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Deep learning for localizing and detecting earthquake swarm activity based on full waveforms: Chances, challenges and questions

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Deep learning approaches have outperformed established methods in various disciplines in recent years. Since earthquake localization is a fundamental first step for seismological studies we test if deep learning techniques can be used for that task when operating on three component full waveform recordings of regional stations. We implemented a deep convolutional neural network with three output neurons representing the three Cartesian coordinates of the hypocenter under investigation. The neural network performs a regression on the data labels. We apply only basic preprocessing like filtering and use absolute amplitudes.

We trained the neural network on full waveform recordings of the 2008 North Bohemia earthquake swarm recorded by 9 stations. Accurate locations based on double difference arrival times are available and provide us with a favorable testing environment. We select time windows based on hand picked first arrivals at the closest station.

After training for approximately 1 hour on a dataset of 2000 events we locate a different set of 900 events to validate and evaluate the location performance. The results show location accuracies of 56.4 m in East-West-, 123.8 m in North-South- and 136.3 m in vertical directions compared to the double difference relocated reference catalog. It takes about 1 second to locate all 900 target events.

Furthermore, we demonstrate, that the filters of the first layer can be exploited as an event detector for earthquakes of the same source region. During training, these filters become sensitive to the signals they are trained on, similar to a pattern matching detector commonly used in seismology.