"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.161
DOI: https://doi.org/10.3846/enviro.2017.161

An Analysis of RTK Network LitPOS Performance

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Abstract. RTK (Real Time Kinematic) method for positioning is used in daily life by different consumers for many purposes. When there are so many measurements, it is essential to know where RTK measurements are concentrated and which stations are obligatory for LitPOS performance. In this paper, using RTK software generated reports and SQL database records, we introduced the geographic information systems show to graphically LitPOS users activity and density of measurements. Using this data we analyze how LitPOS users are divided among Lithuanian municipalities, how much users are working each month and how this affects LitPOS performance. This study is performed in Lithuania, where state wide permanent GNSS reference station network has been maintained since year 2007.

Keywords: GNSS, CORS Network, LitPOS, Real Time Kinematic, geodetic coordinate accuracy.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

The most accurate method for precise Global Navigation Satellite System (GNSS) positioning is Real Time Kinematic or RTK (Talbot *et al.* 1996; Donghyun, Langley 2003). It uses corrections from network or reference stations and is one of the types of positioning state solutions. Others include single point positioning (SPP) (Satirapod *et al.* 2001), precise point positioning (PPP) (Kouba, Héroux 2001), differential GPS (DGPS) (Clark *et al.* 1997) etc. A modern RTK system is made of several separate parts – reference station, mobile received and a radio link. Raw measurements are transmitted to the rover for the integer ambiguity resolution and final coordinate estimation (Wanninger 2017).

However, multiple drawbacks were pointed out regarding the radio link, such as signal interference, short transmission range and other disturbances in communication. Thus protocols for GNSS data streaming over the internet were developed (Dettmering, Weber 2004; Weber *et al.* 2005; McKessock 2007) with one of the most widely adapted being Ntrip. Ntrip was developed in Germany, by Agency of Geodesy and Cartography in collaboration with the University of Dortmund and presented in (Weber *et al.* 2005). Ntrip system consist of three parts: NtripSources, generating DGPS datastreams at specific locations, NtripServers, transferring data in Ntrip format and NtripCaster, the major broadcasting system component. RTK with Ntrip provides real time corrections for high accuracy GPS applications, such as geodetic measurements, surveys etc.

RTK positioning uses carrier phase measurements in differential positioning mode from ideally one epoch (Feng, Wang 2008). It is a process more precise than others existing currently, supplying users with centimeter-level accuracy, but at the same time much more complex. There are differentiating opinions, but overall single-base RTK baseline length should not be bigger than 20km because of ionospheric and tropospheric delays. With growing distance, the instantaneous ambiguity resolution may become unavailable because of increasing noise in measurement data and lacking number of observations for integer selection verification. One of approaches for solving this challenge is Virtual Reference Station (VRS) (Wanninger 2002). Other include Flächen Korrektur Parameter (Wübbena, Bagge 1997), Master-Auxiliary corrections etc. Anaysis and comparison of these methods is presented in (Takac, Zelzer 2008; Berber, Arslan 2013). Interesting research has been done in (Grejner-Brzezinska *et al.* 2005), regarding accuracy of NRTK correction techniques. Various quality indicators were presented in research during years, in (Bisnath *et al.* 2013; Prochniewicz *et al.* 2016) that can be used for further development, experiments and evaluation of service.

RTK method for positioning is used in daily life by different consumers for many purposes. When there are so many measurements, it is essential to know where RTK measurements are concentrated and which stations are obligatory for LitPOS performance. In this paper, using RTK software generated reports and SQL database records, we introduced the geographic information systems show to graphically LitPOS users activity and density of measurements. Using this data we analyze how LitPOS users are divided among Lithuanian municipalities, how much users are working each month and how this affects LitPOS performance. This study is performed in Lithuania, where state wide permanent GNSS reference station network has been maintained since year 2007. Similar research has been done in order to evaluate RTK performance and reveal challenging aspects during years – in Ireland (Martin, McGovern 2012), United Kingdom (Aponte *et al.* 2009) and Latvia (Dobelis, Zvirgzds 2016).

Current situation of LitPOS

LitPOS (Lithuanian Positioning System) is the global position determination system of permanent reference GNSS stations in Lithuania. This network is part of National Geodetic Foundation infrastructure. It allows users to evaluate their position by using RTK, transmitting corrections through communication channels from points of geodetic basis. It uses VRS and Ntrip corrections methods that were explained in previous chapter. LitPOS provides to users a possibility to reach centimeter-level accuracy with single standard rover receiver at any point of Lithuanian territory. LitPOS network consists of 31 station, located evenly in country's territory, and regional management center. The stations are equipted with Trimble NetR9 GNSS receivers and Choke ring antennas. Overall running and management of LitPOS network is executed by Trimble Pivot Platform software. Bigger part of GPS stations are installed in collaboration with Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania. They are set up in fire towers. Average distance in between stations is around 50km. Additionally 9 stations from abroad are incorporated in LitPOS network (3 from Poland and 6 – Latvian). Map of current situation of network is presented in Fig. 1.

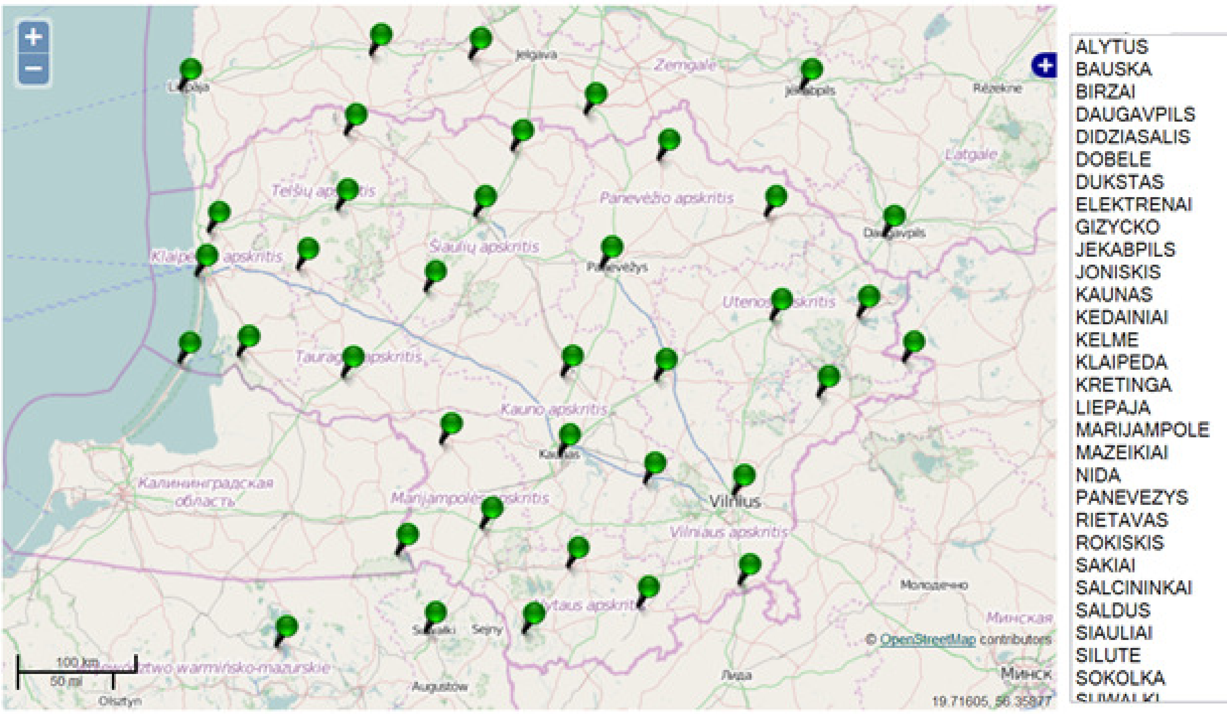

Fig. 1. LitPOS network map

Data streams are transferred in real time from GNSS stations to regional management center in separate data transfer lines. LitPOS network allows to determine position of a particular object in real time by providing corrections via communication channels from fixed points of the network. Users receive geodetic corrections via GSM and GPRS channels.

LitPOS services are provided in RTK (+–2cm accuracy), DGPS (+–0.3m to +–0.5m accuracy), and GPPS (up to 1mm accuracy) methods. Corrections to geodetic coordinates are transferred in RTCM 2.1, RTCM 2.3, RTCM 3.1, RTCM 3.2, CMR, CMR+, CMRx ir DGPS RTCM 2.1, DGPS RTCM 2.3, DGPS RTCM 2.4 formats. In order to receive LitPOS corrections, users have to be registered in LitPOS website and receive username and password. LitPOS uses GPS and GLONASS satellite systems for network solution.

The station covers around 35km radius around it, thus the coverage of the whole country can be observable. Covered are by all LitPOS stations, situated in Lithuania, is presented in Fig. 2.

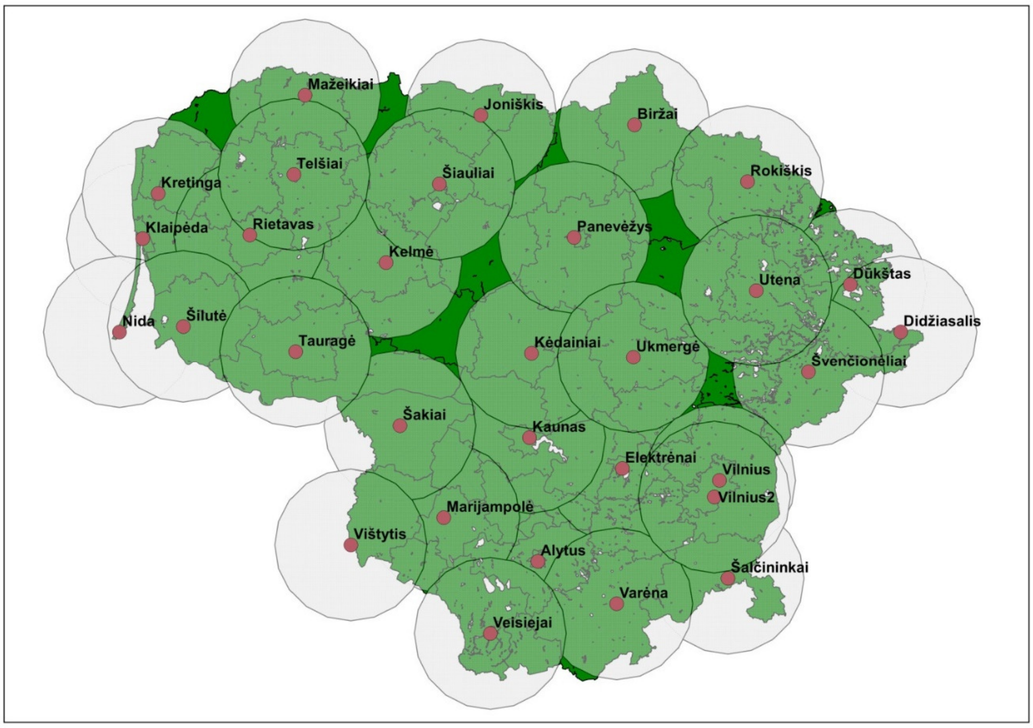

Fig. 2. Coverage of LitPOS stations

Workflow analysis

All management data is stored by Trimble Pivot Platform in Microsoft SQL database. An analysis of the users activities could be executed by SQL queries. The main sentence could be written as shown in Fig. 3.

```
SELECT [UserName]
        ,[ConnectionStart]
        ,TPPDB.dbo.TicksToDateTime(ConnectionStart) as ConnectionStart2
        ,[ConnectionEnd]
        ,TPPDB.dbo.TicksToDateTime(ConnectionEnd) as ConnectionEnd2
        ,[NMEAPositionRecord]
  FROM [TPPDB].[dbo].[View_RTO_Sessions]
  WHERE CONVERT(VARCHAR(25), LogTime, 126) LIKE '%2016-09%' and [ConnectionStart] > 0 and [ConnectionEnd] >0
```

Fig. 3. Example of general SQL sentence

Extracted data is in text format Fig. 4.

```
240itt $GPGGA,082635.00,5442.68049640,N,02521.38049899,E,2,08,1.1,203.285,M,27.441,M,5.0,0120*43
240itt $GPGGA,095514.00,5447.63192306,N,02515.78052205,E,1,11,0.9,162.063,M,27.381,M,,*62
240itt $GPGGA,100448.00,5447.63822899,N,02515.81755830,E,2,08,1.2,163.773,M,27.380,M,5.0,0120*4D
```

Fig. 4. Example of extracted data

Database output provides a big number of data of different kind, so the specific *Perl parsers* were developed in order to extract the needed information. For example, the plane geodetic coordinates indicate the approximate locations of users measurements area. Derived by *Perl script* coordinates are transferred to QGIS system for further users workflow analysis (Fig. 5).

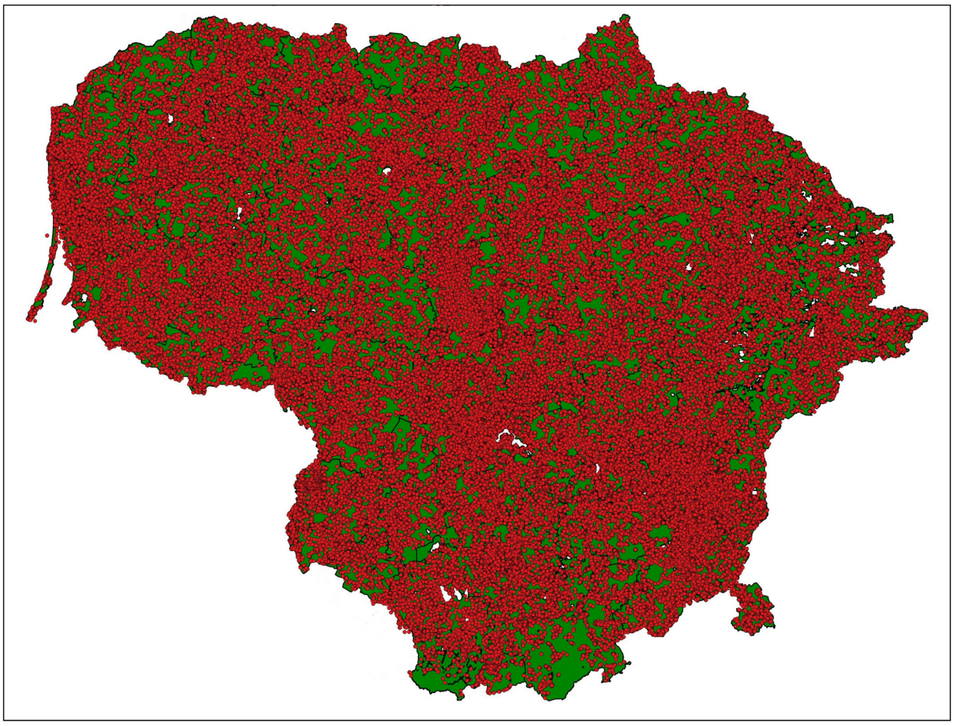

Fig. 5. Users connections during 2016 year (red dots)

Important information is related to amount of workflow in usage of LitPOS during entire year. Prediction was held that the biggest load on the system is during summer when the weather conditions are most suitable for field measurements. But 2016 year users analysis showed that highest activity is during April (almost 60 000 active connections), after cold months of the year and the second highest – August (almost 47 500 active connections). All user connections for 2016 years are visualized in Fig. 6.

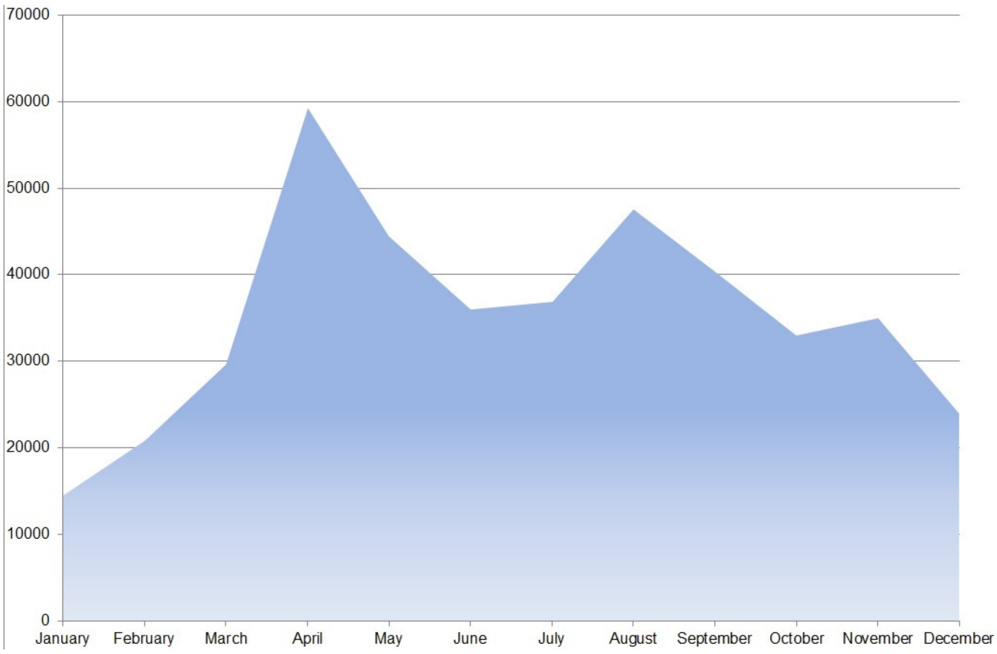

Fig. 6. Total users connections every month of 2016

Distribution of users and their connections according to municipalities in Lithuania is capable of showing interesting data about registered users and load on specific stations and network segments. 60 municipalities' layer with precise area (lake areas were excluded) were used. Numbers of measurements in separate municipalities were calculated and density of users connections is visualized in Fig. 7.

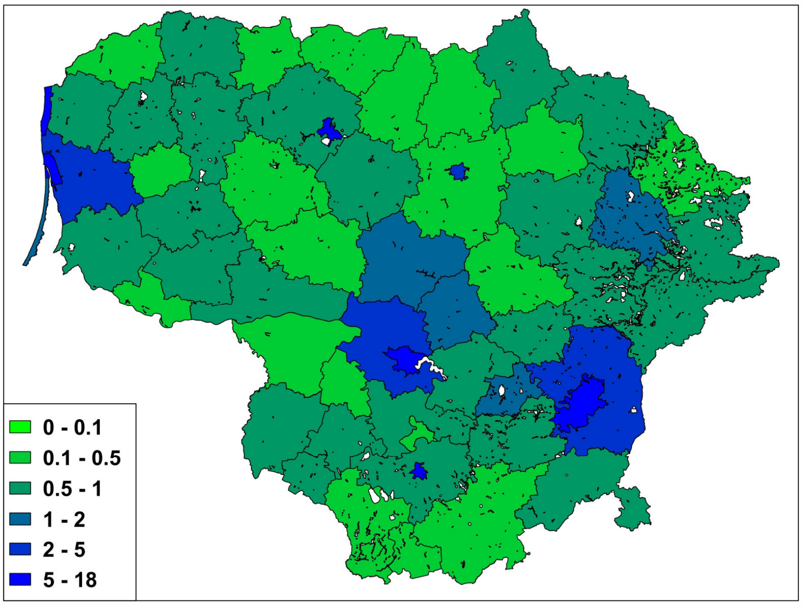

Fig. 7. Density of users connections in April 2016

Without a surprise, the densest areas of RTK measurements were around the largest cities in the country. Percentage of measurements in every municipality is visualized in Fig. 8.

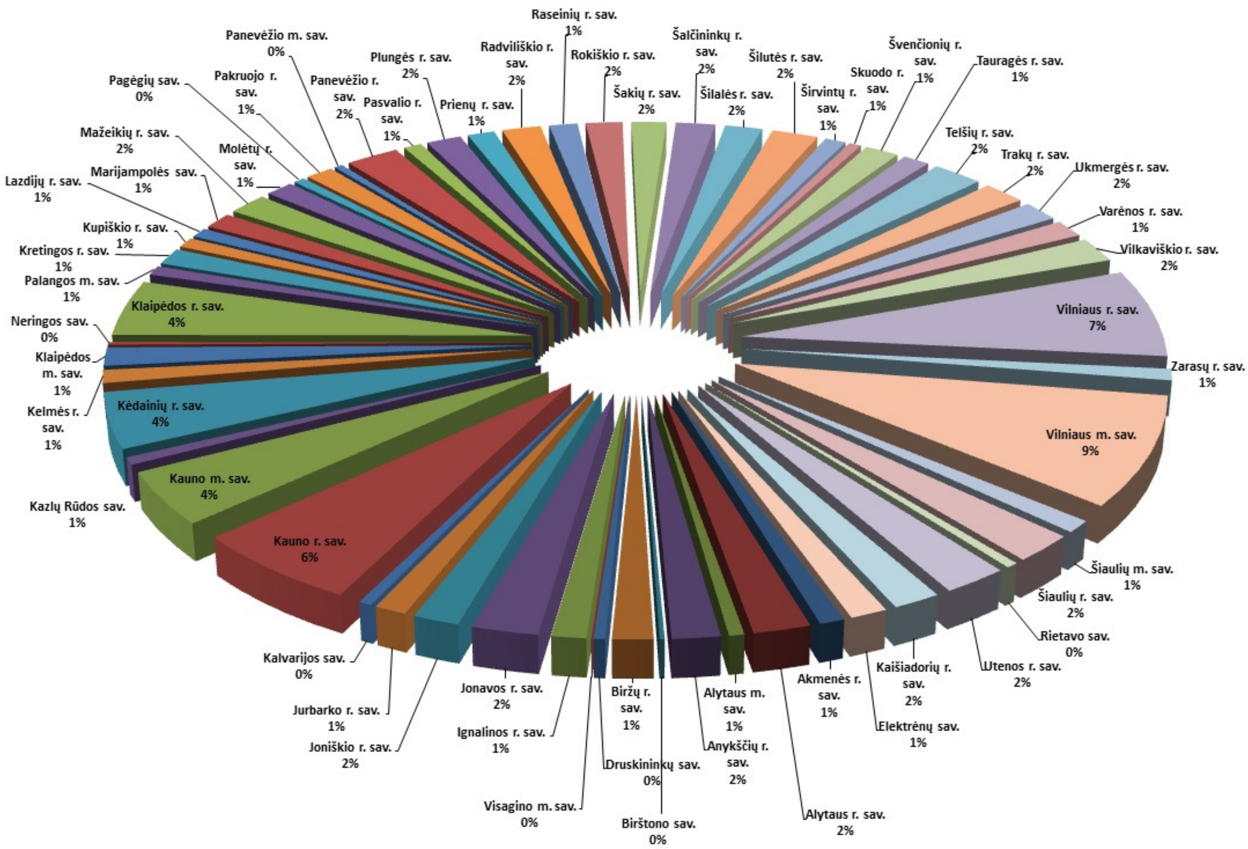

Fig. 8. Percentage of measurements in separate municipalities in Lithuania

The biggest percent of users are registered in Vilnius municipality (36% of all LitPOS users) and accordingly highest percent of measurements were in Vilnius municipality. Municipality of Vilnius area – 7% and Vilnius city – 9%.

Quality analysis of RTK measurements

The quality estimators of RTK measurements such as standard deviation (σ), differences from double measurements were derived from the double differences of obtained geodetic coordinates of more than 1100 points (north (x), east (y) and normal height (H)), evenly distributed in the all territory of Lithuania and covered by LitPOS service. RTK measurements were carried out by Leica Viva receiver applying VRS technology. The observation window was about 1–2 minutes. Field observations were executed during two years, in different weather conditions, and mostly in points having enough good open horizons. Differences of geodetic coordinates are presented in Fig. 9–11.

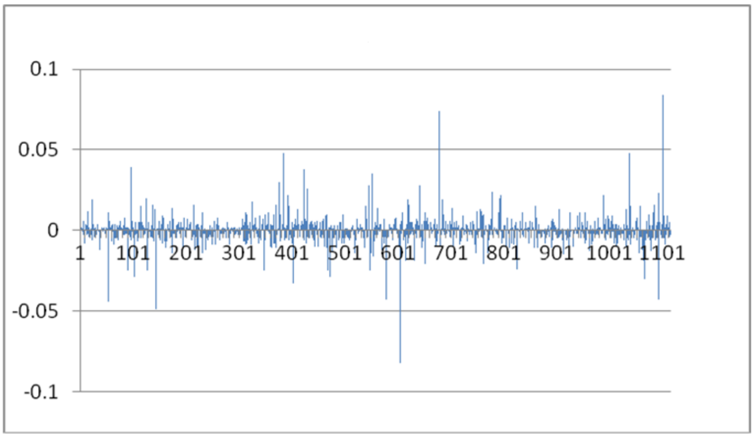

Fig. 9. Differences of geodetic coordinates *x,* m

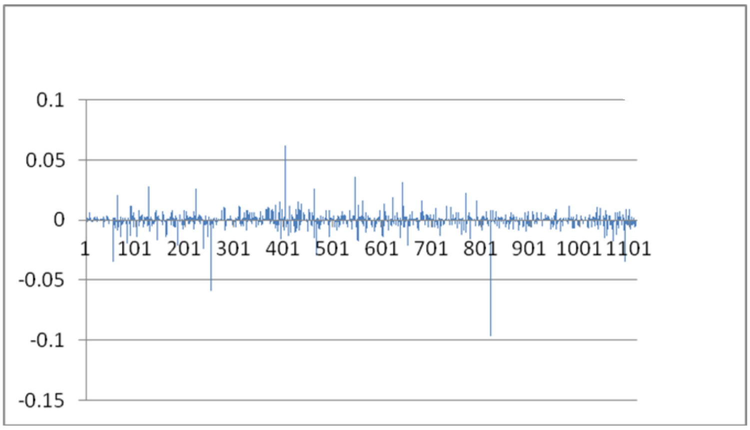

Fig. 10. Differences of geodetic coordinates *y,* m

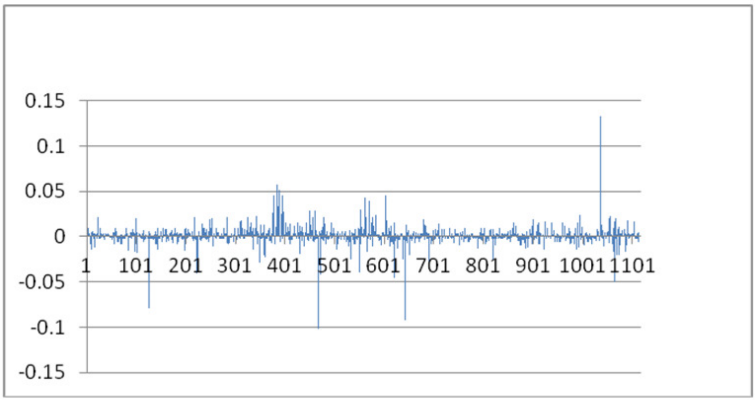

Fig. 11. Differences of normal height *H,* m

The histograms of coordinate differences are presented in Fig. 12–14.

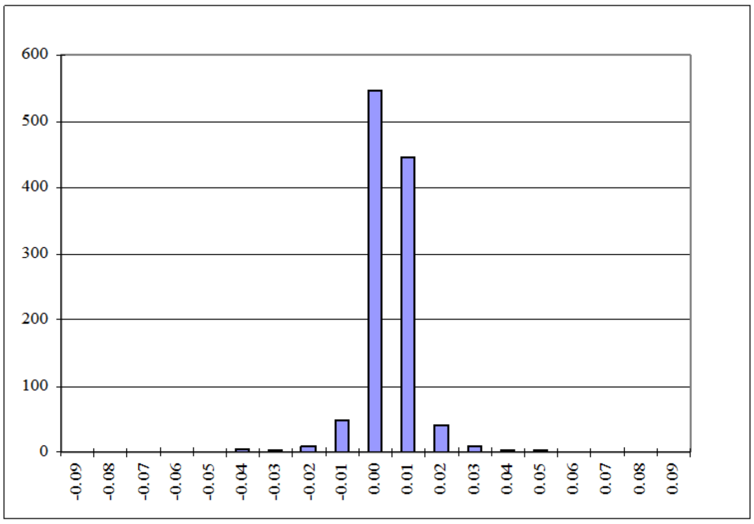

Fig. 12. Histogram of differences of geodetic coordinates *x*

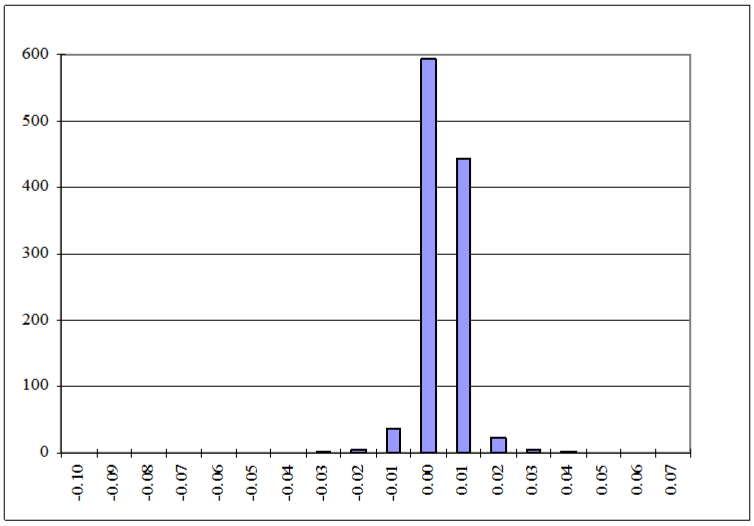

Fig. 13. Histogram of differences of geodetic coordinates *y*

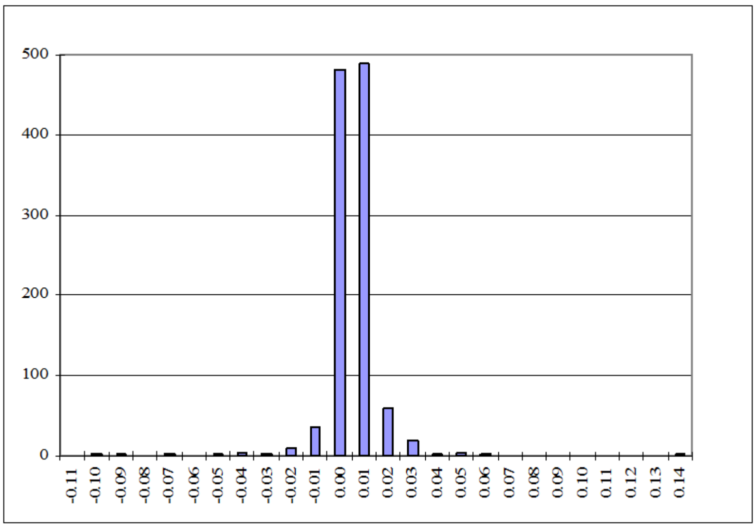

Fig. 14. Histogram of differences of normal height *H*

Figures show, that, firstly, the great part of the differences of plane coordinates and normal heights are not bigger than 2 cm, only few differences are in the interval from 3 to 10 cm, secondly, the vertical mean errors showed surprisingly good results.

In order to use network RTK technology, it is important for the user to closely examine the network geometry around the work area, as network geometry is one of the most important factors affecting network RTK solution quality. It could be stated, that near all territory of Lithuania is enclosed by LitPOS network, therefore the problematic areas exists near the state borders with Belarus and Russia Federation.

The result have revealed expected about 2–3 cm precision for the horizontal and vertical components, that is could be compared to the performance of the similar networks of other countries (Zvirgzds 2007; Graszka *et al.* 2009; Ryczywolski *et al.* 2010; Dobelis, Zvirgzds 2016).

Conclusions

1. LitPOS services are continuously used in Lithuania and neighboring countries today for a decade now with growing infrastructure, user base, quality of service, speed and provided accuracy. Network is used by governmental institutions as well as private sector for free. User dynamic growth and growing time users spend acquiring precise measuring data from LitPOS network shows the need and satisfaction by such network.

2. LitPOS network performance analysis revealed that in most cases the horizontal and vertical errors were lower than the 3σ solution uncertainties, however there were cases of solution biases, drifts and gaps. It is recommended that points should be re-occupied at least twice to avoid un-permissible biases.

3. Existing LitPOS network should be develop to enclose areas near the border of the country or to include stations of similar RTK networks of neighboring countries to LitPOS service.

Acknowledgements

The research was supported by a grant No. (4.22)10MF-37/12621 of the National Land Service of Lithuania.

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