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A new site classification approach based on neural networks

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ABSTRACT

Site classification is an important procedure for a reliable site-specific seismic hazard assessment. On the other hand, the site conditions at strong-motion stations are essential for accurate interpretation and analysis of the recorded ground motion data obtained from different regions of the world. For some countries with insufficient data on the subsurface geological settings, the required site condition information is not available. This paper presents a new and efficient approach for site classification based on artificial neural networks (ANN) along with a selected set of representative horizontal to vertical spectral ratio (HVSR) curves for four site classes. The nonlinear nature of ANN and their ability to learn in a complex environment make it highly suitable for function approximation and solving complicated engineering problems. Two types of radial basis function (RBF) neural networks, namely, probabilistic neural networks (PNN) and generalized regression neural networks (GRNN) were chosen in this study, as no separate training phase is required, rendering them particularly suitable for site classification. The proposed approach has been tested using data of the Chi-Chi, Taiwan, earthquake (Mw=7.6) recorded from 87 stations at which the site conditions are known. Analyses show that both the PNN and the GRNN perform very well with similar accuracy in estimating site conditions, with successful rates of 78% and 75%, respectively.

1. Introduction

The damaging effects of near-surface soft sediments on civil engineering structures have been well evidenced in past destructive earthquakes, such as Manjil-Rudbar (1990), Northridge (1994), Kobe (1995), Kocaeli (1999), Bhuj (2001) and Bam (2003). It has long been recognized that local site conditions alter the amplitude, frequency contents and duration of incident strong seismic waves [1–3]. Hence, estimating site effects is indispensable for a reliable site-specific seismic hazard assessment [4,5]. Seismologists and earthquake engineers have put substantial efforts in the past few decades to understand and estimate more accurately the site effects on ground motion characteristics and to take in account the associated effects in design of new structures and retrofitting of existing infrastructures (e.g., [6–11]).

The influences of site conditions on the earthquake resistant design of structures have been incorporated in the current seismic code provisions and design guidelines (e.g., [12–14]). Such effects are typically quantified by a site factor which is assigned based on site class. The commonly used parameter for site classification is the average shear wave velocity over the upper 30 m of the subsurface geological materials ($\overline{V}_{30}$), of which its measurement in many countries may not be feasible due to various technical or financial constraints. Hence, it is desirable to develop a simpler and more effective site classification method for those regions.

On the other hand, with the increase in the number of strong ground motion stations, as well as the higher quality of instrumentation in different geological conditions around the world, there is a growing interest of the proper use of these sets of strong ground motion data, which provide valuable information for both engineering and seismological communities, e.g., for the development of ground motion prediction equations (GMPEs). However, in many countries like Iran, Turkey and Mexico, there is a lack of detailed information of site conditions at many of those strong motion stations. Site classification based on borehole data or interpretation of geologic maps and geomorphology data could not be done. Hence, simplified methods have been introduced by various researchers for site classification based on analysis of recorded strong ground motion data.

There are a number of site classification estimation techniques. The standard spectral ratio (SSR) method [1] is one of the early and well-known methods, based on comparison of earthquake response spectra obtained simultaneously at a site of unknown site condition and that obtained at a nearby reference rock site. Besides, the most popular method for estimating site conditions is the horizontal-to-vertical spectral ratio (abbreviated hereafter as

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