ISSN 0005–1144
ATKAAF 48(1–2), 53–57 (2007)

Renato Filjar, Lidija Bušić, Tomislav Kos

A Case Study of DGPS Positioning Accuracy for LBS

UDK 654.16:528.4
IFAC 5.8.1;5.7

Preliminary communication

The importance of differential satellite positioning has been intensively questioned in recent times, especially after ceasing of the selective availability (SA) in standard GPS positioning service. Almost without exception, experimental studies have confirmed the improvement in satellite positioning given by differential corrections still exists. In this article, the improvement of positioning accuracy for LBS obtained by differential GPS (DGPS) positioning method is addressed, based on experimental data analysis. Differential GPS positioning accuracy is discussed in relation to satisfaction of LBS positioning accuracy requirements and comparison with standard GPS positioning. While the implementation of DGPS positioning method still does not lead to satisfaction of the high-level LBS positioning performance requirements, it still improves and stabilises standard-level positioning accuracy for LBS.

Key words: differential GPS, location-based services, positioning accuracy, satellite positioning

1 INTRODUCTION

The quality of positioning service (positioning performance) for location-based services (LBS) remains a rather undefined issue [1] in spite of different international organisations (3GPP, OMA, IETF) making an effort in quality of positioning service establishment. Additionally, the lack of properly determined requirements for LBS positioning performance in relation to the groups of LBS solutions often deteriorates their overall commercial success.

Our research group has been challenged for some time to address the problem. As the result, a set of LBS positioning requirements for standard (un-assisted and un-augmented) positioning had been proposed. A recent experimental study conducted in urban area of Zagreb, Croatia in July 2004 addressed the impact of differential GPS (DGPS) service provision on the positioning performance for LBS. This article presents the results of differential GPS accuracy field study and confirms the importance of the utilisation of DGPS service in maintaining the satellite positioning performance and thus the LBS quality of service (QoS) as well.

2 DIFFERENTIAL SATELLITE POSITIONING

Satellite positioning methods utilise the time-of--arrival method for estimation of the end user (radio equipment aerial) current position. In fact, the satellite signal propagation time to the user receiver/aerial is measured. With the propagation velocity known, time measurements are equivalent to distance/range measurements, which leads to terminology of measuring the pseudo-ranges. The term pseudo-range emphasises the fact that the measurements are easily affected by various sources of errors, belonging to one of the following main error sources groups:

– satellite and control component error sources (inaccurate satellite ephemeris, satellite clock errors)
– user equipment component error sources (multipath effects, receiver noise – both hardware- and software-caused)
– propagation media errors (ionospheric delay, tropospheric delay, effect of scintillation).

With at least four GPS satellites in view it is possible to solve the position determination problem, yielding three unknown co-ordinates of the mobile user's position and the unknown user clock synchronisation error.

Differential satellite positioning method is based on presumption that pseudo-range measurements obtained by GPS receiver during positioning process have approximately constant error values in the limited geographical area. This means that, once determined by special so-called DGPS station, the pseudo-range measurement corrections can be used by all satellite positioning system users in local area (for instance, up to 300 km from DGPS station), improving the overall accuracy of the positioning service. Differential GPS method utilises a single DGPS station with a dual-frequency GPS receiver, which determines pseudo-range measurement error for every GPS satellite in vicinity [2].

Collected set of measurement errors are then broadcast to the local user GPS receivers in a form of the DGPS corrections to be applied to the single-frequency pseudo-range measurements [2].

Differential corrections can be distributed by different auxiliary communication networks, such as:
- LF and MF radio beacons
- radio data service (RDS) on commercial VHF broadcasting stations
- signalling in public mobile communication networks
- Internet.

In the experimental validation presented here, the Internet-based differential GPS service maintained by EUREF-IP network [3] was used. The EUREF-IP network consists of the geodetic GPS reference sites that able to provide the DGPS corrections based on their own measurements of GPS signal propagation. Established as the research community, it provides the DGPS corrections in standardised way using generally accepted communications protocols over IP. Differential GPS corrections were accessed from Prague, Czech Republic DGPS station, one of geographically closest to field campaign site.

3 LOCATION-BASED SERVICES

Location-based services form a group of telecommunication services that explore location awareness and combine it with location-related content delivery. One of main concerns in the LBS development is support for a stable quality of service, which should be entirely based on reliable positioning performance. Initial requirements for LBS positioning accuracy were already presented elsewhere [4, 1]. Positioning accuracy is one of the four basic positioning performance parameters (along with positioning service availability, positioning service integrity and continuity of positioning service). In practice, the positioning accuracy is presented as the horizontal positioning error estimate for every positioning sample (taken, for instance, from GPS receiver). Table 1 summarises the requirements for three different positioning performance levels.

Table 1 **LBS positioning performance requirements for three basic layers**

Values for at least 95 % of the time	Positioning accuracy
Low-level positioning performance	100 m
Standard-level positioning performance	30 m
High-level positioning performance	10 m

4 EXPERIMENTAL VALIDATION OF POSITIONING PERFORMANCE

4.1 Description of experiment

Data were collected during the experiment conducted in summer of 2004, using the equipment shown on Figure 1. A vehicle was equipped with two Garmin GPSIII+ receivers, one working in standard and the other in differential GPS positioning mode. Differential GPS corrections were delivered from the Prague differential station through the EUREF-IP network and using the mobile Internet GPRS connection. Separate portable computers were used for collecting position samples from GPS receivers in a form of the NMEA-0183 sentences. Position samples were taken every 2 seconds. Since the single serial port GPS receivers were used, additional software was developed in order to support both the NMEA-0183 acquisition and the DGPS corrections delivery using the same serial port for GPS receiver running in differential GPS mode. The GPS receivers were placed just behind the front windshield. The built-in aerials were used.

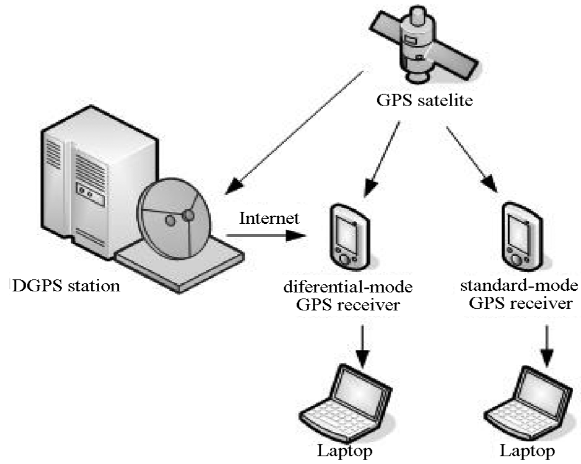

Fig. 1 Equipment used during the field trial

4.2 Positioning conditions and local environment

Field trial was conducted on 27 July 2004, during a bright summer day, with a high-pressure air mass remaining in the area for several days. Large ionospheric storm was detected on the day when the field trial was conducted, causing significant decrease of critical frequency of the F2 layer (f0F2) and disturbed geomagnetic conditions (Kp index maintaining high values between 8 and 9 during the whole day) [5]. A travelling path (Figure 2) was chosen in central area of Zagreb, Croatia, consisting mainly either of narrow streets in city centre or roads passing through the park areas with fully developed vegetation, partly even on the hilly terrain.

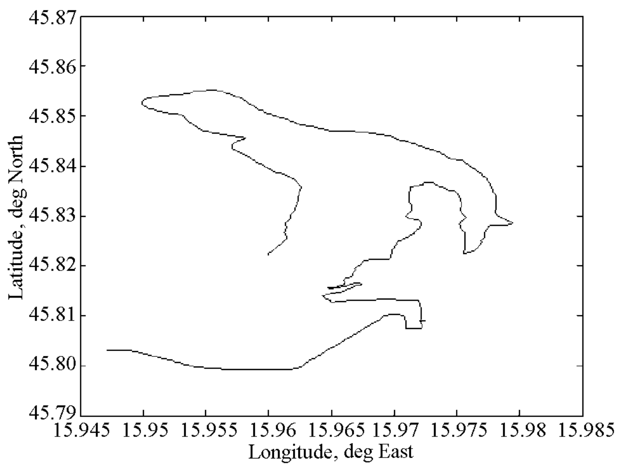

Fig. 2 Field trial track

4.3 Experimental results

Position samples were collected for standard and differential GPS positioning every 2 s. NMEA-0183 sentences have been parsed using the appropriate software package in order to extract the data related to positioning sample.

Every positioning sample consists of the following data:

- GPS time of sampling
- Latitude
- Longitude
- Horizontal positioning error estimate (calculated by GPS receiver)
- Number of visible satellites.

Collected samples formed two experimental data sets that were analysed in order to reveal the compliance with established LBS positioning performance requirements.

5 ANALYSIS OF EXPERIMENTAL RESULTS

Collected position samples are analysed in relation to previously established LBS positioning accuracy definition. Separate statistical analysis was made for both standard and differential positioning. Results were than compared in order to identify improvements given by utilisation of differential GPS positioning.

Horizontal positioning error estimates are presented for standard and differential GPS positioning on Figures 3 and 4, respectively, while the comparative analysis is presented in Table 2.

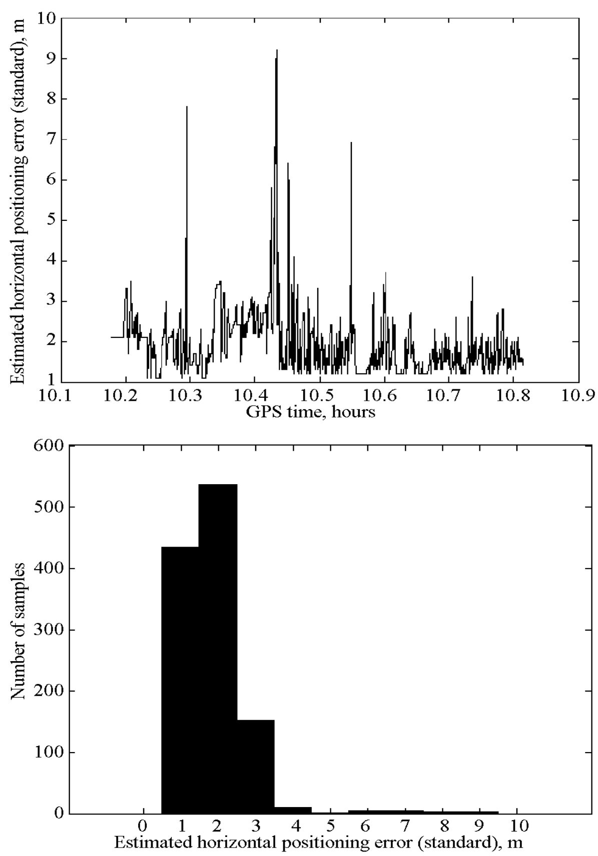

Fig. 3 Estimates of positioning accuracy during the field trial for standard GPS positioning

Table 2 **Comparative analysis of positioning accuracy for standard and differential positioning**

m	GPS	DGPS	Improvement
EHE[1)] mean	1.933	1.876	2.948 %
Standard deviation of EHE[1)]	0.816	0.756	7.353 %
Largest EHE[1)]	9.200	8.700	5.435 %
EHE[1)] median	1.700	1.700	0.000 %

[1)] EHE Estimated Horizontal Error

Both standard and differential positioning provided rather good positioning accuracy. Experimental analysis reveals slight improvement in positioning accuracy after implementation of differential GPS positioning. Differential GPS positioning decreases mean estimated positioning error by 2.948 % and narrows distribution of the positioning accuracy errors (standard deviation decreased by 7.353 %). At the same time, largest estimated positioning errors collected in the city centre (high buildings and narrow streets) are improved by more than 5 % using differential positioning.

It should be noted that the positioning performance improvement is still reached, regardless of unfavourable experimental conditions (a massive ionospheric storm). The effects of the storm was not taken into account and no special correction procedures had been applied.

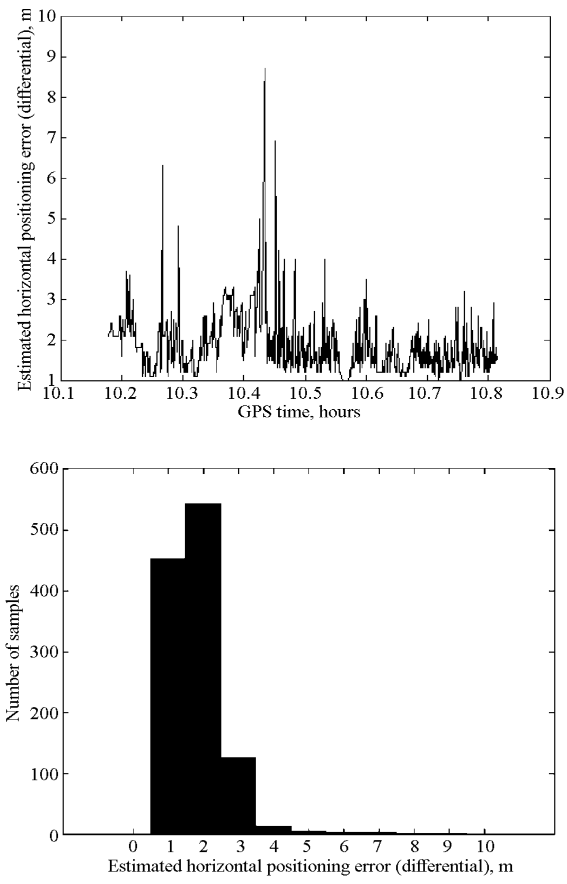

Fig. 4 Estimates of positioning accuracy during the field trial for differential GPS positioning

Figure 4 shows good compliance with positioning accuracy required for low-level and standard-level LBS positioning performance. Still, implementation of differential GPS cannot assure satisfaction of high-level positioning performance requirements.

6 CONCLUSION

Differential GPS positioning improves the LBS positioning performance, compared with the standard (un-assisted and un-augmented) GPS positioning. However, general LBS positioning accuracy still cannot be improved in a way that would satisfy high-level requirements by deployment of differential GPS positioning alone. Thus, the implementation of differential GPS in LBS will be an issue for specific LBS solution development that targets limited groups of users with additional requirements for accuracy within low- and standard-level positioning performance [6, 7]. Future work will concentrate on positioning sensor integration as a potential solution for achievement of high-level positioning accuracy.

REFERENCES

[1] R. Filjar, S. Dešić, K. Tržec, **LBS Reference Model.** Proc. of AV04 Conference (on CD). Westminster, London, UK, 2004.

[2] E. Kaplan (editor). **Understanding GPS: Principles and Applications**. Artech House, Boston and London, 1996.

[3] ..., **EUREF-IP pilot project description**. http://www.epncb.oma.be/euref_IP, accessed on 6 February, 2005.

[4] R. Filjar, et al. **Satellite Positioning for LBS: A Zagreb Field Trial Positioning Performance Study**. Journal of Navigation, vol. 57, no. 3, pp. 441–447, September 2004.

[5] ..., **National Oceanic and Atmospheric Administration (NOAA)**. Space Physics Interactive Data Resource Internet site, http://spidr.ngdc.noaa.gov/spidr/home.do, accessed on 6 February, 2005.

[6] ..., **ITU**. ITU-R M.1371-1 Recommendation, 2001.

[7] T. Moore, et al. **Is DGPS Still a Good Option for Mariners?** Journal of Navigation, vol. 54, no. 3, pp. 437–446, September 2001.

Eksperimentalna studija točnosti određivanja položaja diferencijskim GPS postupkom za potrebe lokacijskih usluga. Značaj diferencijskog satelitskog određivanja položaja intenzivno se istražuje, napose od vremena gašenja selektivne dostupnosti GPS sustava. Gotovo bez izuzetaka, eksperimentalne studije potvrđivale su poboljšanje kvalitete satelitskog određivanja položaja kad je ono bilo podržano primjenom diferencijskih korekcija. U ovom radu istražuje se poboljšanje kvalitete satelitskog određivanja položaja primjenom diferencijskih korekcija u svjetlu zahtjeva koje postavljaju lokacijske usluge. Točnost diferencijskog GPS određivanja položaja analizira se u svjetlu zahtjeva za točnošću određivanja položaja određenih specifikacijama lokacijskih usluga. Dobiveni rezultati eksperimentalne provjere uspoređuju se s rezultatima standardnog GPS određivanja položaja i sa zahtjevima na točnost koji određuju kvalitetu lokacijskih usluga. Iako primjena diferencijskih korekcija još uvijek ne zadovoljava najstrože zahtjeve koje postavljaju specifikacije lokacijskih usluga, DGPS u zamjetnoj mjeri poboljšava i održava standardnu razinu kvalitete lokacijskih usluga.

Ključne riječi: diferencijski GPS, lokacijske usluge, točnost određivanja položaja, satelitsko određivanje položaja

AUTHORS' ADDRESSES

Renato Filjar
MSc FRIN, Ericsson Nikola Tesla d. d.
Krapinska 45, 10000 Zagreb, Croatia
e-mail: renato.filjar@ericsson.com

Lidija Bušić
BSc MRIN, Ericsson Nikola Tesla d. d.
Krapinska 45, 10000 Zagreb, Croatia
e-mail: lidija busic@ericsson.com

Associate Professor Tomislav Kos, PhD AFRIN
Faculty of Electrical Engineering and Computing
University of Zagreb
Unska 3/XII, 10000 Zagreb, Croatia
e-mail: tomislav.kos@fer.hr

Received: 2007-02-15