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ORIGINAL ARTICLE

GPS multipath mitigation: a nonlinear regression approach

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Abstract Under the assumption that the surrounding environment remains unchanged, multipath contamination of GPS measurements can be formulated as a function of the sidereal repeatable geometry of the satellite with respect to the fixed receiver. Hence, multipath error estimation amounts to a regression problem. We present a method for estimating code multipath error of GPS ground fixed stations. By formulating the multipath estimation as a regression problem, we construct a nonlinear continuous model for estimating multipath error based on well-known sparse kernel regression, for example, support vector regression. We will empirically show that the proposed method achieves state-of-the-art performance on code multipath mitigation with 79 % reduction on average in terms of standard deviation of multipath error. Furthermore, by simulation, we will also show that the method is robust to other coexisting signals of phenomena, such as seismic signals.

Keywords GPS · Multipath mitigation · Nonlinear regression · Support vector machine

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Introduction

Multipath is defined as one or more indirect replicas of the line-of-sight signal arriving at the receiver antenna after reflection on objects in the surroundings. It constitutes a major error source that contaminates receiver measurements, causing performance degradation of GPS positioning solutions. The errors induced by multipath are typically up to 15 m for C/A code (Hoffmann-Wellenhof et al. 2001) and up to a few centimeters for carrier phase measurements (Leick 2004). That is significant for precise applications requiring centimeter-level accuracy. Although many positioning algorithms rely on the carrier phase measurements, accurate code measurements (pseudoranges) are important to a variety of applications.

It is still challenging to either rule out or accurately model multipath errors. Various approaches have been proposed to mitigate multipath in the GPS measurement domain. These approaches can be classified as either frequency-domain or time-domain processing. The methods in the frequency domain are based on spectral analysis of the multipath error. After converting multipath sequences into the frequency domain, the multipath error can be ruled out by nullifying the spectrum corresponding to its bounded frequency region (Zhang and Bartone 2004a). More recently, many attempts have been made to apply wavelet decomposition to de-noise high-frequency multipath or to extract low-frequency multipath signatures from GPS measurements that are then applied to correct multipath errors in subsequent measurements (Zhang and Bartone 2004b; Elhabiby et al. 2008, Souza et al. 2008a; b). However, a shortcoming of these methods is the tendency to rule out phenomena signals of interest, such as seismic signals, since their spectrum likely overlaps with the spectrum of multipath signals. Other approaches attempt to