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Retrieval of reflectivity images from ambient seismic noise correlations using machine learning as a noise-panel classification tool

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The theory of ambient seismic noise interferometry offers techniques to retrieve estimates of inter-receiver responses from continuously recorded ambient seismic noise. This is usually achieved by correlating and stacking successive noise panels over sufficiently long periods of time. If the noise panels contain significant body-wave energy, the stacked correlations expected to result in retrieved estimates of the body-wave responses, including reflections. Such application combined with a dense surface seismic array is promising for imaging the subsurface structures at lower cost and lower environmental impact as compared to with controlled seismic sources. Subsequently, this technique can be an alternative to active-source surveys in a range of challenging scenarios and locations, and can also be used to perform time-lapse subsurface characterization.

In this study, we apply seismic body-wave noise interferometry to 30-days of continuous records from a surface line of 31 receivers spaced by 25 meters in the South of the Netherlands with the aim to image subsurface reflectors, at depths from a few hundreds of meters to a few kilometers. As a first step, we compute stacked auto-correlations and compare the retrieved zero-offset section with a co-located stacked section from a past active reflection survey on the site.

Yet, the retrieval of reflectivity estimates relies on the identification and collection of a sufficient number of noise panels with recorded body waves that have travelled from the subsurface towards the array. Even in the case of favorable body-wave noise conditions, the panels are most often contaminated with stronger anthropogenic coherent seismic noise, mainly in the form of surface waves, which in turn prevents the stacked correlations to reveal reflectivity. Because of the limited effect of frequency filtering, the application of seismic body-wave noise interferometry requires in fact extensive effort to identify noise panels without prominent coherent noise from the surface activity. Typically, this leads to disregard a significant amount of actually useful data.

For this reason, we designed, trained and tested a deep convolutional neural network to perform this classification task more efficiently and facilitate the repetition of the retrieval method over long periods of time. We tested several supervised learning schemes to classify the panels, where two classes are defined, according to the presence or absence of prominent coherent noise. The retained classification models achieved close to 90% of prediction accuracy on the test set.

We used the trained classification models to correlate and stack panels which were predicted in the class with coherent noise absent. The resulting stacked correlations exhibit potential reflectors in a larger depth range than previously achieved. The results show the benefits of using machine learning to collect efficiently a maximum amount of favorable noise panels and a way forward to the upscaling of seismic body-wave noise interferometry for reflectivity imaging.