Seismic wave similarity estimation based on the time-frequency characteristics and non-linear response characteristics

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1. Introduction

Advance of numerical simulation and observation technologies lead us to the availability of accurate time histories data of seismic waves. Quality of those data are often discussed based on indices such as peak values, correlation function, and “appearance” of time histories. The conventional indices are useful, but their mathematical meaning are not directly associated with the characteristics of the seismic waves. Methodology to estimate quantitatively and accurately the performance of the seismic waves is needed in both academic and practical fields.

2. Methodologies

We propose two types of indices to measure the “similarity” of seismic waves. One pays attention to the time-frequency characteristics of the seismic waves. The other puts more emphasis on the engineering aspects. It measures the discrepancy of the response of non-linear structural systems.

(1) Index based on the Time Frequency Characteristics

RMS (root mean square) of the difference is one of the most used index to quantify the difference of of the time series signals. It measures the power of the difference and has a clear mathematical meaning, but is not suitable for frequency characteristic analysis. For time-frequency analysis, wavelet transform is widely used. Kristekova et al. (BSSA, 2006) used Morlet wavelets to propose indices to discuss “envelope misfit” and “phase misfit” of seismic waves, but their indices do not have strict mathematical foundation. We modify them to generate indices that can clarify the contribution of “amplitude” and “phase” of the difference to the RMS.

(2) Index based on the Nonlinear System Response

Considering the purpose of strong motion simulation, it makes sense to discuss the characteristics of ground motions according to their effect on the structural systems. Various indices such as PGA, PGV, total power, seismic intensity, response spectra are in use but no single index is dominant enough to discuss the similarity of strong motion characteristics. We propose to estimate the similarity of seismic waves based on multi-indices. We consider stochastic property of the multi-indices under uncertainty of structural parameters. Their informations are integrated into a single scaler index by using information theory.

3. Numerical Simulations

Applicability of the proposed indices are verified by the numerical simulations using strong motions records and time series signals with parametric variations.