Techniques of GPS positioning for precision agriculture

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Abstract

The analysis was performed to evaluate the accuracy of four GPS acquisition systems. The surveys were conducted by control of the geodesic vertex of GPS net of São Paulo State, Brazil, denominated Botucatu Point. In the first survey the accuracy was determined from autonomous surveys, in a fast way, with a time of reading, except for the Pro-XR, which accomplished readings for posterior post-processing with C/A code between a control station in the São Paulo city and the Botucatu vertex. Another evaluation was with the transport of coordinates from the Botucatu vertex to a place 6.25 km distant. The obtained results were satisfactory for all the investigated systems; therefore, the accuracy of the surveys was according to the specifications of systems, devices and types of accomplished processings.

Key words: global positioning system; accuracy.

Introduction

On May 1st 2000 the U.S. Government announced the desativation of SA (Selective Availability) for 0h (time from Washington, USA) of the next day, improving the accuracy provided by Global Positioning System (GPS), in about ten times. The SA technique affected satellites clocks coordenates, limiting the level of accuracy provided by the system for users that execute the location by point, using measures of simulated distances result from C/A code (MONICO, 2000). From deactivation of SA code, the surveys conducted by GPS on a civil and commercial sphere started to present a higher degree of reliability. This fact provided a qualitative leap in the use of the system for many different purposes, including precision agriculture.

Among the technologies of precision agritulture presented on their work, Legg e Stafford (1998) emphasized that, the American Global Positioning System (GPS, NAVSTAR system), based on a 24-sattely-constelation, is almost worldwide used as a positioning system to precision agriculture (although the Russion system GLONASS has found some applications). According to Soares (1998), the GPS, as a positioner system, is available for use since last century. Although, was only in mid-1994, that it was effectively ready to integrated use in geoprocessing.

Nowadays, with the development of precision agriculture, new techonologies related to GPS are constantly presented, and among them, those about geodesic positioning. However, it is still necessary to clarify which GPSs presents good results in terms of agriculture.

Although, reliable information from DGPS (Differential Global Positioning System) is needed, farmers and service providers still experience interruptions and interference in the GPS signal or in the differential correction signal, creating gaps in sequential data collected, or loss of control of application or alignment. The availability of the Navstar specified (at least four satellites in view at any location) is 99.85%, with a reliability (the system is on service when it needs to be) of 99.97% as Napa (1995), quoted by Pierce e Nowak (1999). However, the authors emphasize the appropriateness of the geometry of the satellites to calculate a solution for positioning, called as dilution of precision (DOP) is a problem in agriculture, where natural or manufactured structures block the view of some satellites by the GPS receiver or interfere with the reception of differential correction. There are also locations in which the geometry has been inapropriate for the required accuracy of positioning in certain periods during the day. In addition to that, Pierce e Nowak (1999) comment that, some GPS signal receptors are vulnerable to interference from unwanted signals from a variety of sources, including agricultural machinery, making the receiver useless on navigation or positioning.

Johannsen et al. (1999) reported that farmers already have available services that involve data from satellites, local transmission of information and supply of data from many sources (sensors on tractors, harvesters or other equipment, sensors on aircraft to assist in surveys of culture, reception or analysis of information received from satellite). The authors also mentioned that, other technologies are also involved in making a successful data collection, analysis and interpretation (GIS for data acquisition and additional information, as soil map or digital elevation model, to support analysis of remote sensing; GPS to locate observations on field, so the computer can associate them to other data; and to increase in communications, such as the Internet to transmit information and other data sets).

Going from this prerogative, an evaluation was developed among four techniques of GPS positioning, along with their receptors, which are: positioning by point or absolute, static relative positioning, differential positioning by Wide Area DGPS (WADGPS) and stand-alone positioning with a correction system to the internal receiver. Surveys were conducted fast, with only one time, simulating the surveys conducted in the field, except with Pro-XR, in which it was obtained three times for post-processing in C/A code and a time for post-processing stage.

Material and Method

Material

The receptors used in the evaluation were: a GARMIN®, eMap model – a receptor that tracks only the C/A code, with horizontal precision in order of 10 m, in a level of probability of 95%; a pair of TRIMBLE® receptors, Pro-XR model- both track the C/A code and the L1 carrier frequency, with centimeter accuracy on the relative mode; a SOKKIA AXIS-3 –GPS receptor with L1 carrier frequency and WADGPS correction, with sub metric precision (DRMS), a TRIMBLE®, AG-132 model – GPS receptor, with L1 carrier frequency and with firmware from Trimble installed to eliminate the correction through WADGPS. All the evaluated receptors have 12 parallel channels.

The Botucatu Point (BC) was taken as control points, to the Geodesic vertex from São Paulo state, and the vertex I.8.1. It was also used a control station placed in São Paulo city, 200.5km far from the BC point and 198.8km from the I.8.1 vertex. This station has a CBS TRIMBLE receptor, with 12 channels, with L1, compact L1 antenna with earth plan. The SP station is located in the following coordinates in WGS – 84: latitude of 23°37`06,245581" S (UTM N = 7.387.019), longitude of 46°40`36,293557``W (UTM E = 328.940) and altitude of 803.09m (HAE). The survey was conducted in Botucatu city, São Paulo state, Brazil.

Method

The first survey was conducted over the BC point, getting one time (reading) to each receptor. With TRIMBLE Pro-XR was taken three different times. The first receptor evaluated was eMap, next, it was AG -132, the Axis – 3 and by last it was Pro-XR. The total time with these readings was 4 minutes. The survey time was the shortest possible, with the purpose to match the reading conditions of all receptors, meaning that, with the same 7 satellites and with PDOP of 2.3. This situation also aims to repeat the finding conditions in different activities of precision agriculture. With the Pro-XR, three times were gotten, that were processed with SP station from the C/A code.

The survey of the second point was performed along with the I.8.1 vertex. These surveys were in two phases, where the first one was performed according to the proceders used in the previous survey and the second using a pair of receptors (Pro-XR) to get a static relative positioning from the BC point (Base) and with I.8.1 (Rover). With Pro-XR, three different times were taken, to pos-process with C/A code, and after that, the point was used for one hour to pos-process with C/A code and the carrier frequency. This last techinique of survey was used to correct the coordinates from the mentioned vertex and to use them as a reference to other surveys.

Results and discussions

The discussion of results is based on comparation between the estimated coordinates to the Botucatu point and the coordinates considerate real, accepting the strategies that were previously presented.

In the first survey, differences were found at the UTM plane coordinates, estimated to the BC point, related to the known coordinates of this point for the four strategies of positioning techniques, for a time by GPS equipment. The differences between the UTM obtained coordinates and those already known were lower than 2 meters in vertexes E and N for GPS's Axis-3, AG-132 and Pro-XR. However, to the eMap the values were lower than 5 meters. In the H (height) coordinated differences were significant between the values obtained by different equipments, varying from 0.85 cm obtained by Pro-XR, to 13.52 m, determined by eMap.

The higher values to the coordinate H can be explained with the fact that, this coordinate has an error of 40% average, higher than planimetric coordinates.The other factor that changes the obtained results, are the used algorithms to model the data, because the GPS's used are essentially different and they use different solutions to determinate these coordinates.

Table 1 shows the values of these different planimetric positions (E and N) compared to the BC point, meaning, the direct distances of obtained coordenates by GPS's until the considerated as true coordinates to the BC point.

The results presented in table 1 confirm a certain equivalency between GPS's Axis-3, AG-132 and Pro-XR. Only the eMap GPS provided a difference of 7.19 m, which is within the characteristics of the equipment.

Table 2 shows the behavior of plane UTM coordinates (E, N and H) on the vertex coordinates estimated for I.8.1.

Analyzing the results of E and N coordinates obtained by GPS's Axis-3, eMap and AG-132, we can observe that they maintained the standards of accuracy of the previous survey. However, the Pro-XR achieved an improvement in the level of accuracy of positioning. The improvement can be explained by analysing the three different processing strategies: the third was processed with the BC point using only 3 times, but the distance between the points were only 6.2 km, and therefore, we concluded that, the effects of the ionosphere were considerably reduced; the second strategy was similar to the third, but it was used the SP base, 198.8 km away, and we find a greater influence of the effects of the ionosphere, mainly on the determination of coordinate N; the first strategy obtained the best accuracy, even when it was processed with the SP base, but the time of occupation was 1 h, providing thus, a greater amount of data to determine the coordinates and minimizing the effects of the ionosphere.

The coordinate H presents higher values, which can be a result of higher PDOP than the previous survey, around 3.1, influencing the VDOP. Only the fisrt strategy obtained better accuracy,

Table1. Planimetric differences to the coordinates E and N to the BC point.

GPS	Planimetric differences (m)
AG-132	1.02
Pro-XR	1.18
AXIS-3	1.94
eMap	7.19

Table 2. Differences in position near the I.8.1 vertex.

GPS	E (m)	N (m)	H (m)
Pro-XR C/A 1h SP	-0.056	0.236	0.635
Pro-XR C/A SP point	-0.229	-1.997	15.850
Pro-XR C/A BC point	0.203	-0.685	16.305
AG-132	0.996	-4.221	8.695
AXIS-3	1.942	-1.858	9.745
eMap	4.462	-7.848	10.745

Table 3. Differences in relation to estimated coordinates to the I.8.1 vertex.

GPS	Distances (m)
Pro-XR C/A 1h SP	0.243
Pro-XR C/A SP point	2.010
Pro-XR C/A BC point	0.714
AG-132	4.336
EMap	9.028
AXIS-3	2.688

because with a higher time of occupation resulted in better satellites geometries.

Table 3 presents the grafic of differences from planimetric positions (E and N) related to the corrected coordinates to I.8.1 vertex, which means that, the direct distances of the obtained coordenates by GPS's until the considerated coordinates as corrected and true for I.8.1. vertex.

The decrease of accuracy in the last survey, for the GPS's Axis-3 and AG-132, can be explained due to the increase in PDOP. However, the Pro-XR has remained consistent, except in the second strategy, which was processed on the SP base, where the distance between the points, the atmosphere and the time of reading influenced the outcome of the positioning.

Conclusions:

The most used technique in precision agriculture and in surveys of big areas is the WADGPS. Nowadays, a new positioning techinique was released into the market and is used by AG-132 with *firmware* by TRIMBLE. It is possible to conclude that, despite the techinical differences of positioning between GPS's Axis-3 and AG-132, they got satisfactory and similar results in both surveys.

The GPS's Axis-3 and AG-132 approach in accuracy to Pro-XR, depending on the technique of positioning and strategy of pos- processing used.

Nowadays, with the deactivation of SA, the ionosphere refraction is the most important source of error to position by point, when used receptors of simple frequency of L1.

With the deactivation of SA, the measures of pseudo distances obtained by the C/A code improve by 10 times, providing a more often use of navigation GPS's (C/A code), even in precision agriculture, because frequently the scales demanded to certain works grant total conditions to its use.

The choice of GPS for use in the agriculture field will depend on the goals of the work. Although, most of procedures from precision agriculture require an instantaneous positioning of a point, in this way, the GPS's that offer techniques of positioning in real time are the best ones, at the expense of providing better accuracy, but they need post-processing.

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