Time-Frequency Analysis of Seismic Signal Processing with Arbitrary Orientation Selectivity

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Developing countries and developed countries are both exposed to various types of risks including natural disasters. Earthquake mitigation is one of the most important topics considering natural disasters. The study of seismic design has been developed in order to enhance the resistance of the structure encountering earthquakes.

In the study of seismic design, dynamic analysis has become an important procedure to test the performances of the target structure under earthquake on the conception of performance based earthquake engineering (PBEE). For dynamic analysis, selection of the input ground motion could influence the uncertainty in the process of seismic design. Historical records of ground motion and artificial ground motion could both be utilized as input ground motion, while artificial earthquakes are considered as the better option nowadays with the development of the computational capability. But the present schemes and practice on seismic simulation have their demerits that need to be improved. In this research, a new method based on continuous wavelet transform (CWT) for generating artificial ground motions by altering phase spectrum is to be proposed and the past researches on seismic simulation is also to be studied.

Chapter 1 would introduce the background of seismic design and the conception of seismic simulation. The importance of selection and generation of artificial design input motions is to be clarified. In Chapter 2, there would be a literature review of the past researches on seismic design and ground motion simulation including design codes, empirical simulation methodologies and stochastic methodologies based on the signal processing. From the view of performance-based design, design codes only consider the performance of each components of the structure and the target structure is not studied as a whole. Empirical simulation methodologies relies too much on the precision of the fault model which is limited and they are not suitable for high-frequency components of the signal. Stochastic method and discrete wavelet transform cannot give the arbitrary orientation selectivity in frequency domain or time-frequency domain. So our main purpose is to suggest a new methodology to eliminate all these demerits.

Chapter 3 shows the proposed methodology of generating artificial ground motions based on CWT, through which phase disturbances could be arbitrarily oriented in time-frequency domain of the signal. In this research, both Shannon wavelet and Gabor wavelet are selected as the candidate to approach the purpose. With each of both mother wavelets, phase disturbances would be added to the signal in single-disturbance case and multiple-disturbances case. The results is to be plotted and studied how the specific disturbances is localized in the time-frequency domain. Meanwhile, the performance of Shannon wavelet and Gabor wavelet will be compared and optimized one is going to be selected. The target earthquake is 2000 Tottori Earthquake and the record is downloaded from K-NET.

Chapter 4 will show the advantage of the proposed method. The advantage of the proposed method is time domain is relatively obvious as we could implement the methodology in the dominant part of the ground motion signal and it could be directly observed. As for the advantage in frequency domain, it is to be proved by a numerical simulation of the dynamic analysis, through which we could find that it benefits in the view of engineering to arbitrarily fluctuate original seismic signal near the modal frequencies so that the performance of the target structure encountering earthquake could be much more diverse, thus the uncertainty during the process of seismic design could be reduced.

In Chapter 5, summaries and conclusions of this research is presented. Meanwhile the future works based on this study and proposed method is going to be discussed, in which the most important step is to have a better understanding of the amplitude factor of each disturbance added to the signal and how it influences the total power and physical characteristic of the ground motion wave.