ADDRESSING THE POTENTIAL OF GNSS MOVING BASE STATION TECHNIQUE FOR VEHICULAR C-ITS APPLICATIONS: PRELIMINARY TESTS AND RESULTS

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Abstract

Effective transportation of people and goods requires an efficient positioning service. This service currently relies to a certain extent on Global Navigation Satellite Systems (GNSS). However, the problems associated with obtaining an accurate and reliable position solution in challenging environments are often underestimated and need to be dealt in greater detail. This paper discusses the concept of GNSS moving baseline station in critical ITS applications and provides preliminary results from the testing of the technique in variant observation scenarios.

Keywords: Cooperative Positioning, GNSS Moving Baseline, C-ITS

INTRODUCTION

Today, the provision of low-cost, accurate and robust positioning is a key requirement for many urban mobility applications, especially those supporting emerging Intelligent Transportation Systems (ITS) (Gikas et al., 2019). With the evolution of connected vehicles and the gradual shift towards fully autonomous transport systems in the coming years, the need of reliable vehicle positioning forms an integral part of the deployment of cooperative ITS (C-ITS) services (Schwarzbach et al., 2019), (GSA-MKD-RD-UREQ-250283, 2019). However, the variable vehicular environment, the motion dynamics and the adoption of low-cost grade technology pose various restrictions on positioning systems performance (Clausen et al., 2017), (Antoniou et al., 2018). Therefore, a combination of technologies including GNSS, is required to meet the positioning needs for the most demanding C-ITS applications (COST Action TU1302. SaPPART White paper, 2015). In effect, as GNSS improves constantly through the provision of new constellations and signals and the proliferation of low cost receivers, satellite positioning will continue to play a dominant role for ITS (978-92-9206-049-7, 2020). In this direction, emerging data collection technologies and new processing techniques are examined to testify the performance capabilities and the potential of low-cost GNSS (receiver and antenna) systems (Shuo et al., 2020), (Stern and Kos, 2018). The scope of this article is to examine the potential and limitations of GNSS “moving baseline” technique for C-ITS applications, in the context of RobPos4VApp project. A test was undertaken employing low-cost GNSS receivers in alternative setup configurations both at urban and sub-urban environments. Finally, the findings of this work are examined in the context of a Cooperative Positioning

(CP) GNSS/INS approach and user requirements proposed in RobPos4VApp project.

MOTIVATION AND OBJECTIVES

Overly, RobPos4VApp project aims at developing a unified framework of CP GNSS solutions and detailed testing procedures for testifying the performance capabilities of low-cost GNSS receivers while maximizing their benefits for vehicular, safety critical ITS applications. At first, the technical requirements in terms of positioning metrics and data communication needs will be defined. The core of the project resides on the development of a suite of novel, Kalman filter, cooperative GNSS / MEMS-INS algorithms and a strategy generation for optimal evaluation and validation of the method based on simulated, field and record and replay tests.

Particularly, the CP GNSS approach adopted in this research resides on positioning information (i.e., the raw GNSS observations, the Position-Velocity-Time (PVT) state and associated quality metrics) derived from neighboring vehicles in a sequential but continuous manner. Differential positioning of the target vehicle makes use of the concept of “moving baseline station” in a dynamic manner. The selection of best candidate neighboring vehicle to serve as a moving base station will reside on the implementation of a multi-criteria, prioritization algorithm (US 2010/0214161 A,1,2010), (US 6,961,018 B2, 2005), currently being under investigation. The use of moving base station concept resides on carrier phase and pseudorange observations. The details concerned with the integration of the proposed approach in the overall positioning algorithm (i.e., time to switch between successive base stations / vehicles, the possibility of using simultaneously multiple base stations, etc.) will be examined as the project is fully under way.

COOPERATIVE POSITIONING USING MOVING BASELINE

The Real-Time Kinematic (RTK) GNSS technique is used in many accuracy demanding navigation applications due to the high quality content of carrier phase measurements. In standard operation, the RTK technique presupposes the use of a stationary base receiver to broadcast its known position and the corrections in the carrier signal from each satellite in view to a GNSS receiver in motion. The moving GNSS receiver processes its own phase measurements with those received from the base station and other information to determine its absolute position.

Not rarely, in many positioning and navigation applications it is important to compute for the position state of an object of interest with respect to another one – for instance, the relative distance among moving vehicles, or the change in the heading of a vehicle. In GNSS, this technique refers to the concept of moving baseline. In this setup, both receivers (base and rover) are mounted on moving platforms. The superior accuracy in relative positioning stems out from the fact that, in addition to its own position state and raw measurements, the moving base station also computes and broadcasts its velocity vector in near real time. Kalman filtering is the key processing algorithm; however, the implementation details vary between manufacturers and remain preparatory (Shuo et al., 2020), (Clausen et al., 2017).

As has already been stated, the use of moving base station technique in this research assumes the selection of the "best" neighboring vehicle in dynamic mode (Gayatri and Chetan, 2013). In order to fulfil data communication requirements in such a multi-vehicle, rapidly changing environment the standardized, widespread and low size, NMEA 0183 messages are used. Currently, alternative types of the long list of available NMEA 0183 messages are examined to decide which ones suit best to the needs of problem.

EXPERIMENTAL TESTING AND RESULTS

In order to assess the performance of the moving base station technique for the scope of this research a number of test trials were carried out that also employ comparisons against the standard RTK technique. Experimental testing includes running a passenger vehicle equipped with two low cost u-blox® M8T receivers, placed on the roof top at a fixed distance of 0.98 m. The test vehicle travelled a trajectory of a total length about 9 km, passing through urban and deep urban environments, collecting 2049 epochs from L1 frequency GPS, GLONASS, and GALILEO signals spanning a time length of 40 min. A Virtual Reference Station (VRS) was established at the center of the test area to provide base station data for the duration of the trials.

Analysis of the collected data reveals two independent solutions for the connecting distance between the two u-blox® receiver antennae. The first solution results from computing the baseline length between the two receivers using the moving baseline technique, while the second one is obtained from the RTK solutions computed separately for each u-blox® receiver.

Fig. 1 summarizes the results obtained. The top plot shows the inter-receiver antennae baseline length difference from actual (trueness) derived using the two phased based computational approaches (moving baseline and RTK).

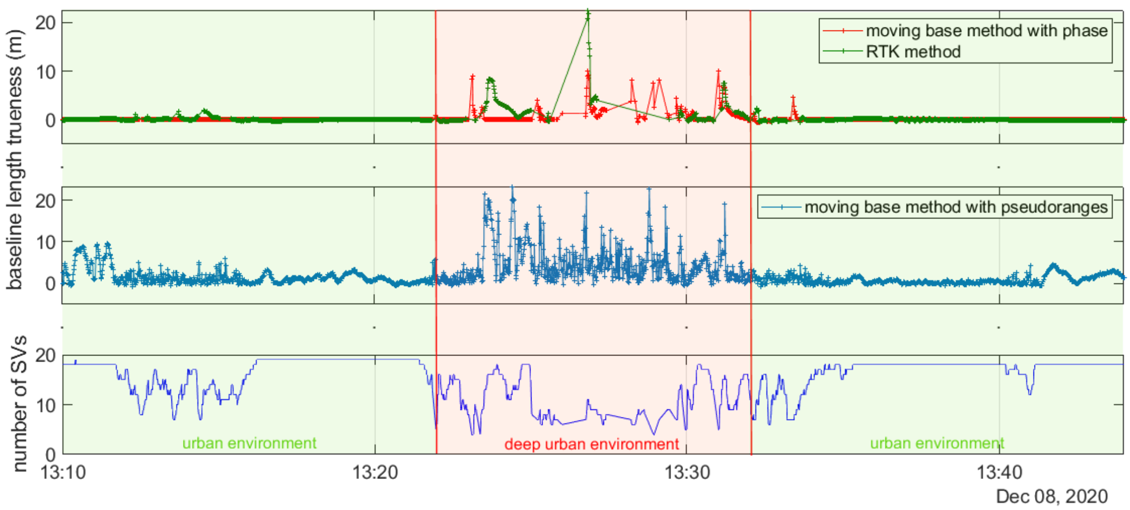

Fig. 1. Baseline length trueness estimated with the moving base / phase measurements and the RTK method (top), the baseline length estimated with moving base / pseudorange observations (middle), and the number of satellites in view along the travelled trajectory (bottom)

Also, the middle plot shows the baseline length difference from actual (trueness) obtained using the moving base technique on pseudorange measurements only. Finally, the plot at bottom shows the number of satellites in view, along the travelled trajectory.

The results shown in the top plot reveal the degradation of positioning solution as the vehicle travels through the deep urban area ($HPE_{MBS/phase}$=0.90±1.77m, $HPE_{RTK\text{-}based}$=1.97±3.28m) as opposed to the solution derived for the urban environment ($HPE_{MBS/phase}$=0.01±0.17m, $HPE_{RTK\text{-}based}$ =0.02±0.25m). From these results, the superiority of the moving base station solution is evident (improvement of the order 40%). This is due to the similar reception conditions of the two receivers, and also due to the short baseline length between the moving base and the rover. Also, in terms of position availability, the phase based moving base station solution presents higher performance against the RTK-based solution at urban and deep urban environment, where an improvement is evident by 6% and 50% respectively. Concerning the moving base station solution obtained using pseudorange data, the high availability is compromised by the low position accuracy particularly in the deep urban environment.

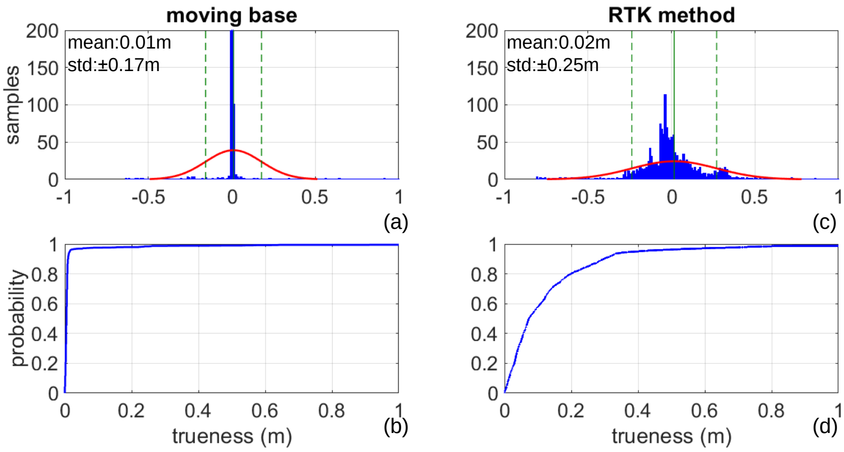

Fig. 2. Probability density histograms, PDF (a,c), and cumulative distribution functions, CDF (b,d) of the baseline length trueness for both moving base and RTK methods at urban environment section of the trajectory

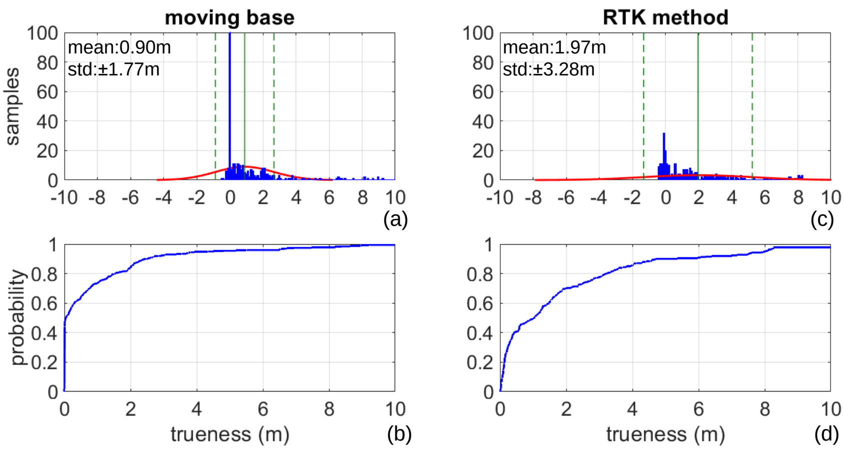

Fig. 3. Probability density histograms, PDF (a,c), and cumulative distribution functions, CDF (b,d) of the baseline length trueness for both moving base and RTK methods at deep urban environment section of the trajectory

Fig. 2 and 3 show an alternative representation of the same results for the urban and the deep urban environment respectively. It presents the empirical probability density function and the cumulative distribution function of the inter-antennae baseline length obtained from moving base and RTK techniques. From plots in Fig. 2c, 2d and Fig. 3c, 3d it is obvious that RTK technique gives relatively higher and more dispersed values than those from moving base technique.

These results indicate clearly the superiority of the phase based moving baseline technique against the standard RTK both in the urban and deep urban environments.

CONCLUSIONS AND PERSPECTIVES

The qualitative and quantitative results obtained from these trials will be used as a driver in the research steps to follow. More specifically, a more detailed test trial would be carried out employing as a minimum three vehicles to obtain moving base station results as a feeder the "best neighbor" selection algorithm under development.

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