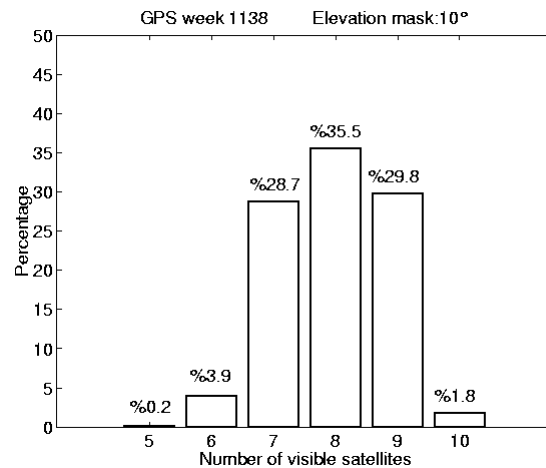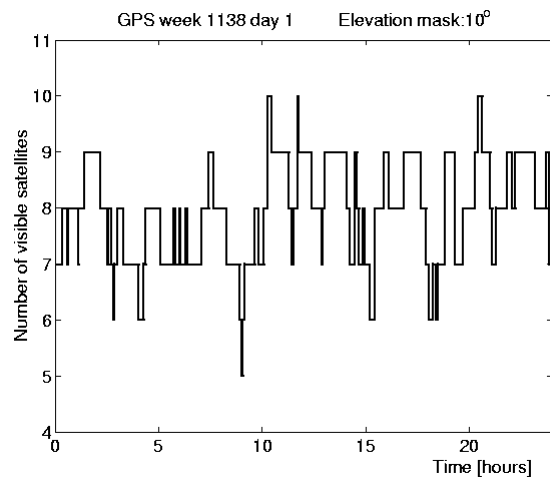
Conclusion

The GPS simulation package for MATLAB was designed with the idea of teamwork and cooperation. In case any reader finds this article interesting, feel free to contact the author on his e-mail address. The author will be very pleased to share the results of his effort.

Literature:

[1] HRDINA, Z., PÁNEK, P., VEJRAŽKA, F.: *Rádiové určování polohy, družicový navigační systém GPS.* Vydavatelství ČVUT, Prague, 1999.

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[3] SEIDL, L.: *Analýza chyb v GNSS.* [PhD thesis]. ČVUT FEL, Prague, 1999.

[4] TETEWSKY, A. K., SOLTZ, A.: *GPS MATLAB Toolbox Review.* GPS World, 1998, 7, s. 50 – 56.