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Simulation of EGNOS Navigation Data for Vehicles

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Abstract: *In this paper, a software tool developed in Matlab for simulation of navigation data, which are representative of EGNOS satellite based system, is presented. Each run simulates data, which describe different (with random accelerations) vehicle motion scenarios. The navigation system error is modelled also as random process, based on preliminary accomplished statistical analysis of the EGNOS error process. For this purpose many error realizations are extracted from the real data measured by EGNOS monitoring station placed in the Technical University of Sofia. Information from specialized literature is also used.*

The designed software tool is intended for the researchers in order to help them analyze by Monte Carlo approach, the performances of different algorithms for additional navigation error reduction.

Keywords: *Satellite based navigation systems, Monte Carlo simulation analysis.*

1. Introduction

The development and completion of the Global Positioning System (GPS) was the most significant navigational achievement of the 20th century. GPS allows users to know their location anywhere on Earth thereby opening up multiple possibilities for various applications. Unfortunately, the accuracy and level of confidence the user can obtain by stand-alone GPS do not meet many navigation requirements. This is a result of some design characteristics and possible failures of system's satellites. Moreover, signal propagation can be delayed by environmental phenomena (ionosphere, troposphere, environmental noise), sometimes significantly degrading the accuracy of computed position. A GPS user can expect a position accuracy of 20 up to 40 m.

All the techniques used to improve GPS data provide additional information from a complementary system, “augmenting” both the accuracy and quality. The European Geostationary Navigation Overlay System (EGNOS) is a wide area Satellite Based Augmentation System (SBAS) which broadcasts “augmented” GPS data over the whole continent. SBAS uses a combination of specialized satellites and ground-based stations to send correction signals to GPS receivers, as well as to provide integrity information for each satellite's signal and thereby to improve the accuracy of the GPS signal approximately 5 times. For applications that require a high level of confidence in the computed position the additional navigation data improvement is desirable. That is why some manufacturers (u-blox, Trimble, Motorola, etc.) offer receivers which give the possibility of firmware upgrades. Such toolkits are not always available to the researchers.

In this paper, a software tool developed in Matlab for stochastic simulation of navigation data, which are representative of many currently available EGNOS receivers, is presented. It is intended for the researchers in order to help them analyze by Monte Carlo approach, the performances of different algorithms for additional navigation error reduction.

2. Vehicle trajectory simulation concept

In this work horizontal position data, estimated by EGNOS receiver are of interest. These navigation data are obtained using the measured data on North-East plane. Because of this the simulated vehicle position data are decoupled into two independent channels: north and east.

Each trajectory realization presents vehicle motion random scenario. During a 30 minutes time period, six velocity changes are realised by normal distributed values of acceleration which acts for 4÷10 s. The maximum velocity value on North-East plane is 65 m/s. The sampling period is user selectable, as in real EGNOS receivers.

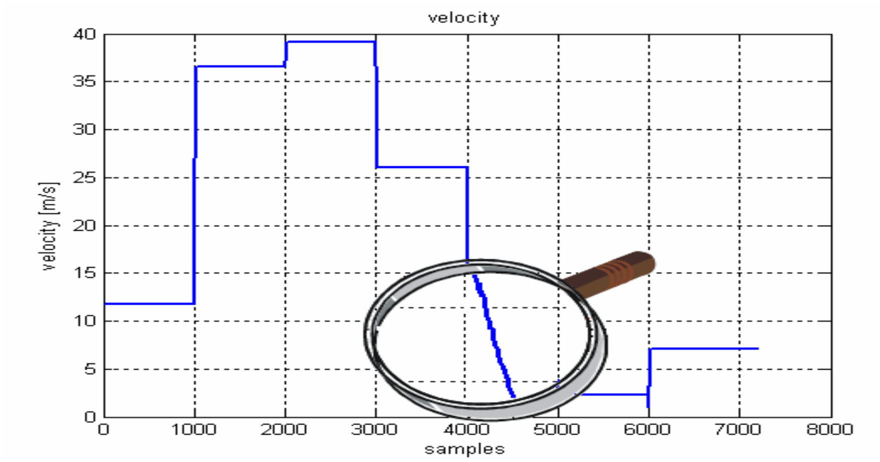

Fig. 1. Example for simulated vehicle velocity values

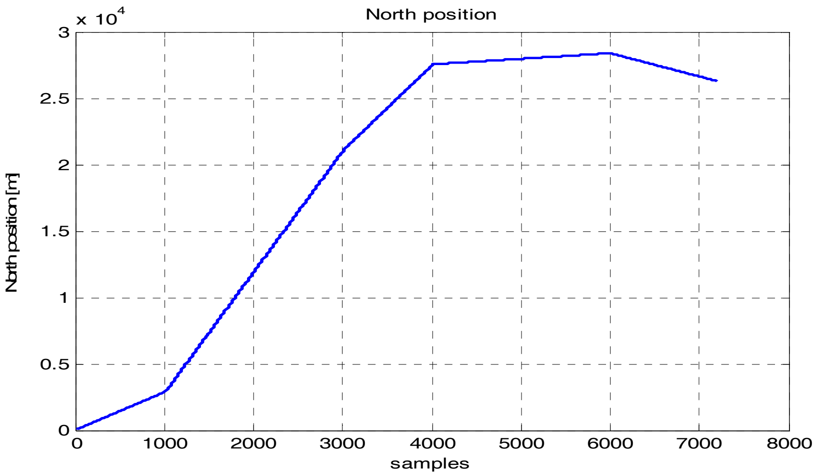

Fig. 2. North direction trajectory

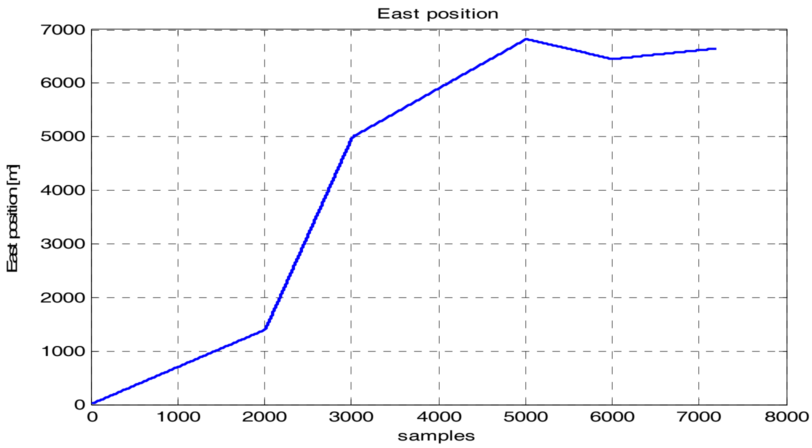

Fig. 3. East direction trajectory

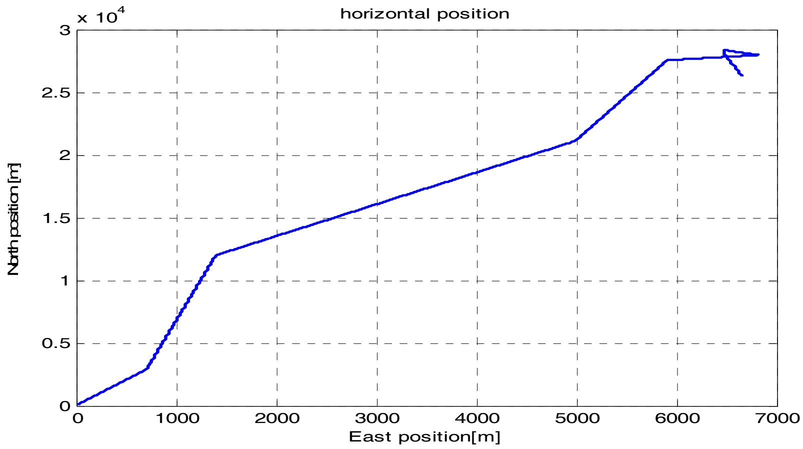

Fig. 4. Horizontal plane trajectory realization (for the velocity scenario presented in Fig. 1)

Fig. 5. Another realization of horizontal plane trajectory

Fig. 1 shows one realization of the vehicle north-east velocity model. The sampling period is T = 0.25 s. Without any restriction on the results, the simulated trajectory always begins at the origin of the Cartesian coordinate system. It must be noted that for navigational use the World Geodetic System (WGS84) defines a reference frame for the earth. Figs. 2-4 show the trajectory curves in north and east directions and horizontal plane respectively for the velocity scenario presented in Fig 1. Fig. 5 shows the resulting trajectory for another software tool run. The sampling period is T = 1 s.

3. Simulation of the navigation error processes

To create an adequate model of Navigation System Errors (NSE), Information from specialized literature presented in [1-4] and real statistical data are used. In 2003, in the frame of the activities in preparation for the future operational validation, EGNOS monitoring stations have been set up at six different universities geographically distributed around Europe. One of these stations is placed in the Technical University of Sofia. The precise position of the antenna phase center was determined on the basis of 24-hours data collection. The so obtained coordinates are used for navigation errors extraction. As a part of data monitoring, error statistics are investigated. For this purpose three receivers (Septentrio, NovAtel and u-blox) with different performance features are used.

The acquired knowledge and statistical results are a good basis for the design of the position error simulation model. Fig. 6 shows realizations of the position errors in the east and north channels. The sampling period is T = 1 s. According to [3] the Gaussian distribution is an upper bound on the true error distribution in each channel. That means that the error distribution on the horizontal plane is assumed to be Rayleigh distributed. Distribution of process, compounded of two orthogonal, independent and normally (Gaussian) distributed processes. The error mean values vary in time but are close to $0\,\mathrm{m}$. The error variance varies in the range 0.25÷3 m when system work “within tolerance limits” is simulated. From 1275-th to 1335-th second the system is assumed to be “out of tolerance limits” with a hundred times bigger error variance. In this way non-integrity event due to multipath, ionospheric storms, bad satellite geometry, etc., is simulated. It is expected that with the final EGNOS operational system these kinds of anomalies will rarely happen.

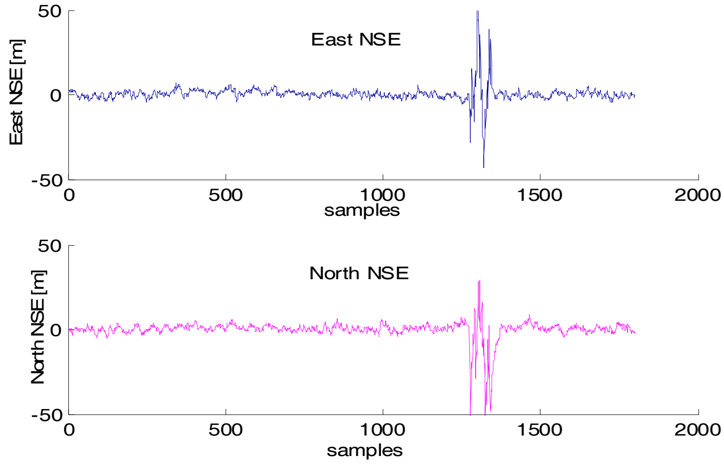

Fig. 6. Realizations of the position errors in the East and North channels

The conducted experimental tests show that the exponential correlation function with coefficient $\alpha = 0.12$ is a good approximation of the EGNOS position error correlation ($\exp(-\alpha|T|)$). This correlation function model is basic for the position error simulation algorithm [5, 6].

Fig. 7 shows two sections of horizontal plane trajectory realization. They represent the cases when navigation system works "out of tolerance limits" (a) and "within tolerance limits" (b).

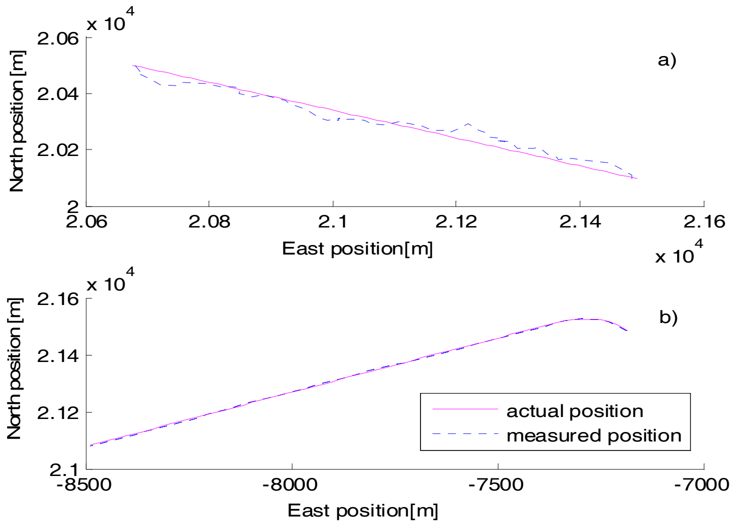

Fig. 7. Two sections of horizontal plane trajectory realization

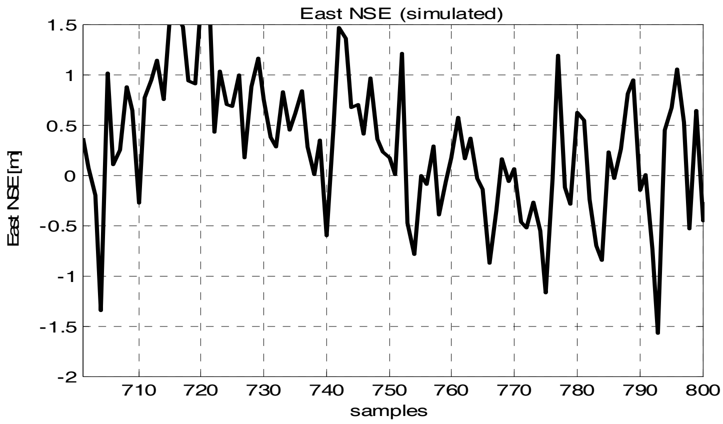

Fig. 8. Simulated EGNOS East position errors

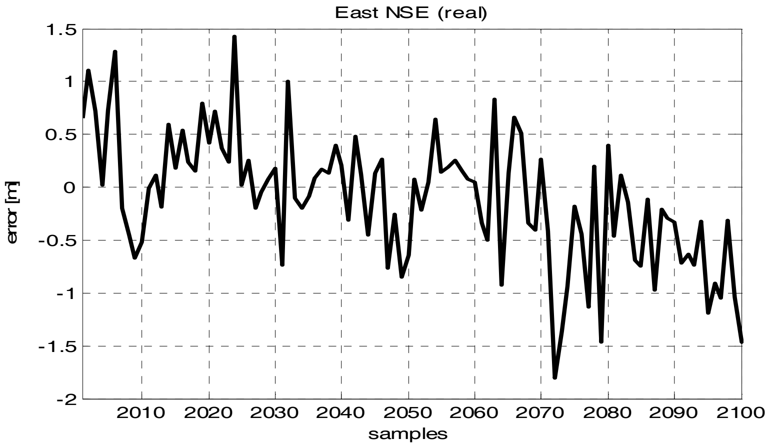

Fig. 9. Real EGNOS East position errors

Figs. 8 and 9 shows samples of simulated and real East NSE, respectively. They illustrate the simulation model adequacy.

Conclussion

EGNOS is one of the keys to manage transport in Europe. It will increase both the capacity and safety of transport. EGNOS can also be a good tool for Road Management. Examples include virtual tolling, Highway emergency alerts and so on. For applications that require a high level of confidence in the computed position (such as safety-of-life applications) the additional navigation data improvement is desirable. The designed software tool is intended for the researchers in order to help them analyze by Monte Carlo approach the performances of different algorithms for additional navigation error reduction within the user receivers.

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