Broadband ground-motion synthesis using embeddig machine learning

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Broadband ground-motion predictions are performed to estimate seismic hazards. A standard hybrid approach combines long-period motions calculated by a numerical simulation and short-period motions by a statistical method to synthesize broancband motions. But it still has drawbacks that generated short period motions do not reflect source and path effects, and resulting building responses can be inconsistent over the joint periods between the long and short periods.

In recent years, another approach has been proposed which models the relation between long and short period, and estimates short-period waves from long-period ones (Iwaki et al., 2016; Paolucci et al., 2018). Iwaki et al. (2016) modeled the relations of envelope waves in different bands using earthquakes similar to a target earthquake. We attempt to model this relation using a machine learning method.

The envelope waves are estimated using embedding. A common embedded space representing both long and short period motions is built by an extended version of t-SNE (van der Maaten and Hinton, 2008), so that neighbor identities of envelopes are preserved. Then, unknown broadband envelopes for test data can be interpolated in this space. The similarity of envelopes is measured by the Wasserstein distance of the optimal transport theory.

Then, the frequency property is estimated using neural networks. The Fourier spectrum of the short period motion are estimated from that of the long period motion. We first train the network with large data from all sites to model a general frequency property, and then retrain it with small data from a specific site to model a site-specific frequency property. We found that this approach could avoid overfitting and improve the accuracy. Finally, the estimated time and frequency properties are combined to synthesize broadband ground motions using random phases.

We investigated an M7.0 Ibaraki-oki earthquake in 2008, and showed that the resulting broadband ground motions could match the ground-truth observations well both in envelope shapes and building responses.

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