DISPERSION OF GLOBAL POSITIONING MEASUREMENTS IN REAL-TIME CORRECTION NETWORKS

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Abstract

Global positioning (GP) plays an important role in our modern world, especially in geodesy. GP is used in the cadastral survey and topographic survey. There are confirmed laws in Latvia that define the accuracy with which the survey job must be done. For example, in the cadastral surveying, the acceptable error of the border point position in relation to the geodetic net must be between 0.03m and 0.10m, depending on the position of the border point (city, village or field). At topographic survey works, the difference between two coordinates of points cannot exceed 5 cm and the height – 3 cm, during the repetitive measuring in areas where the visibility is clear. These are very high requirements, thus measuring with GP must be done with tested tools and specific methods. Because of this, there was an idea to conduct an experiment to test the precision and abilities of few GP tools from different brands.

Key words: Global Positioning, errors, experiment, different brands

Introduction

This paper examines the process of the scientific experiment "GPS measurements during an active ionosphere”. It analyzes the experiment data, examines measurement data scattering and describes its possible causes.

Materials and methods

January, 2012 a scientific experiment on *GPS measurements during an active ionosphere* was conducted at *Tīreļi,* G3 class point No. 3 in the vicinity of Bridge of Lielupe on the Rīga – Liepāja highway (see Figure 1).

Figure 1. A Map of the Experiment locale

If one describes the location of the experiment in relation to correction network base stations, the surveyed area was approximately 35 km away from the LatPos and Trimble stations in Riga, 30 km away from the LatPos base station in Dobele and relatively closer to the Trimble base station of Jelgava – 23 km away.

The weather was favourable for the purposes of the experiment. The air temperature was around -3 centigrade and wind velocity was minimal.

The research was conducted in a plain field in order to avoid the interference of nearby objects that could introduce additional error to the measurements and increase the inter-non-correlation of the measured data.

The principal hosts of the experiment were Department of Land Survey and Geodesy of Latvia Agriculture University in collaboration with Trimble representatives in Latvia – GeoStar (see Figure 2). In order to obtain a large and varied volume of data in the course of the experiment with the use of geodesy tools produced by Global positioning equipment manufacturers, the hosts invited representatives of various land surveying companies. Thus the experiments were conducted with three different GNSS receivers.

Figure 2. Experiment participants and the used GNSS receivers in action

Author's contribution in the present case is the result of the experiment yielded data summary, which shall offer an analysis and a detailed description of the strengths and weaknesses of the each tested real time correction network at the specific time.

Upon commencing work with the laser beam of the electronic tachymeter, an alignment towards the centre of the surveyed support centre is performed. It is followed by attaching a rail specifically produced for the purposes of the experiment, which is then set in an S – N direction and levelled. GNSS receivers are then mounted on the attached rail with 25cm intervals between each other.

GNSS tools were used simultaneously in the course of the experiment. Also a land surveyor with a Topcon Hiper GGD receiver was present at the experiment; however, the tool was not used for data collection due to the fact that it was impossible to connect the device to the internet for unknown reasons. Two identical Trimble receivers were placed on either end of the metal rail were used on additional basis to control the receiver location on the rail as well as to compare measurements conducted in both correction networks.

Automatic measurement mode was used for the purposes of data collection with all geodesy instruments making simultaneous measurements of 50 separate points registering them at an interval of one second, after which a reinitialization of the instruments. When a certain number of points have been measured within a single correction network, all instruments, except for one Trimble R8 receiver which was operating on Trimble VRS Now TEC network for the duration, switched to other correction networks and repeated the entire procedure.

In order to ensure a faster and more comfortable reinitialization of the GNSS receivers between measurement stages, a special cover was produced from metal sheets, which was then used to cover all receivers simultaneously after the measurement of each 50 points was completed; additionally, the cover was also grounded connecting it the a metal beam in the ground via a wire. The solution was highly effective – the reinitialization of the tools took less time.

As a result of the said experiment, a total of 1250 points were measured with each GNSS receiver, first 500 of them were in Trimble VRS Now TEC network with GPS+GLONASS correction, the following 250 points were measured in LatPos network with NETW IMAX correction. The next 250 were conducted in LatPos network with NS v3.0 GLONASS by automatically connecting to the closest base station, but the final 250 were measured at the LatPos network without the use of GLONASS satellites with SITE correction.

The measurement procedure took place with no significant interruption both in Trimble and LatPos correction networks.

Results and discussion

Prior to the commencement of the analysis, constant values are added to the coordinates based on the location of the instrument in relation to the centre of the stand. The mounting positions on the rail on which the GNSS receivers were mounted were spaced with 25 cm steps away from the centre of the rail. Considering, the condition that the rail was aligned in N-S direction, most correction was made to Y coordinates, while X coordinates and heights were subject to minimum correction.

Provided that certain registered points are of highly erroneous nature a visual representation, of the point distribution, approximated, to the majority of the points is presented in Figure 3.

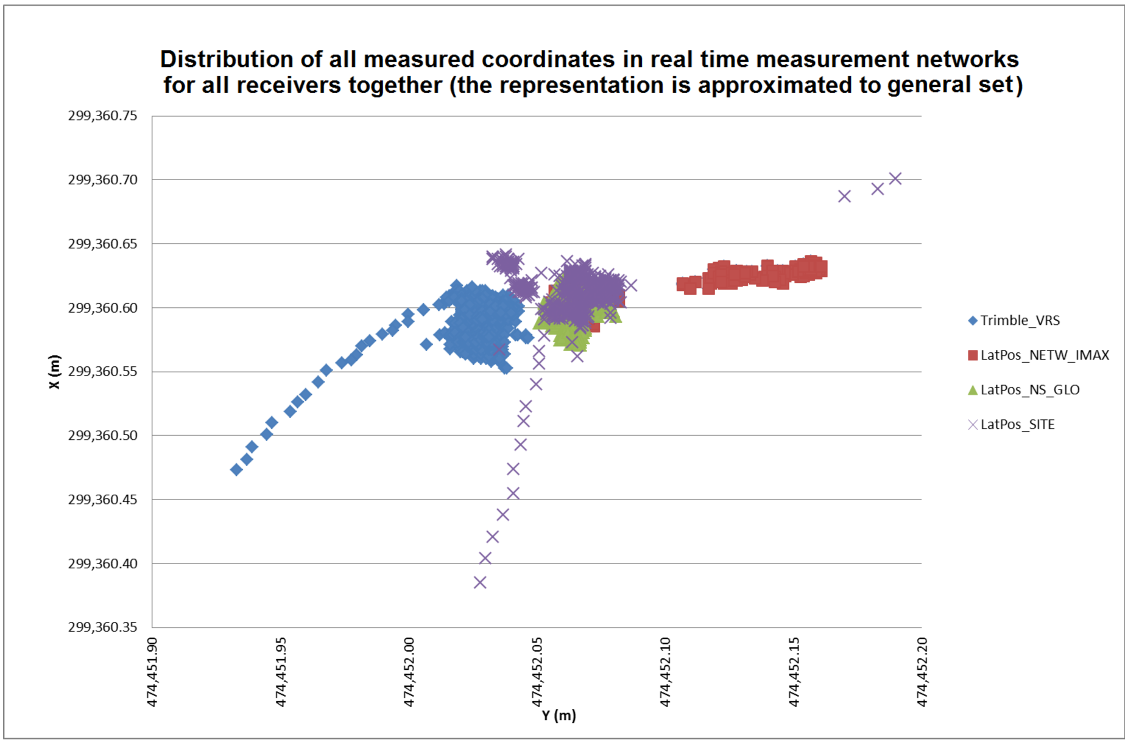

Figure 3. Distribution of all measured coordinates within real time correction networks (representation approximated to the general set)

Firstly, with the use of the obtained data the coordinate distribution range registered by instruments in each correction network are calculated, as well as the standard deviation of the data sets is determined. Applying standard deviations of the group relative to arithmetical mean did all calculations. Standard deviations, was calculated using formula:

$$S = \sqrt{\frac{\sum_{i=1}^{n}(l_i - \bar{l})^2}{n-1}} . \qquad (1)$$

Where *l* is x,y or h value of each baseline solution of the group.

Upon completing the aforementioned mathematical calculations, it is possible to review the quality of the obtained data.

Upon reviewing the calculated values of table 1, one may immediately conclude that the data set obtained with the use of various tools in various corrections represents mutually significantly different values or a high distribution of points around the mean arithmetic value which is indicated by the high standard deviation.

Table 1. Calculated standard deviation, m

	Trimble R8 No. 1			Geomax		
Correction network	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	0.005	0.004	0.011	0.723	0.781	1.003
LatPos TR_Netw_Imax	0.037	0.012	0.009	0.003	0.004	0.013
LatPos TR_NS_v3_GLO	0.004	0.005	0.012	0.004	0.007	0.012
LatPos TR_SITE	0.006	0.010	0.028	0.023	0.052	0.125
	Ashtech			**Trimble R8, No. 2**		
	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	0.005	0.005	0.008	0.004	0.005	0.013
LatPos TR_Netw_Imax	0.003	0.002	0.011			
LatPos TR_NS_v3_GLO	0.006	0.004	0.010			
LatPos TR_SITE	0.015	0.011	0.035			

For the purposes of calculating measurement error, one must first establish the primary sources of such errors. in the specific experiment gross mistakes were practically excluded because the measurement process was highly automated, thus avoiding any incorrect indications by the measurement tools or recording incorrect results as well as the possibility of similar mistakes were excluded in the same manner.

However, notwithstanding the above, a gross technical error had arisen in the correction of GeoMax GNSS receiver Trimble VRS Now TEC network. This phenomenon could be explained with the fact that the receivers used in the measurement were not applied with any measurement point registration filters that would filter out data with slight and even gross error. In the result of that, the data set shall contain points that will highly differ from the expected result. For the purposes of reliable error detection, the erroneous data shall be discarded in the following estimates.

In order to calculate the eventual error of the measureable value, the mean squared deviation must be multiplied with Student coefficient for the number of made measurements at 95% reliability possibility. The estimated values of eventual errors are presented in Table 2.

Table 2. Estimated values of eventual errors (m)

	Y	**X**	**H**
Trimble R8 No.1	0.002	0.001	0.002
Geomax	0.000	0.000	0.001
Ashtech	0.001	0.000	0.003
Trimble R8, No.2	0.001	0.001	0.002

In order to provide a clear representation of the similarities and differences of various correction networks, it was assumed during calculation that base station errors are equal within all correction networks, thus such errors are not added during calculation. It was concluded while calculating the systematic error at 95% reliability probability that the systematic error of all tools used during the experiment make up an error of +/-0.011m.

Upon comparing the values of eventual and systematic errors it was concluded eventual error is at least three times as large as the systematic error and thus it is deemed the absolute error of the measurement.

It was established during a closer review of measured data that in essence all tools have registered in the respective correction network to a greater or lesser extent a statistically reliable set of data. The calculated values in Table 1 indicate towards the fact the specific data in its current state may not be used, in fact is it of a very unstable nature if one considers the fact that due to unknown reasons data from separate initializations (in groups of 50), suddenly differ from the expected or previous recorded data. It is observed in the calculated distribution range of Ashtech Pro Mark 800 with LatPos TR_SITE correction, where the present value significantly differs from other calculated values.

Upon considering the previous observation and basing on the extent of the systematic error the erroneous initialization data sets of whom the standard deviation of the general set exceeded +/- 20 mm were filtered out. In the specific case the marginal value of the standard deviation was increased to the possible base station error values, which should not exceed the error of the measurement instrument. Upon filtering out the erroneous initialization data sets and recalculating the registered data distribution range of each receiver as well as the standard deviation, the characteristic values as per Tables 3 and 4 are subsequently obtained.

Table 3. After filtering out erroneous data – calculated distribution range - m

	Trimble R8 No.1			**Geomax**		
Correction networks	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	0.020	0.021	0.058	0.026	0.024	0.059
TR_Netw_Imax	0.020	0.021	0.045	0.016	0.029	0.087
TR_NS_v3_GLO	0.021	0.026	0.054	0.017	0.037	0.063
	Ashtech			**Trimble R8, No.2**		
	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	0.035	0.040	0.049	0.021	0.031	0.075
TR_Netw_Imax	0.015	0.012	0.050			
TR_NS_v3_GLO	0.026	0.018	0.043			

After filtering out data, it was established that the amount of data recorded in LatPos TR_SITE correction is subjected to restrictions in terms of further successful analysis. Due to the aforementioned reason, this correction shall not be included in the further data review.

Any further calculations in the work are conducted based on the measured data set where as a result of unsuccessful initialization the erroneous data were filtered out.

Table 4. After filtering out erroneous data – calculated standard deviation – m

	Trimble R8 No.1			**Geomax**		
1	2	3	4	5	6	7
Correction network	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	0.005	0.004	0.011	0.006	0.005	0.009
TR_Netw_Imax	0.016	0.005	0.010	0.003	0.004	0.013
TR_NS_v3_GLO	0.004	0.005	0.012	0.004	0.007	0.012
1	2	3	4	5	6	7
	Ashtech			**Trimble R8, No.2**		
	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	0.005	0.005	0.008	0.004	0.005	0.013
TR_Netw_Imax	0.003	0.002	0.011			
TR_NS_v3_GLO	0.006	0.004	0.010			

One may conclude upon making a comparison between the calculated standard deviation with the information provided in the technical specification of the tool that the accuracy rated by the manufacturer matches the observations made.

A mean arithmetic value is calculated for each recalculated data of every instrument in each correction which is subsequently considered the real value of the measured subject (see Table 5).

If one takes a closer look to Table 5, one may see that the measured points within Trimble correction networks differs quite significantly, since multiple times exceeds the estimated mean standard deviation, from the data measured in LatPos network.

It was established with the use of estimated mean coordinate values that if in the course of each geodesy instrument one compares the values obtained within Trimble and LatPos networks, the mean difference amounts to 4 cm on Y axis and 1 cm on X axis.

Table 5. Mean values of Point characteristic quantities, m

	Trimble R8 No.1			**Geomax**		
Correction network	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	474452.032	299360.596	23.695	474452.032	299360.598	23.690
TR_Netw_Imax	474452.071	299360.605	23.702	474452.063	299360.610	23.742
TR_NS_v3_GLO	474452.071	299360.606	23.737	474452.062	299360.604	23.771
	Ashtech			**Trimble R8, No.2**		
	Y (Δ Y)	X (Δ X)	H(e)	Y (Δ Y)	X (Δ X)	H(e)
Trimble VRS Now TEC	474452.029	299360.573	23.662	474452.030	299360.596	23.704
TR_Netw_Imax	474452.067	299360.594	23.727			
TR_NS_v3_GLO	474452.062	299360.584	23.746			

Due to so far unknown causes, the mean values of data registered by the Ashtech receiver exhibits a 2 cm offset on X axis compared to the obtained mean values of the rest of the tools used within the experiment, both in Trimble and LatPos networks.

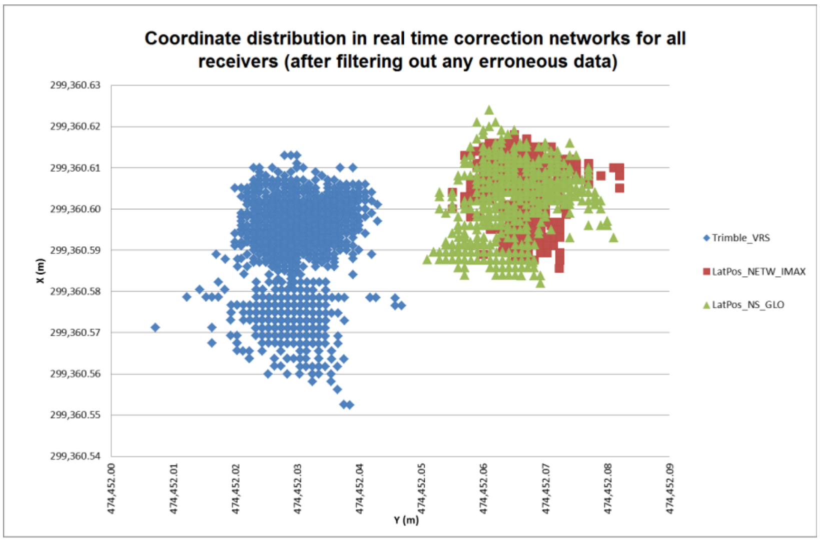

Figure 4. Filtered data coordinate distribution within the real time correction networks

If one looks at Figure 4 or at Annex 3, a clear representation is given of the differences between the reviewed correction networks. An individual illustration of the registered data distribution in each correction network is given in.

While the goal of the research was to study the coordinate distribution on X and Y axis, upon conducting a summary a clear representation with registered high distribution was made with the use of previous filtered data.

While analysing the obtained data it was found in the course of the work that the erroneous data for the most part were made up by data that were yielded due to unsuccessful initialization. In order to be able to assess the frequency of the said aspect for each individual instrument in every correction network an erroneous initialization percentage relation for initializations made by all instruments was calculated (See Table 7).

Table 7. Proportion of Successful initializations

	Trimble R8 No.1	Geomax	Ashtech	Trimble R8, No.2
Trimble VRS Now TEC	100%	50%	100%	100%
TR_Netw_Imax	40%	100%	100%	
TR_NS_v3_GLO	100%	100%	100%	
TR_SITE	100%	50%	80%	

If one assesses the values given in Table 7, it may be observed that in essence unsuccessful initializations maybe observed in for all instruments except for Trimble R8 No.2

receiver, as well as in all corrections, except for LatPos TR_NS_v3_GLO correction network. Subsequently a conclusion may be drawn that in most cases it is not important to focus on the type of instrument or network used, but one must rather pay closer attention to the fact if the initialization of the receivers was successful by verifying it with the point with known coordinates. In the event that incompliance is observed during such verification, the receiver needs to be reinitialized, possibly even multiple times in order to obtain a successful state of initialization.

Thus one must always verify when working with GNSS receivers that the conducted initialization has been successful each time such initialization is lost when one approaches to close to a house, trees, fence or any other large objects or due to other reasons.

The difference between manufacturer's rated success rate of initialization and the observed rate a significant difference may be observed due to the fact that the successful initializations varied from 40-100% compared to manufacturer's rated success rate of 99.9%. However, these values may not be taken unambiguously because one must also take consideration that the reliability of the initialization maybe affected by atmospheric conditions, signal reflection and type of satellite as well as other factors affecting the operation of global positioning systems.

Conclusions

1. The real time correction networks placed in Latvia provide varied sets of measurement results.
2. The accuracy of the geodesy instruments established within the experiment confirms the values rated by the manufacturer.
3. One of the basic reasons behind a high distribution of the measurements is an unsuccessful initialization of the instruments.
4. One may control the distribution of measurements by conducting a verification at a point with known coordinates, which thus characterises the reliability of the initialization.
5. The conditions suitable for the performance of measurements with the use of GNSS equipment is not always of ideal nature thus the 99.9% initialization reliability of the tool is not always observed during field measurements.

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