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# Time history dynamic analysis of structures using filter banks and wavelet transforms

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**Abstract**

Dynamic analysis of structures is achieved by wavelet transforms and filter banks. The method reduces the computational burden of the large-scale dynamic analysis. A time history analysis is carried out for a seismic analysis. To reduce the computational work, fast wavelet transform is used. To compute fast wavelet transforms, the Mallat and the Shensa algorithms are used. These two methods are used for wavelet theory together with filter banks. The low and high pass filters are used for the decomposition of accelerogram ground acceleration into two parts. The first part contains the low frequency of the record, and the other contains the high frequency of the record. The low frequency content is the most important part; therefore this part of the record is used for dynamic analysis. A number of structures are analysed and the results are compared with dynamic analysis using the original earthquake record.


*Keywords:* Dynamic analysis; Filter banks; Wavelet transforms; Time history analysis

## 1. Introduction

Wavelet transforms are well known as useful tools for various signal-processing applications. Continuous wavelet transform is best suited for signal analysis [1–3]. The semi discrete and full discrete wavelet transforms have been used for signal coding applications. Wavelet transforms have been applied in many other fields, some of the applications are presented in Ref. [4].

Wavelet analysis is a technique of great interest for the analysis and approximation of non-stationary signals [5]. The analysis of non-stationary signals often involves a compromise between how well sudden variations can be located, and how well long-term behaviour can be identified. Choosing basis functions well suited for the analysis of non-stationary signals is an essential step in such applications.

In this paper, the accelerogram is decomposed using FWT into a smaller points and the dynamic analysis of structures is carried out against this reduce points. Dynamic analysis of the structures against the original earthquake record is, in general time consuming and the computational cost of the process is high [6].

Using Fourier transform (FT) and fast Fourier transform (FFT), a signal can be expressed as the sum of a, possibly infinite, series of sinus and cosines. This sum is also referred to as a Fourier expansion. Fourier series are examples of basis functions used in function approximation. If a function is piecewise smooth, with isolated discontinuities, the Fourier approximation is poor because of the discontinuities [3]. Wavelets are well suited to approximate piecewise smooth signals. There is an

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important difference between Fourier analysis and wavelets. Fourier basis (sinus and cosines) are localized in frequency but not in time. Wavelets are local in both frequency and time. Consequently, piecewise smooth signals can be represented by wavelets in a more compact way [5].

The major disadvantage of FT and FFT is that they have only frequency resolution and no time resolution [7]. This means that although we might be able to determine all the frequencies present in a signal, we do not know when they are present. To overcome this problem, in the past decades several techniques have been developed which are more or less able to represent a signal in the time and frequency domain [3]. The main idea behind these time-frequency representations is to cut the signal under consideration into several parts and then analyse each part separately. By analysing a signal in this way, we will give more information about when and where different frequency components exist. Suppose that we want to know exactly all the frequency components present at a certain time. We cut out only this very short time as a window, transform it to the frequency domain and compute the frequency in this part. Sometimes the result of this method is inaccurate, due to an incorrect choice for the width of the window [8]. Another disadvantage of the FT and FFT is that it cannot separate the low and high frequencies [9].

The wavelet transform (WT) is probably the most recent solution to overcome the shortcomings of the FT [9]. In Ref. [10] some applications of wavelet in earthquake, wind and ocean engineering are explained. In Refs. [11–15] wavelet transform is used for structural optimisation and dynamic analysis of structures.

In WT the use of a fully scalable window solves the signal-cutting problem. The window is shifted along the signal and for every position the spectrum is calculated. Then this process is repeated many times with a slightly shorter (or longer) window for every new cycle. In the end the result will be a collection of time-frequency representations of the signal, all with different resolutions [7]. Because of this collection of representations we can speak of a multiresolution analysis.

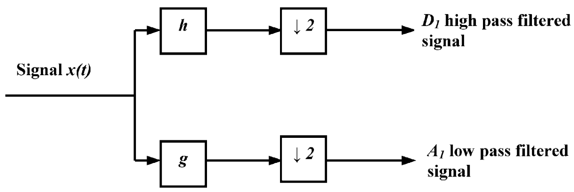


Fig. 1. Decomposition of a signal using a filter bank.

In the present work we use fast wavelet transform (FWT) for time history dynamic analysis. To compute the fast wavelet transform the Mallat algorithm (FMA) [16] and the Shensa algorithm (FSA) [17] are employed. In these two methods FWT is used to transfer the ground acceleration record of the specified earthquake into a signal with very small number of points. Thus the time history dynamic analysis is carried out at fewer points. The accelerorgram is broken into multilevel records. The original record passes through two complementary filters and emerges as two signals. For many earthquake records, the low frequency content is the effective part, because most of the energy of the record is in the low frequency part of the record. On the other hand, for a record, the shape and the effects of the entire low frequency component are similar to those of the main record. The numerical results of the dynamic analysis show that this approximation is a powerful technique and the required computational work can be greatly reduced. The errors in the proposed methods are small.

## 2. Filter banks

There is a relationship between the wavelet transform and the digital filter banks. It turns out that the wavelet transform can be simply achieved by a tree of digital filter banks, with no need of computing mother wavelets. Hence, the filter banks have been playing a central role in the area of wavelet analysis. The theory of filter banks was developed a long time ago, before modern wavelet analysis became popular [18].

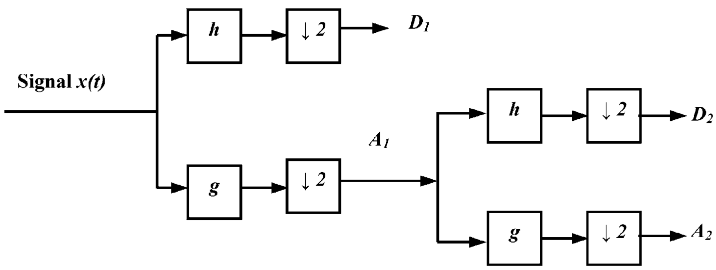


Fig. 2. Multilevel decomposition of a signal by using the low-pass output signal as input to the filter bank.