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Performance evaluation for deep-learning based point-source parameter estimation using a well constrained manual database: examples from the Hengill Geothermal Field, Iceland

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In this study, we present a new approach based on recent advances in deep learning for rapid source-parameter estimation of microseismic earthquakes. The seismic inversion is represented in compact form by two convolutional neural networks, with individual feature extraction, and a fully connected neural network, for feature aggregation, to simultaneously obtain moment tensor and spatial location of microseismic sources. The neural network algorithm encapsulates the information about the relationship between seismic waveforms and underlying point-source mechanisms and locations allowing rapid inversion (within a small fraction of a second) once input data are available. A key advantage of the algorithm is that it can be trained using synthesized seismic data only, so it is directly applicable to scenarios where there are insufficient real data for training including temporary seismic networks and hydraulic stimulation experiments, for example. Moreover, we find that the method is robust with respect to perturbations such as observational noise and data incompleteness (missing stations). We apply the new approach on a database of small magnitude ($M \leq 2$) earthquakes recorded at the Hellisheiði geothermal field in the Hengill area, Iceland, which is the demonstration site in the EU-GEOTHERMICA project COSEISMIQ (http://www.coseismiq.ethz.ch). For the examined events, the model achieves very good agreement with the inverted solutions determined through standard methodology. The new approach offers great potential for automatic and rapid real-time information on microseismic sources in a deep geothermal context and can be viably used for microseismic monitoring tasks in general.