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ORIGINAL ARTICLE

Multipath mitigation via component analysis methods for GPS dynamic deformation monitoring

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Abstract Multipath is one of the main error sources in high-precision global positioning system (GPS) dynamic deformation monitoring, as it is difficult to be mitigated by differencing between observations. In addition, since a specific frequency threshold value between multipath and deformation signals may not exist, multipath is usually inseparable from the low-frequency vibration signal using conventional frequency-domain filter methods. However, the multipath repeats in two sidereal days when the surroundings of a GPS antenna remain unchanged. This characteristic can be exploited to model and thus mitigate multipath effectively in dynamic deformation monitoring. Unfortunately, a major issue is that the degree of repeatability decreases as the interval between first day and subsequent days increases. To overcome this problem, we develop a new sidereal filtering referred to as reference EMD-ICA (EMD-ICA-R), where empirical mode decomposition (EMD) and independent component analysis (ICA) are jointly used to model multipath and renew the reference multipath. For the successful implementation of the EMD-ICA-R, an a priori denoised multipath signal is needed as a reference. We further propose to use the principal component analysis (PCA) method to extract more accurate reference multipath signal and form a combined PCA-EMD-ICA-R approach. Simulation experiments with a motion simulation platform were conducted, and the testing results indicate that the proposed methods can mitigate the multipath by around 67 % when a reliable reference multipath signal is extracted from a static situation. Furthermore, simulation experiments with different deformation signals added into the coordinate time series of three consecutive days show that the two proposed methods are also effective in a dynamic situation. Since wavelet filtering is used to denoise the reference multipath signals in the new approaches, simulation experiments with several wavelet filters are tested, and the results indicate that the PCA-EMD-ICA-R approach can work well with various wavelet filters.

Keywords GPS · Multipath mitigation · Independent component analysis (ICA) · Empirical mode decomposition (EMD) · Principal component analysis (PCA)

Abbreviations

EMD	Empirical mode decomposition
ICA	Independent component analysis
ICA-R	ICA with reference
PCA	Principal component analysis

Introduction

The global positioning system (GPS) has been widely used in dynamic deformation monitoring of engineering structures in recent years. However, GPS observations are always contaminated by various errors that affect the accuracy and reliability of positioning. In short-baseline GPS measurements for deformation monitoring, various error sources, such as satellite and receiver clock errors, can be eliminated by double-difference processing. Ionospheric and tropospheric delays can also be precisely modeled. Nevertheless, multipath effects occur when satellite signals arrive at a GPS antenna via different paths

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