SYNTHESIS OF DESIGN INPUT GROUND MOTIONS WITH FEATURE IDENTIFICATION BY AUTOENCODER

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1. INTRODUCTION

For the design purpose, a tough ground motion is desirable. Many researches focused on the frequency characteristics ground motion [e.g. 1], and little attention has been paid to the time history. For non-linear response, time domain is also essential; two ground motion with the same amplitude but different time history characteristics can induce quite different response on one structure. Modifying the ground motion without increasing its amplitude but make it more tough for structures should be considered, but it is a difficult task. Since machine learning is a powerful tool to process a large amount of data, it can be used to analyze the relation between ground motion and response time history of structure. We propose to use AutoEncoder to identify the features of ground motions, so that they can be exploited for the synthesis of design ground motions.

2. FEATURE IDENTIFICATION BY AUTOENCODER

AutoEncoder is used to analyze the data. Ten encode layers are defined to compress the complex information included in ground motion and response time history into 5 abstract latent features, and another ten decode layers to decompress the latent features and reconstruct the ground motion and response time history. Half of 20,000 groups of data (response time history and ground motion) are used as training data, and another 10,000 groups are used as validation data. Through observing the change of loss value with the increase of epoch, the epoch number is finally defined as 10.

After training the AutoEncoder model, the validation of model can be examined through comparing the output ground motion and response time history with that in input data. Five latent features which is extracted from input data can tell us what this model learned from these data, and how are they related to input data. Through changing the value of these five latent features, we can generate a stronger or weaker response time history, and observe what is the difference in ground motion. By this way, we can learn the relation of non-linear response time history and ground motion.

3. NUMERICAL SIMULATION

The original ground motion information is downloaded from K-NET. These ground motions have a time duration of 100 seconds and sampling at 100Hz. Considering the complexity of the data and the ability of algorithm intelligence model, we only use first 40 seconds. Fourier Transform is used here to transform the ground motion into frequency domain. We randomized the phase between 1Hz to 1.5Hz to generate 20,000 similar ground motions. After the phase randomization, these 20,000 ground motions are totally the same on frequency domain, but some difference in the time domain can be seen. Through the OpenSees software, the non-linear time history analyzes of one specific structure under these 20,000 ground motions can be realized. The computation gave us the 20,000 pairs of ground motions and corresponding response time histories. In each pair, there are 4,000 points for ground motion and 4,000 points for response time history. We splice each ground motion at the end of the corresponding response time history and make it as our input data; each group of input data has 8,000 points.

4. SIMULATION RESULTS

Figures 1 and 2 show the examples of time histories of the response of structures; original data and the reconstructed data. Although the real data and reconstructed data still have some differences especially in Figure 1, because of the good fitness of main part around 20 second, the resultant model should be usable. Especially the simulation of peak value is good enough. Figure 3(a) shows the relation between features and peak value in response time history. The x-axis denotes the

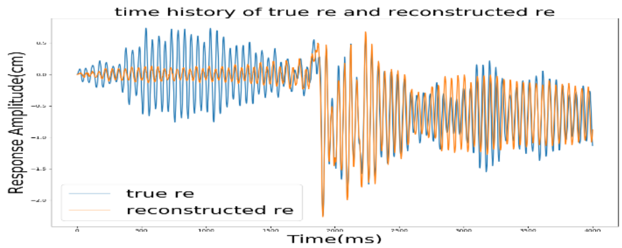


Fig 1 The real response and reconstructed response

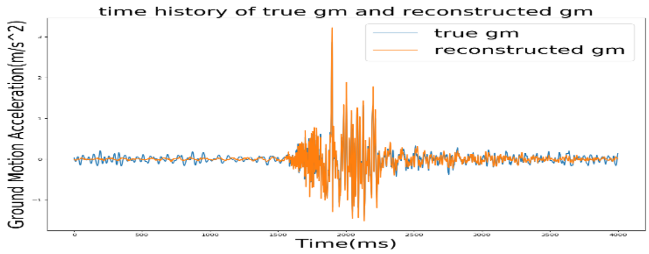
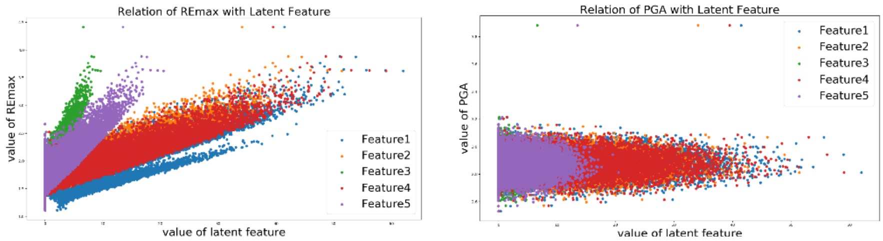


Fig 2 The real ground motion and reconstructed ground motion

value of features, and y-axis the peak value in response displacement. The results of five features are plotted in different colors. Similarly, Figure 3(b) shows the relation between features and peak ground acceleration. The x-axis denotes the value of features, and y-axis the peak ground acceleration. The positive correlation between five latent features and the peak value of response time history is apparent, which means stronger response can be generated by increasing the value of latent features. Conversely, the peak ground acceleration did not change significantly with latent features.



(a) Peak response displacement (b) peak ground acceleration

Fig 3 The relation between features and indices in ground motion or response time history

The influence of different latent feature on the peak value of response are different. Some features can have a relatively greater influence on the response. Figure 4 shows that, when we change the feature 1 and feature 5 to the same value respectively and keep the value of other features constant, the modified response of former one will be greater than that of latter one. Figure 5 shows that the peak ground acceleration did not change so much as the response. After we can correlate these features to specific characteristics of ground motions, through modifying the value of different latent features, we could even know which characteristics of ground motion is more significant in generating greater response time history, and at the same time, which will not change the amplitude of ground motion significantly.

It provides us a possibility to find some other reasons which are ignored so far are related to these features and can indirectly explain the increase of peak value in response time history by changing the value of these latent features and observing the difference in ground motion.

The response presented above are outputs of the AutoEncoder, not the results of the nonlinear dynamic analyses. These results indicate that we can identify the features that are related to the response of the structures and also, we can generate input ground motions based on those features. Performance of the synthesized input motions, however, are to be verified.

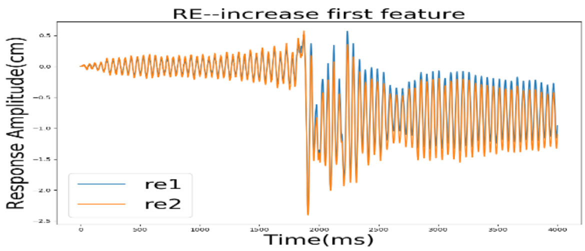


Fig 4 Two response after modifying the value of latent

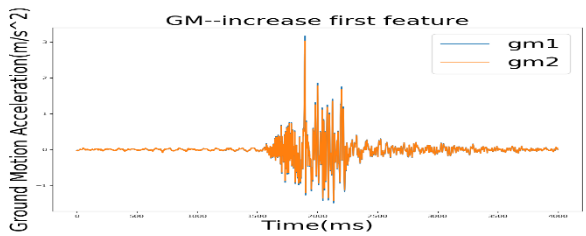


Fig 5 Two ground motions after modifying the value of latent

5. SUMMARY

AutoEncoder is trained to learn ground motions and response time histories, and reconstruct them, extracting the feature as latent variables. The relation between features and ground motion or response allows us to generate design ground motions considering various aspects of influence on the structural response. Verification of the performance of the synthesized ground motions should be reported in the conference.

REFERENCE

[1] Baker J W, Allin Cornell C. Spectral shape, epsilon and record selection. *Earthquake Engineering & Structural Dynamics*, 2006, 35(9): 1077-1095.