Structural Dynamics Analysis Using Non-Uniform Fast Fourier Transform in Frequency Domain

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Abstract

Nonuniform seismic motion affects the seismic behavior of large structures such as long-span bridges. Three main reasons for this nonuniformity have been identified. They are local soil conditions, wave passage, and incoherency effects. Other effects, such as extended source and attenuation, are relatively small. The importance of nonuniform seismic motions, especially for sensitive and important structures, has led to the development of several methods of analysis. This paper presents a direct frequency-domain method that is based on neural network and optimization. The use of this direct frequency-domain method for solving nonuniform seismic motions is shown. Finally, the application of the proposed method to a simple multiple particle damped system under harmonic loading is presented and the validity and feasibility of the transformation algorithm in time-domain and frequency-domain are numerically verified.

Keywords: Structural dynamics, Seismic wave, Nonuniform fast Fourier transform, Neural network, Optimization.

1. INTRODUCTION

Spectral analysis using the Fourier Transform has been one of the most important and most widely used tools in earthquake engineering. Fourier analysis is based on the notion that any regular periodic function and certain nonperiodic functions with finite integral can be expressed as a sum of trigonometric functions in an infinite time. Fourier transform gives a unique representation of the wave in the frequency domain and provides information about which frequencies appear in the wave. However the requirement for using FFT algorithms is that the input data must be equally spaced while in practical situations the input data is nonuniform (i.e., not equally spaced) and hence the regular FFT does not apply.

The attempts to face these problems led to the search of the so-called Generalized or Nonuniform FFT, which would have the complexity of the Cooley-Tukey algorithm and would be exact. These desiderata were not yet achieved, since the trick used by Cooley and Tukey for uniform FFT is not valid in the nonuniform case. Though for some trivial nonuniform grids a scheme similar to the Cooley-Tukey FFT can be derived, the question is open for general nonuniform grids.

Today, the majority of fast nonuniform transform have to reduce the nonuniform problem to the uniform one in order to take advantage of the Cooley-Tukey FFT or a similar method, and are approximate. To overcome this difficulty Dutt and Rokhlin [1, 2] and Beylkin [3] studied the problem of FFT for nonuniform (unequally spaced) data. To the best of our knowledge, within the past several years researches have used complicated mathematics which were difficult to understand and apply, however, with the general availability of inexpensive, high-speed personal computers the fast Fourier transform for nonuniform data can be obtained without the use of complex mathematical techniques. Therefore, the modern structural engineer who has a physical understanding of the structural dynamics can perform NUFFT without being concerned with complex mathematical formulations.

In this paper, with respect to the dynamic response analysis of damped system subjected to harmonic loading, the response solutions in time and frequency domain are derived. Then, to verify the accuracy of the proposed methods, the frequency amplitude is compared with the analytical solution. The numerical results showed that the NUFFT performed by neural network and optimization is identical with analytical solution in calculating the spectrum of frequency. A problem that may arise in using the FFT, results from the fact that spectrum of the FFT is not continuous; it is a discrete function where the spectrum consist of integer multiples of the fundamental frequency. It is possible, however, that some significant frequency component