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Extended Abstract

Applying Fourier and Wavelet Transforms to Extract Instantaneous Unit Hydrograph

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Introduction

The methods of system identification used to estimate the ordinates of Instantaneous Unit Hydrograph (IUH) encounter the presence of noise in the form of oscillation. Noise in the IUH originates from the errors in the rainfall- runoff data and the linear assumptions in unit hydrograph theory. Rao and Delleur (1971) used Fourier transform to estimate IUH. In their work noise is controlled by the moving average technique. The aperiodic and transient signals with short duration (like in an IUH) are signals for which wavelet transform are particularly useful. Chou and Wang (2002) controlled the noise using a Haar wavelet with a boxcar-like function. Soman and Ramachandran (2005) showed that for smoothly varying signals a smooth wavelet function such as Daubechies (1992) wavelets should be selected. In this paper, the fast Fourier transforms (FFT) are used to estimate the IUH in the presence of noise. Daubechies wavelets are also applied for noise reduction.

Objectives

In this study, the IUH is extracted using FFT, which is a well-known method in engineering. Furthermore, the Daubechies wavelets with different filter length are used to reduce the noise of the IUH.

Methodology

A time invariant linear system indicated by convolution integral in time domain is changed to a simple multiplication operation in the frequency domain. First, the FFT is used to extract IUH from the frequency domain and the inverse FFT gave back IUH in the time domain. Then the discrete wavelet transform is applied to decompose the IUH into low and high frequency bands. The noise in the IUH is estimated by wavelet coefficients. The close-to-zero coefficients were set to zero. The obtained result is a hydrograph with the information of low frequencies, which approximates the real IUH.

As the case study, the rainfall – runoff data for a selected sub-watershed from Walnut Gulch Experimental Watershed (WGEW) encompassed the 8.98 square kilometers in southeastern Arizona; U.S.A, is used in this analysis.

Results and Discussion

IUH is extracted by FFT for nine events. As average error to compare the observed and regenerated hydrographs, the relative error of peak discharge (EQ_p), the absolute error of time to peak (ET_p), and the coefficient of efficiency (CE) are 0.0253, 0.33 (min), and 0.96, respectively. Then nine IUHs are synchronized based on their peak values to result in the average IUH. The averaged IUH is decomposed to four levels by wavelet transform to separate its approximation (low frequencies) and detail (high frequencies) components. Results showed that a wavelet introduced by Daubechies (1992) with a filter length of 6 is the best alternative in this study. The successive approximation components from level 1 up to 4 appear to be smoother, and IUH is well reconstructed at level 4 (Fig. 1).

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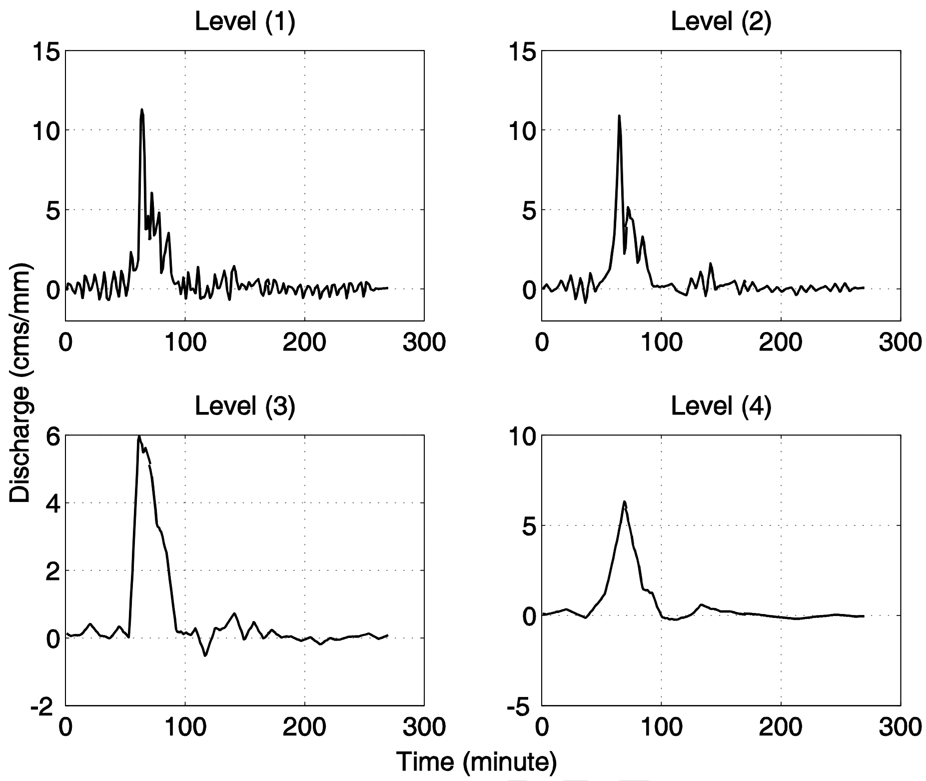

Figure 1- Noise reduction in IUH by removing high frequencies via Daubechies wavelet (filter length 6).

Accordingly, the detail components are ignored and the IUH is reconstructed by the approximation components in the inverse wavelet transform. The smoothed IUH is applied to five events of rainfall – runoff for validation. The average error criteria are 0.2011, 8.8 (min) and 0.69 for EQ_p, ET_p, and CE, respectively. The results showed that the error criteria values are acceptable in validation events.

Conclusion

Noise in IUH can be reduced by removing high frequencies from the decomposed IUH in wavelet domain. Fast Fourier and wavelet transforms evaluated as appropriate tools for extracting and denoising IUH as well as for applications in flood events.

***Keywords*:** Instantaneous Unit Hydrograph, Fast Fourier Transform, Wavelet

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