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**EXTENDED ABSTRACTS**

# Iran Accelerograph Data Contraction Using Wavelet Analysis

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## 1. Introduction

The main purpose of this paper is to find an approximation of Iran strong motion records by a relatively small number of pulses (i.e. wavelets in an orthogonal wavelet family) considering wavelet importance in introducing the nature of ground strong motion. The Coiflet 5 wavelet family is used, which is orthogonal, smooth and nearly symmetric. Such representation is obtained by the expansion of velocity in orthogonal wavelet series using the Fast Wavelet Transform, and approximation by only the largest energy terms in the series. The goodness of the approximation is examined. The efficiency of the procedure is assessed by comparison some seismic indices such as input seismic energy, peak power and nonlinear oscillator collapse time which are achieved from the main and contracted signals.

## 2. Methodology

### *2.1. Wavelet series representation of discrete time signals*

For a basis of compactly supported wavelets, the coefficients of the expansion are computed by the pyramid algorithm, which consists of splitting the original signal in a low- and high-frequency component followed by downsampling by a factor of two, and further recursively splitting the lower frequency component, J times total. In each splitting, the low-frequency component is a lower-level resolution approximation, and the high-frequency component contains the detail of the signal that was removed. Hence, the wavelet expansion is nothing else but splitting the signal in subbands, and expanding each subband in a series of wavelet functions, which are shifts of one another, and all have central frequency corresponding to the one of the subband (Todorovska et al., 2009).

### *2.2. Measures of goodness of fit in terms of nonlinear oscillator response*

As measures of goodness of the approximation, the energy and peak power of the input ground motion and subsequently the corresponding times of collapse of a nonlinear oscillator excited by such motions from the exact signal and form the approximation are compared. These quantities were estimated as follows.

## 3. Results and discussion

### *3.1. Detailed results for a sample record*

Fig. 1 shows a wavelet map of the coefficients for the Tabas record of the top 8% of the wavelet coefficients. Such maps show the wavelet coefficients (coefficients of expansion in wavelet series) plotted as vertical bars versus the central time (centroid in the time domain) of the corresponding wavelet, for each of the detail subbands (cD1-cD6) and the remaining smooth subband (cA6). The frequency bounds indicated for

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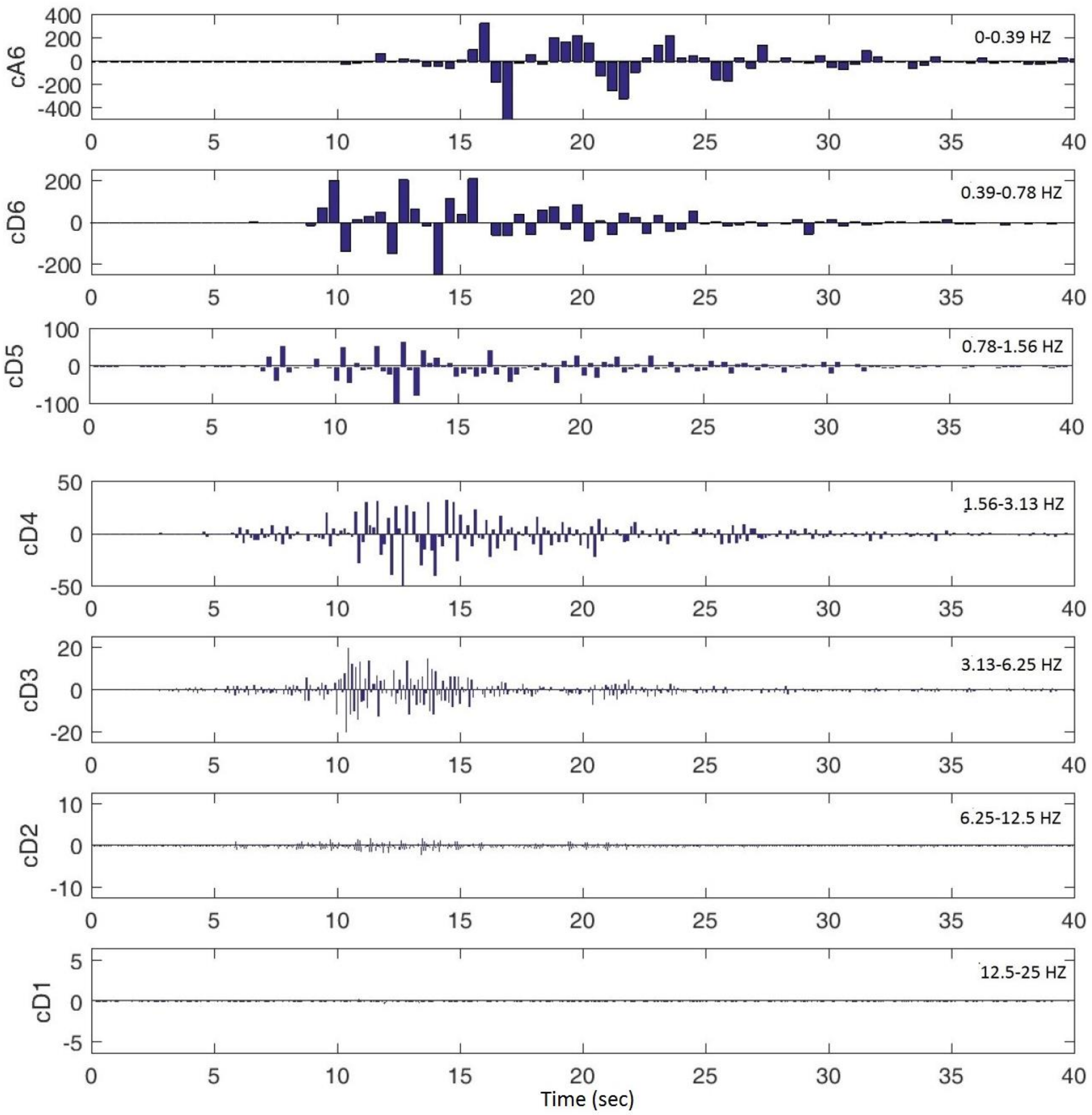


**Fig. 1.** The top 8% wavelet coefficients of the expansion of the velocity of component Tabas strong motion record, plotted versus their central time for each sub band.

Each subband are those for ideal (box) filters. The actual filters decay gradually across the ideal bounds to avoid the Gibbs effect, and consequently there is some partial overlap between these intervals for the actual filters used. The wavelet maps, therefore, show the position of the wavelets used for the approximation both in time and in frequency. According to the Parseval equality, the square of these coefficients would be the contribution of the corresponding term in the series to the energy of the (velocity) signal. Such a map, therefore, indicates the distribution of the energy of the signal on the time–frequency plane.

Comparing the exact and approximated motions for the 1% and 4% level approximations of the acceleration, velocity, power and energy time history, it can be seen that the agreement is better for the velocity than for the acceleration signals, which is due to the fact that the thresholding was applied to the velocity signal, from which the acceleration was then derived by differentiation, and that the velocity signal has less energy in the higher-frequency subbands, leading to all or most coefficients in these subbands being eliminated by the thresholding. These plots also show that, while the low-amplitude high-frequency pulses are smoothed in such low approximation levels, the largest amplitude pulses are still represented quite well even in the acceleration signals. This is characteristic to data compression by thresholding, in which the high-frequency components are filtered where they are small but are preserved where they are significant. It can be also seen that the growth of energy of the input ground motion with time, for the actual and approximations by 1%, 4%, 6% and 8% of the coefficients will be closer by further increasing the number of coefficients. The comparison between the power versus time for the exact signal and the 1% approximation demonstrates good fitness of them. Consequently it is obvious that this approximation represents quite well the peaks in the power time history, and in particular the largest peaks. For collapse times of nonlinear SDOF oscillator in the linear range of response, small difference in the input motion implies small difference in the response of the oscillator. However, that does not hold for the nonlinear range. For the bi-linear oscillator considered in this study, the agreement of the time of collapse was chosen as a measure of the goodness of fit, and a weak oscillator was chosen for this test that would fail for most of the records in the database. Figure 2 depicts the correlation coefficients distribution of peak power, total energy and collapse time of nonlinear oscillator in different periods for actual and contracted signals of 806 records. This figure illustrates high correlation of these indices that can be confirm the procedure efficiency and capability.

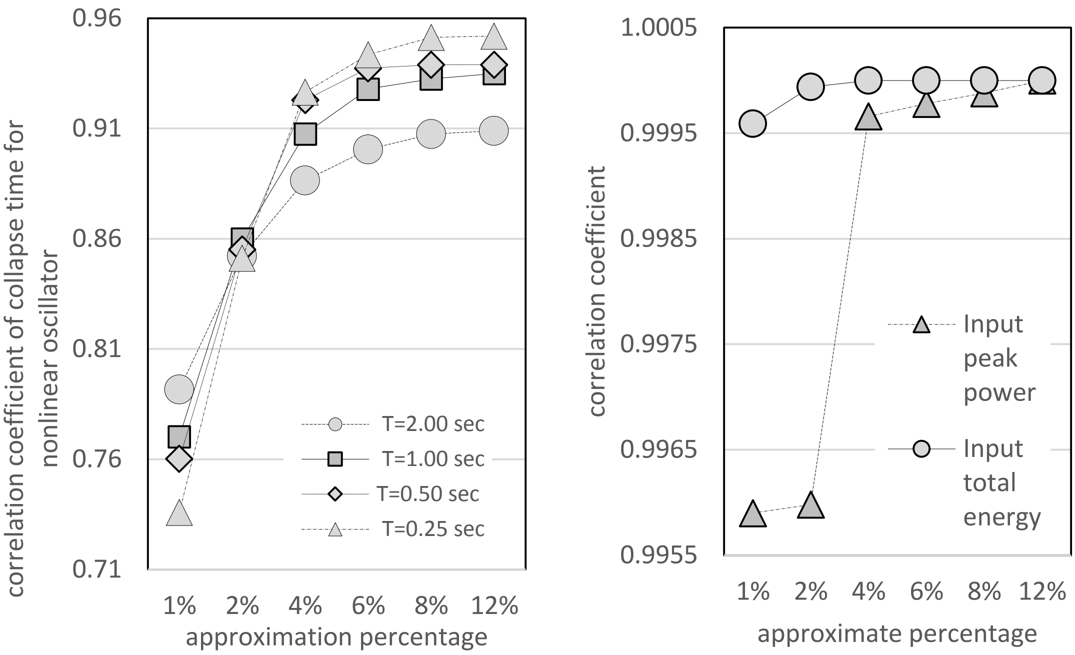


**Fig. 2.** Correlation coefficient of peak power and total energy (right side) and correlation coefficient of nonlinear oscillator collapse time for different periods of T=0.25, 0.5, 1 and 2 sec (left side).

## 4. Conclusions

The paper objective is to find an approximation of Iran strong motion records by a relatively small number of pulses (i.e. wavelets) such that would produce a reasonably good fit for different indices such as acceleration, velocity, peak power and total energy and subsequently would predict closely the response of a nonlinear oscillator. To satisfy the first requirement, Coiflet wavelets (Mallat, 1989), which are orthogonal, nearly symmetric, and relatively smooth. The orthogonality property is convenient for the evaluation of the energy directly in the wavelet transform domain, the symmetry is desirable to reduce phase distortions in the approximation, and the smoothness is desirable because it helps achieve better fit for strong motion records with smaller number of wavelets. It is concluded that expansion of strong motion records in a wavelet basis is an efficient tool for extraction of pulses from a strong motion record, and representation of strong motion records as a sum of a relatively small number of pulses. This efficiency (good approximation by a small number of pulses) is due to the fact that the basis functions are localized in time (besides in frequency), resembling in nature the strong motion records.

## 5. References

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