THE JOURNAL OF NAVIGATION (2004), **57**, 441–447.
DOI: 10.1017/S0373463304002851 Printed in the United Kingdom

Satellite Positioning for LBS: A Zagreb Field Positioning Performance Study

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Recent studies confirm the importance of satellite positioning in location-based services (LBS) development. A field study was conducted in suburban and rural areas near Zagreb, Croatia in order to examine the real-time data compliance with recently established positioning performance requirements for LBS quality of service (QoS). Data analysis was based on comparison between actual positioning performance and pre-specified positioning parameter values using defined comparative procedures. The results presented here confirm a good correlation between the actual and required positioning performance, even without implementation of any of augmentation or assistance positioning methods.

KEY WORDS

1. satellite. 2. positioning. 3. performance. 4. LBS.

1. INTRODUCTION. In the history of location-based services (LBS) development, satellite positioning has been presumed to be a foundation positioning method (Beatty, 2002). The importance of satellite positioning in LBS development was established using third-party simulations and local field trials described in references. In order to confirm this presumption, a Zagreb field trial was conducted on 12 June, 2003. Dynamical positioning performance of satellite navigation in semi-urban and rural environments is analysed in this paper. Four basic LBS positioning performance parameters were pre-defined, and their definitions were applied on a set of data collected during the field trial. The paper concludes with the plan of future activities in relation to obtained results of the field trial data analysis.

2. PREVIOUS WORK. Satellite positioning is the most promising positioning method for LBS currently available (Filjar *et al*, 2001). The positioning performance of satellite navigation systems, GPS in particular, is comprehensively described in the related specifications (Department of Defense, 2001) and thoroughly examined during numerous field trials worldwide. However, the implementation of satellite positioning as the foundation of the location-based services (LBS) has not, so far, been appropriately challenged. Special requirements for LBS development

have not been applied in the examination of satellite navigation performance. Multipath mitigation, solving the problem of availability, continuity of positioning and the continuous strive towards the better accuracy remain the main topics to be researched.

Basic satellite positioning augmentation has recently emerged as an interesting topic. A range of augmentation methods (new systems like Galileo, augmenting non-satellite and even non-positioning services) has been researched, creating a particular integration challenge. At the same time, signal processing methods for weak signal detection and multipath mitigation are under development. Additionally, proper specification of LBS positioning performance requirements are to be developed in order to give directions for future research and development. A proposal for satellite positioning performance for LBS has been recently given in a conference paper (Filjar *et al*, 2003). While based on a simulation of mobile user dynamics, the proposal needs to be challenged by a real-time situation. This supports the decision to conduct the field study and prove the proposed values of positioning parameters with the experimental results.

3. LBS POSITIONING PERFORMANCE PARAMETERS DEFINITION. After the thorough examination and numerous discussions, a set of the following positioning performance parameters has been identified (Filjar *et al*, 2003):

- positioning availability
- positioning integrity
- positioning accuracy
- continuity of positioning service

In this section, the positioning performance parameters listed above are comprehensively defined. Additionally, the methods for practical implementation of these definitions in field trial analysis are presented.

3.1. *Availability*. Positioning availability for LBS is presented as a percentage of positioning system coverage area and the percentage of time during which the required number of position signals are provided to the mobile user, allowing him/her to obtain position with certified positioning performance. In practical implementation on dynamical positioning analysis, a number of visible satellites was counted for every time step (position sample) and the percentage of number of samples when the number of visible satellites exceeds a necessary limit (4) was calculated, giving the positioning availability value.

3.2. *Integrity*. Positioning integrity for LBS is the ability of the positioning system to detect temporal inability of the system to provide the position service and inform the users about it. It is to be expressed as the time difference between the start of service denial and the time of sending the appropriate message to the users. As the focus of the field trial was the basic GPS service, positioning integrity was not available and therefore not measurable.

3.3. *Accuracy*. Positioning accuracy for LBS is given by the largest horizontal positioning error, obtained at given percentage of positioning system coverage area and at given percentage of time. While there were no means for actual positioning error determination for dynamical positioning (map matching would be possible

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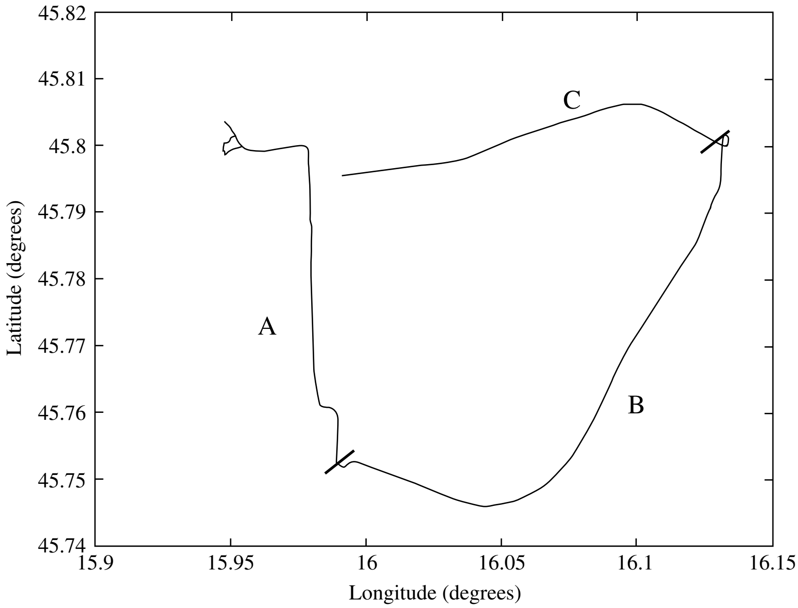

Figure 1. Field trial track.

solution, but there were no accurate maps available at the moment of the trial), positioning error estimates were taken from the GPS receiver. Statistical analysis of positioning error time series was conducted in order to evaluate the positioning accuracy value.

3.4. *Continuity of positioning service*. Continuity of positioning service (CPS) is usually specified as the time-to-first-fix (TTFF) parameter. In our experimental data analysis a more convenient approach was taken, with the CPS estimation given by observing the distribution of time intervals between two adjoining positioning samples.

4. FIELD TRIAL DESCRIPTION.

4.1. *Equipment description*. The field trial was conducted using a one-frequency (commercial) GPS receiver Garmin GPSIII+ connected to a notebook PC. Dedicated communications software was developed in order to support communication between devices and to store NMEA-formatted data for post-processing. The equipment was set on the back seat of a car. Only the original detachable helicoidal aerial was used, without implementation of any special or external aerials. Positioning samples were taken every 2 seconds using the NMEA-0183 protocol. Data were received from the Garmin GPS III+ serial port and stored on the hard disk for post-processing purposes. No further analysis had been taken in real time.

4.2. *Route and experimental environment description*. The route was chosen in order to provide different kinds of microenvironments, open space and suburban environment included, as shown on Figure 1. The first part (A) of field trail route consists of roads in a suburban environment, located in central-western and southern part of Zagreb. This environment is characterised by usually low buildings

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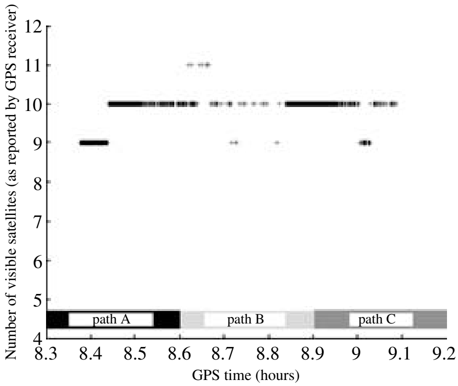

Figure 2. Positioning availability during trial as defined in section 3.1. Paths A, B and C correspond to those shown in Figure 1.

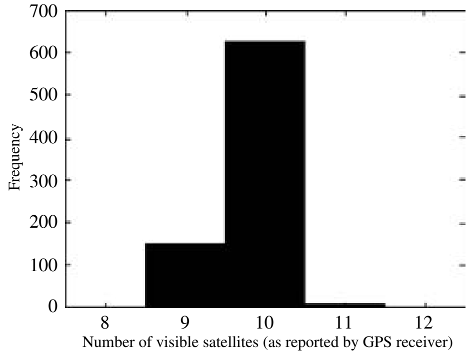

Figure 3. Histogram of the number of visible satellites during the trial.

(up to 7 levels) with the exception of few skyscrapers and towers. Mask angle is usually below 20°. However in the narrower streets near the centre, mask angle can reach 50° in particular directions. Travelling speed in this part of field trial route did not exceed 70 km/h. For the second part (B) of the route, a part of Zagreb detour (half-ring motorway) was chosen. In this practically rural environment, only a mild visibility obstruction can be noticed when the user approaches flyovers. Mask angle is usually well below 15°. Classified as a motorway, this part offers a travelling speed of 130 km/h. The last part (C) of the field trial route returns again to the suburban environment. Path C travels mainly through an industrial area with broad roads and buildings well displaced from the road. Occasionally and in selected directions the mask angle exceeded 20°. Maximum travelling speed was 80 km/h.

5. FIELD TRIAL DATA ANALYSIS AND DISCUSSION.

Data was collected during the field trial along the route shown on Figure 1. Experimental data were analysed using the positioning performance parameter definitions described in section 3. The results are presented and discussed separately, in relation to every particular positioning performance parameter.

5.1. *Positioning availability.* The results of positioning availability analysis are presented in Figure 2. In general, no considerable lack of availability was observed in spite of the casual choice of aerial position and occasional poor satellite visibility. The path B set expresses certain lack of information caused by noisy NMEA data generated by the GPS receiver. The analysis software did not correct for this. A histogram of the number of visible satellites is presented in Figure 3. It should be noticed that a rather high number of visible satellites was continuously reported, despite the fact that no special measures were implied in order to assure good availability. Two possible reasons emerge as an explanation of this observation:

- most positioning samples were taken in the less critical (suburban and rural) environments
- averaging algorithms were implemented in the GPS receiver, which caused a sluggish response on a very brief loss of satellite signal.

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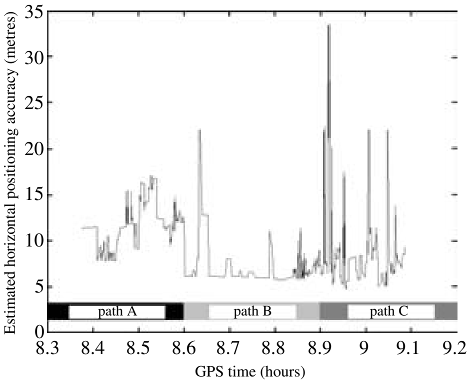

Figure 4. Time series of estimated positioning accuracy samples during the field trial.

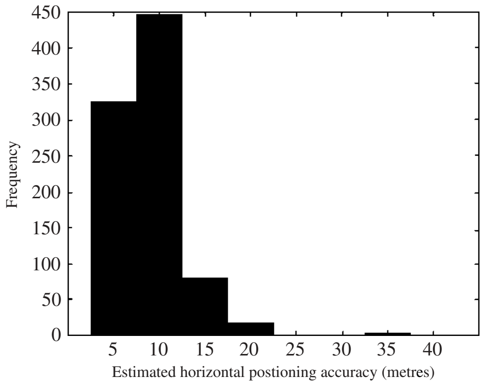

Figure 5. Histogram of estimated horizontal positioning error.

Positioning availability during the field trial was 100%. Furthermore, the number of visible satellites was at least nine throughout the trial, which is more than sufficient for successful 3D positioning.

5.2. *Positioning integrity*. The basic GPS service does not provide integrity data; therefore this parameter cannot be discussed in relation to this field trial.

5.3. *Positioning accuracy*. Positioning accuracy is presented using the estimated horizontal positioning error for every positioning sample during the field trial. The histograms of estimated horizontal positioning error are shown on Figures 4 and 5, respectively. Estimated positioning errors are computed using the algorithm implemented on the GPS receiver and supplied as a part of NMEA message. Statistical analysis of estimated horizontal positioning error time series reveals the following:

– average horizontal positioning error: 9·4272 m
– standard deviation: 3·7586 m
– median: 8·2000 m

Table 1 shows the comparison between the observed positioning accuracy and the performance required by the proposed LBS specifications (Filjar *et al*, 2003). Only 85 error estimation samples of the overall number of 874 (9·72%) were found to exceed the 13 m limit (positioning accuracy level defined by (Filjar *et al*, 2003)). The percentage of the number of error estimation samples satisfying the positioning requirements for LBS (as proposed in (Filjar *et al*, 2003)) are presented in Table 1. Evidently, the basic GPS positioning service was completely capable of satisfying the requirements for both low- and standard-level accuracy. The high-level positioning accuracy performance asks for implementation of an assisted GNSS service (Filjar *et al*, 2001) and advanced position computing procedures (Filjar *et al*, 2002).

5.4. *Continuity of positioning service*. As described in section 3.4, the continuity of positioning service is examined by observing the separation time between neighbouring samples. Results of the analysis are presented in Figure 6, describing the number of samples where the actual separation time equals or exceeds the reference value. The proposal for LBS positioning performance requests two neighbouring positioning samples to be within a 10 second interval for at least 95% of all positioning samples. Only 26 samples show separation time equal to or greater than

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Table 1. Compliance of field trial accuracy performance with the required accuracy performance for LBS.

LBS service level	Required accuracy	Percentage of field trial samples satisfying the requirements
Low-level positioning accuracy performance	100 m (95%)	100·00%
Standard-level positioning accuracy performance	30 m (95%) (10 m … 50 m, as stated in (Filjar *et al*, 2003))	99·54%
High-level positioning accuracy performance	10 m (95%)	62·47%

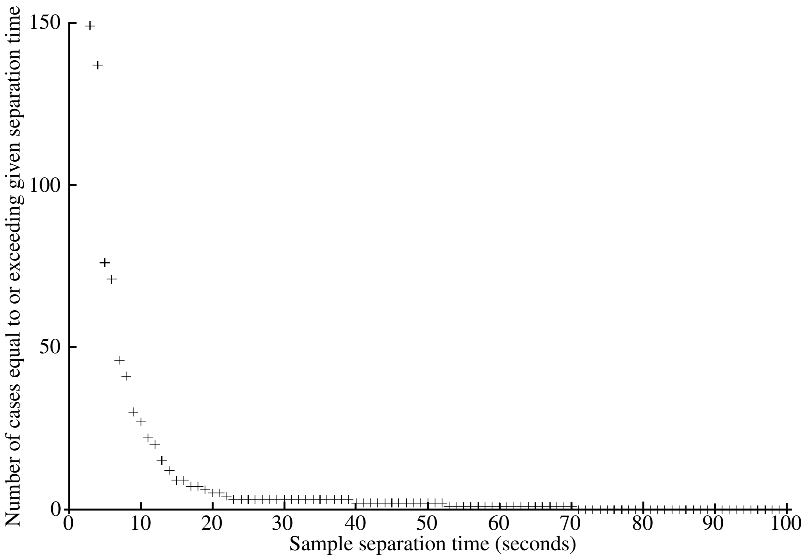

Figure 6. Continuity of service during the field trial.

10 seconds. As this is only 2·97% of all positioning samples collected, this evidently satisfies the continuity of service requirement.

6. FUTURE WORK. The field trial described above has provided a valuable set of data for the practical establishment of LBS positioning performance criteria, determined by theoretical analysis and computer simulations. This trial, however, did not cover densely populated urban area, such as strict city centre. This is to be a topic of the next field trial, scheduled for the autumn/winter 2003. The results of the next field trial could influence the development and revisions of the LBS positioning performance proposal.

7. CONCLUSION. The Zagreb field trial offered a valuable insight into the practical status of LBS positioning performance in rural and suburban areas. Basic

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GPS is currently the only fully available satellite positioning system for commercial users, regardless of their location, so it was very important to investigate its LBS positioning performance status. Experimental data analysis revealed good compliance with the previously presented LBS positioning performance proposal (Filjar *et al*, 2003). While GPS positioning performance in rural and suburban environments requires only a slight improvement, sustaining satellite positioning performance in urban environment emerges as a rather more challenging problem. Scheduled investigation of basic GPS positioning performance in strict urban conditions should reveal more information about positioning performance in critical environments and shape further the positioning performance requirements for LBS.

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