Wavelet Transform Based Kalman Filtering Algorithm for Anti-SA Effect

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Abstract

A new mathematical approach, wavelet transformation, is introduced for GPS data analysis. Based on its good features on both time-domain and frequency-domain, one can obtain a true time-frequency representation of a signal. The so-called mutiresolution analysis (MRA) will be used for data analysis, such as for the removal of noises, and the detection and rejection of gross errors from signal. In this paper the authors present a wavelet-based algorithm for the modeling and prediction of SA effect by combining time series analysis methods. A new self-adaptive Kalman filtering algorithm is presented for anti-SA. Some preliminary test results from experimental data are also summarized.

I. INTRODUCTION

Global Positioning System (GPS) has been widely applied in the guidance of ships, cars and aircraft. For all these applications GPS is affected by both systematic errors or biases and random noise, including the clock error, ephemeris error, ionospheric delay, the refractive effect of the troposphere, multipath and especially the SA (selective availability). These biases have heavily blocked the further application of GPS in the precise approach and landing. The primary error of GPS point positioning comes from the SA effect, which mainly consists of low frequency components. Wavelet transformation is an efficient tool for distinguishing signal from noises. Positioning errors can be decomposed into various components (high frequencies and low frequencies) by the wavelet transformation. In recent years wavelet analysis has been developed very quickly and has been widely applied in image processing, fracture graphs, CT imaging, Radar, earthquake, cycle slip detection of phase measurements etc (Chatfield, 1984; Huang and Zhuo, 1997). Arbitrary details of a signal can be observed and analyzed by the aid of wavelet analysis. SA effects whose primary components are of low frequency, shows as a random process. Time series analysis method can be used for the modeling of SA effect. Practical data analysis manifests that SA effect has the characteristics of an AR (auto-regressive) random process and the one-step predictive results of AR (p) model are very precise. Since the parameters of AR model vary with time, a self-adaptive algorithm is used to obtain parameters in the model AR (p) and this in turn could be utilized for anti-SA filtering.

II. MALLAT DECOMPOSITION AND SIGNAL-NOISE SEPARATION

Discrete wavelet transform (DWT) is often for practical use, which provides sufficient information both for analysis and synthesis of the original signal with a significant reduction in computation time compared to the continue wavelet transform. For a given signal, one can compute the DWT and uses it in different ways. We can discard all the values in DWT that are less than a certain threshold, i.e. let these coefficients be zero, and save only those DWT coefficients that are above the threshold. When these coefficients are used to reconstruct the original signal, a significant data reduction can be done without losing too much of the information. We can also analyze the signal at different frequency bands, and reconstruct the original signal by using only the coefficients that are of a particular band. This makes it possible for us to obtain different components from the signal.

For a given multi-resolution analysis, the Mallat decomposition procedure can be written as:

$$f(x) = A_{J_2} f(x) + \sum_{j=J_1+1}^{J_2} D_j f(x) \tag{1}$$

$$A_j f(x) = \sum_{k=-\infty}^{\infty} C_{j,k} \varphi_{j,k}(x) \tag{2}$$

$$D_j f(x) = D_{j,k} \psi_{j,k}(x) \tag{3}$$

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