Self-Consistent NLOS Detection in GNSS-Multi-Constellation Based Localization under Harsh Conditions

Pierre Reisdorf, Gerd Wanielik

Technische Universität Chemnitz
Reichenhainer Str. 70, 09126, Chemnitz, Germany
Email: firstname.lastname@etit.tu-chemnitz.de

***Abstract*—Nowadays, precise and reliable localization is a key technology for many applications around the world. The localization should have an availability around the globe for a minimum price and for each person. Localization with satellites like Global Positioning System (GPS) or Glonass has become a standard in the last years for outside positioning. Satellites are available around the world and the positioning results are good for many applications, except in restricted areas. In urban areas in particular, the reception of the satellite signals is restricted. Often, the signals are received under Non-Line-Of-Sight (NLOS) conditions in these areas. Hence, a good approach should detect NLOS and use knowledge to handle the NLOS measurements. We implement a self-consistent approach to detect NLOS in the measurement domain and use the information for the position estimation process. In contrast to other existing approaches, we need no external information or hardware.**

***Keywords*–Global Navigation Satellite System (GNSS); Non-Line-Of-Sight (NLOS) detection; self-consistent; multi-constellation.**

I. INTRODUCTION

A reliable vehicle positioning is a crucial part of nearly every Intelligent Transportation System (ITS). While the importance of localization is obvious for certain applications such as navigation, fleet management, or location-based services in general, future applications, such as vehicle-to-vehicle-communications, which are solely based on absolute positioning, are currently the main driver behind the technological developments in this field. Absolute localization as implemented by Global Navigation Satellite Systems (GNSSs) seems to be a promising technological candidate to solve this task. Although many commercial vehicles are nowadays equipped with low-cost GNSS receivers, such systems provide only limited performance in dense urban areas. Especially, when buildings or foliage are acting as reflection surfaces, so called multipath errors which are caused by Non-Line-Of-Sight (NLOS) measurements, happen to appear. A brief introduction for Line-Of-Sight (LOS) and Non-Line-Of-Sight (NLOS) in urban areas is shown in Figure 1. The reception of each satellite signal depends on the position of the receiver and the satellite to each other. Satellites S_2 and S_3 are in LOS, satellite S_4 is blocked and satellite S_1 has NLOS. If such NLOS observations are not handled carefully within the localization algorithm, an unwanted bias is introduced in the final position estimate.

The paper is structured in a related work section, followed by an idea description, preliminary results and a section for next steps regarding this topic.

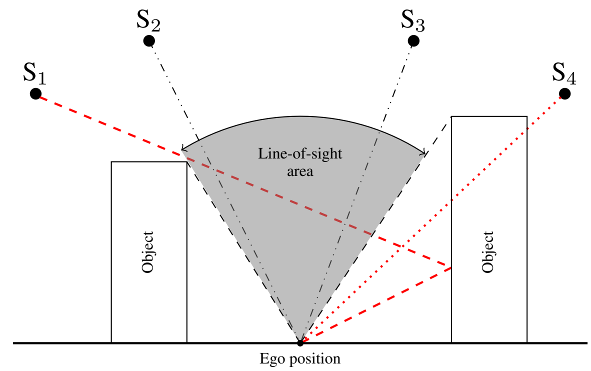

Figure 1. A typical situation in an urban area. This is a schematic representation of the electronic waves emitted by the satellites.

II. RELATED WORK

There are varying methods and approaches to detect and handle NLOS detections. A good introduction and description of different methods is given by Groves [1] and a good taxonomy is given by Obst [2]. The current approaches detect NLOS with additional hardware, special information like a 3D map with building information [3] or based on the Receiver Autonomous Integrity Monitoring (RAIM) concept with consistency checking [4]. None of these methods works with raw measurements, without additional information from external resources and can detect or exclude several satellites.

Our approach detects NLOS without additional external information and work as a self-consistent method.

III. IDEA DESCRIPTION

The NLOS effect caused by different environments generates an additional error part in the pseudorange measurement, besides the other common errors for example ionosphere, troposphere or ephemeris. A pseudorange ρ is modeled after [5] as

$$\rho = r + c(dt - dT) + d_e \qquad (1)$$

$$d_e = d_{NLOS} + d_{ion} + d_{trop} + d_{eph} + \dots \qquad (2)$$

In Equation (1), c is the speed of light and r the true range between the receiver and the satellite. The satellite clock error dT will transmit from the satellite by the navigation message

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of each satellite. The receiver clock error dt is unknown. Equation (2) describes some additional errors like ionosphere, troposphere, ephemeris or NLOS. There are various estimators and models for the different errors except NLOS. NLOS depends on the environment and the behavior is very dynamic.

The basic idea of our algorithm approach for detection of NLOS is using jumps in different parameters of raw measurements from a GNSS receiver. In more detail, the parameters are Pseudorange, Signal-To-Noise-Ratio (SNR), Carrier Phase or Doppler. A jump in this field is defined as an unusual strong increase or decrease between two or more measurements. For this purpose, we use a sliding window approach in post-processing over the last x measurements and estimate at first step the mean or median over these measurements, without the use of obvious outlier. This threshold is defined by a static long-term measurement campaign over multiple days. The second step calculates the mean or median over the complete dataset for each satellite and the result will be used in a third step as a threshold for separating as LOS or NLOS.

In post-processing, our approach used the challenging GNSS datasets from [6]. Therefore, we choose the data from the Frankfurt Main scenario for the preliminary results in Figures 2 and 3. In future work, we will use the other challenging scenarios too.

In [2], there is a good taxonomy of the multipath/NLOS problem. Our approach belongs to the class *Fault detection/ outlier classification* and open a new branch.

IV. Preliminary results

The result of the NLOS detection with the parameter pseudorange for GPS satellite 22 with the Novatel receiver is shown in Figure 2. This method to classify data by a ground truth with a Novatel receiver is described in detail in [2]. The preliminary results of the current status with the jump detection is shown in Figure 3. The results obtained with the parameters SNR and carrier phase are similar. In contrast, the doppler shows a lower rate of NLOS detection. All parameters need a deeper investigation of the different behavior with a varying size of the sliding window or other approaches to estimate the thresholds.

Figure 2 shows the detection with a state of the art method. Figure 3 depicts the state of the art method (red) and the jump approach (orange) in one diagram. Our approach detects more NLOS at the beginning of the dataset.

V. Next steps

The current approach detects NLOS measurements and excludes these measurements from the position estimation in a next step. This approach is called fault detection and exclusion (see taxonomy in [2]). In dense urban areas, the number of LOS measurements could not be enough and no position fix is available. Hence, the next step behind the classification in NLOS and LOS is to use the knowledge of NLOS data and estimate the pseudorange using this historic knowledge. A simple estimator or a filter like Kalman-filter perform this estimation process. By weighting several aspects of the jump information from the parameters, we have a chance to estimate a fixed position with the satellite information. To estimate the accuracy, we plan to implement an ego motion model and a motion model for the satellites. Accordingly, we expect a more stabilized estimation with this knowledge. Furthermore, we extend the self-consisteny approach for multi-constellation scenarios with GPS, Glonass, Galileo and Beidou.

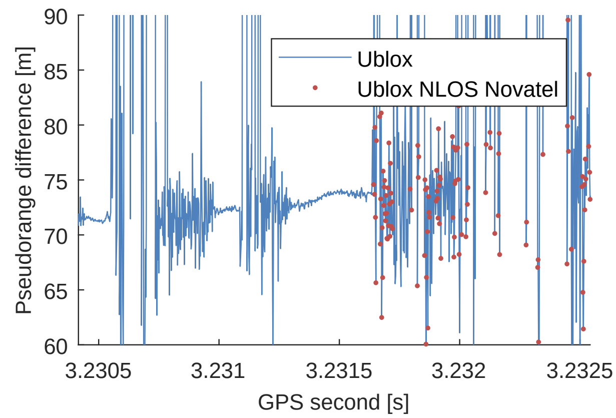

Figure 2. Ublox EVK-M8T (LEA-M8T) pseudorange measurements from GPS satellite (PRN 22) with our Novatel OEM6 NLOS (red dots) detection.

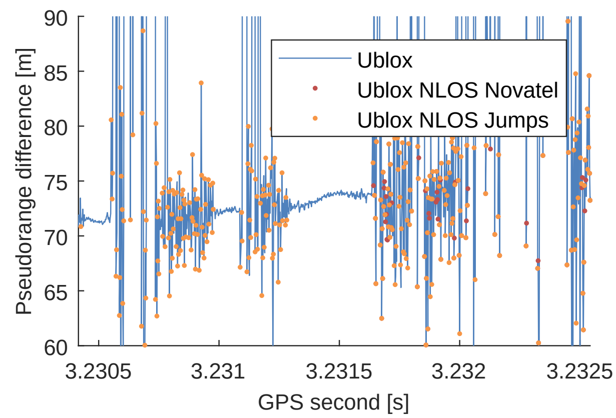

Figure 3. Ublox EVK-M8T (LEA-M8T) pseudorange measurements from GPS satellite (PRN 22) with our Novatel OEM6 NLOS (red) and our Jump NLOS (orange) detection.

Acknowledgment

For the evaluation and generation of the ground truth, precise real-time corrections provided by axio-net (http://www.axio-net.eu) were used.

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