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Analysis of the usability of the global positioning system

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ABSTRACT

Thus, the general objective seek to highlight the importance of analyzing the usability of the Global Positioning System. The specific objectives seek to describe what GPS is, show its principle of operation and, finally, address, through a descriptive study, the general splitting of errors for the Global Positioning System. The method adopted in the formulation of this work is in agreement with the study proposal, which is adequate due to the objectives to be achieved. The development of science is based on the achievement of results that allow us to validate hypotheses about a certain event or fact, present in our lives or not. It was concluded that the error analysis of the Global Positioning System is a complex process, which must take into account many variables. First, it is necessary to distinguish between the analysis of the ground segment and the space segment, being an essential information in the calculation of the positioning.

Keywords: science. space. global positioning system.

INTRODUCTION

In telecommunications, the Global Positioning System (GPS) positioning system is a US military satellite navigation and positioning system. Through a dedicated network of artificial satellites in orbit, it provides a mobile terminal or GPS receiver with information about its geographic coordinates and its time in all weather conditions, anywhere on Earth or in its surroundings where there is an unobstructed contact with to at least four system satellites. The location is done by transmitting a radio signal by each satellite and processing the signals received by the receiver [1].

It is operated by the government of the United States of America and can be accessed free of charge by anyone with a GPS receiver. Its current degree of accuracy is of the order of a few meters, depending on weather conditions, availability and position of satellites in relation to the receiver, quality and type of receiver, from the effects of radio propagation to the radio signal in the ionosphere and troposphere (eg refraction) and the effects of relativity [2].

The GPS project was developed in 1973 to overcome the limitations of previous navigation systems, integrating ideas from several earlier systems, including a series of classified studies from the 1960s. The GPS was created and built by the United States Department of Defense (USDOD) and originally had 24 satellites. The system became fully operational in 1994 [3].

In 1991, the USA opened the service to the world for civilian uses under the name of SPS (Standard Positioning System), with specifications different from those reserved for use by the US military forces called PPS (Precision Positioning System). The civil signal was intentionally degraded through Selective Availability (SA) which introduced intentional errors in the satellite signals to reduce the detection accuracy, allowing accuracies in the order of 900-950 m [1].

This signal degradation was disabled in May 2000 by an ordinance of the President of the United States, Bill Clinton, thus making the current accuracy of about 10–20 m available for civilian uses, even if there are differences between the two systems described below. To avoid mounting them in missiles, some limitations must be present in models for civil use: maximum 18 km for altitude and 515 m/s for speed. These limits can be overcome, but not at the same time [2].

Within this context, this work will seek to answer what is the importance of analyzing the usability of the Global Positioning System?

Thus, the general objective will seek to highlight the importance of analyzing the usability of the Global Positioning System. The specific objectives will seek to describe what GPS is, show its principle of operation and, finally, address, through a descriptive study, the general splitting of errors for the Global Positioning System.

Aiming to contribute to the academic world, this research is justified by its rich contextualization regarding the theme, adding or reinforcing the existing knowledge in the literature on the subject addressed here.

In addition, the research is also justified by its contextual presentation that simplifies the theme, adding to its social environment, where people even without technical knowledge on the subject can understand and know the scenario presented, thus, the population can be informed about the which is addressed in this research.

The method adopted in the formulation of this work is in agreement with the study proposal, which is adequate due to the objectives to be achieved. The development of science is based on the achievement of results that allow us to validate hypotheses about a certain event or fact, present in our lives or not.

Research is of fundamental importance for the evolution of knowledge in a given field of study, that is, through research it is possible to broaden the horizons of knowledge on a given topic.

METHODOLOGY

This research was developed through the descriptive case study, starting from the general understanding of the subject, seeking to describe the facts or situations and provide knowledge about the studied phenomenon and prove or contrast the relationships evidenced in the case. This type of study aims to explain the content of the premises.

Descriptive research is used to describe characteristics of a population or phenomenon under study. Does not answer questions about how/when/why the features occurred. Instead, it addresses the question of "what" (what are the characteristics of the population or situation being studied?) The characteristics used to describe the situation or population are usually some sort of categorical schema also known as descriptive categories.

Thus, descriptive research cannot describe what caused a situation. Thus, descriptive research cannot be used as the basis for a causal relationship, in which one variable affects another. In other words, descriptive research may have a low internal validity requirement.

This research project will be carried out by the non-experimental typology, as there will be no influence or manipulation of data by the researcher, where the variables of interest to the study will be observed or measured.

The research as a data collection instrument will be bibliographical. Since the use of bibliographic research is related to the fact that the study uses many bibliographies from different authors to highlight the importance of this research project.

RESULTS AND DISCUSSION

The positioning system consists of three segments: the space segment, the control segment, and the user segment. The United States Air Force develops, manages, and operates the space segment and control segment [4].

The space segment includes 24 to 32 satellites. The control segment consists of a master control station, an alternate control station, several shared and dedicated antennas and monitoring stations. Finally, the user segment is composed of GPS receivers [5].

Currently, 31 active satellites are in orbit in the GPS constellation plus a few deactivated ones, some of which can be reactivated if necessary. Additional satellites improve system accuracy by allowing for redundant measurements. As the number of satellites increased, the constellation was modified according to a non-uniform pattern that was more reliable in the case of simultaneous failures of several satellites [4].

The working principle is based on the spherical positioning method (trilateration), which starts from measuring the time it takes a radio signal to travel the satellite-receiver distance.

As the receiver does not know when the signal was transmitted from the satellite, to calculate the time difference the signal sent by the satellite is of the time type, thanks to the atomic clock present on the satellite: the receiver calculates the exact propagation distance of the satellite from the difference between the time received and that of its own clock synchronized with that on board the satellite, taking into account the propagation speed of the signal. This difference is on the order of microseconds [5].

The clock of GPS receivers is much less sophisticated than that of satellites and needs to be corrected frequently and is not as accurate in the long run. In particular, the synchronization of this clock occurs when the receiving device is turned on, using the information that arrives from the fourth satellite, thus being continuously updated. If the receiver also had a cesium atomic clock perfectly synchronized with that of the satellites, the information provided by 3 satellites would be sufficient, but in reality, this is not the case and therefore the receiver must solve a system of 4 unknowns (latitude, longitude, altitude and time) and therefore requires at least 4 equations [6].

Each satellite broadcasts on two channels: L1, the only one available for SPS service (for civil use), and L2 for exclusive use for PPS service (military use). The carrier frequencies are 1575.42 MHz and 1227.6 MHz respectively, derived from a single oscillator with high clock stability equal to 10.23 MHz which is multiplied by 154 and 120 to obtain the frequency of the two carriers. In the last 5-10 years, some models of GPS receivers for civil engineering use have been able to use the second L2 channel, thus allowing to achieve centimeter accuracy [7].

The purpose of dual frequency is to eliminate error due to atmospheric refraction. On these carrier frequencies, modulated in phase, the navigation message is modulated, which has a transmission speed of 50 bits per second with a numerical modulation of the binary type (0; 1), containing [6]:

- Satellite broadcast time (satellite broadcast time).

- Satellite effemeridi (satellite ephemeris).

- Degree of satellite functionality (satellite health (SIS).

- Relativistic Satellite Clock Correction (Satellite Clock Correction).

- Signal delay effects due to the ionosphere (ionospheric delay effects).

- Correlation with Coordinated Universal Time (UTC) as specified by the United States Naval Observatory (USNO).

- State constellation (constellation status).

The function of the on-board receiver is, firstly, to identify the satellite through the code database it has; in fact, each satellite has a code, thanks to which the receiver identifies it. The other important function of the receiver is to calculate the delta t, which is the time it takes for the signal to arrive from the satellite to the receiver. It is obtained from the measurement of the slip necessary to adapt the bit sequence received by the satellite to the identical one replicated by the on-board receiver [7].

Each satellite transmits the almanac (approximate orbital parameters) of the entire constellation and exclusively the ephemeris that concern it. The ephemeris part lasts 18 seconds and repeats every 30 seconds. It takes 12.5 minutes to completely download the almanac of the entire constellation [2.]

In this way, the GPS receiver, when performing the Doppler counting, receives the parameters of the orbit from which the satellite's position is derived: thus, it has all the necessary elements to define the position of the surface in space [1].

User Equivalent Range (UERE) errors are shown in the table. There is also a numerical error with an estimated value of approximately 1 meter (3 ft 3 in.). The table also shows the standard deviations, for coarse/acquisition (C/A) and accurate codes. These standard deviations are calculated by taking the square root of the sum of squares of the individual components (ie, RSS for sum of squares). To obtain the standard deviation of the receiver position estimate, these range errors must be multiplied by the appropriate dilution of the precision terms and then sent via RSS with the numerical error. Electronic errors are one of several degraded accuracy effects described in the table above. When taken together, civil autonomous GPS horizontal positions are accurate to approximately 15 meters (50 feet). These effects also reduce the precision of the more accurate P(Y) code[2].

The term user equivalent range error (EBU) refers to the error of a component in the distance from the receiver to a satellite. These UERE errors are given as ± errors, implying that they are unbiased or zero-mean errors. These UERE errors are then used in the calculation of standard deviations. The standard deviation of the error in receiver position, is calculated by multiplying the Position Dilution of Precision (PDOP) by the standard deviation of the user's equivalent range errors. is calculated by taking the square root of the sum of the squares of the standard deviations of the individual components.

PDOP is calculated according to receiver and satellite positions. A detailed description of how to calculate PDOP is provided in the Geometric Dilution of Precision Calculation (GDOP) section [2]:

$$3\sigma_R = \sqrt{3^2 + 5^2 + 2.5^2 + 2^2 + 1^2 + 0.5^2}\,\mathrm{m} = 6.7\,\mathrm{m}$$

The standard deviation of the error in the estimated position of the receiver, again for the C / A code, is given by:

$$\sigma_{rc} = \sqrt{PDOP^2 \times \sigma_R^2 + \sigma_{num}^2} = \sqrt{PDOP^2 \times 2.2^2 + 1^2}\ \mathrm{m}$$

The error diagram on the left shows the relationship between the indicated receiver position, the actual receiver position, and the intersection of the four surfaces of the sphere.

CONCLUSION

It was concluded that the error analysis of the Global Positioning System is a complex process, which must take into account many variables. First, it is necessary to distinguish between the analysis of the ground segment and the space segment. Another important distinction is between errors related to satellite orbitography, synchronization errors, errors related to the propagation of signals towards the ground and those caused by electronics. Errors due to electronics, such as delays that signals are subjected to in circuits, are often handled through direct hardware calibration and testing. A limitation of this management stems from the possible degradation of the hardware over time, which launching into orbit or exposure to cosmic rays and solar wind can cause.

Errors related to signal propagation are mainly due to variable and unknown propagation delay, which has as its fundamental cause the rate of free electrons in the atmosphere. This parameter, in turn, depends on the solar wind and cosmic rays. Thus, solar activity can directly affect signal quality and GPS performance. Orbitographic errors, for example those caused by ephemeris errors, are managed with a continuous monitor of the entire constellation of ground segment satellites.

Synchronization errors, in addition to those mentioned above, are largely attributed to on-board clocks, their stochastic behavior and any anomalies. To reduce them, several countermeasures were adopted during the evolution of the system. Firstly, the clocks are redundant on board, that is, there are three or four clocks so that, in addition to responding to the problems of total failure of a clock, the set can guarantee a more accurate measurement of time. Second, improved ground control techniques and improved performance of the clocks themselves have been important elements in error monitoring. Until 2000, the accuracy of civil GPS was intentionally degraded by decision of the US government (Selective Availability).

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