A deep convolutional neural network 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. Earthquake localization is a crucial first step for seismological studies. We explore in howfar deep learning regression 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. We apply only basic preprocessing like filtering and use of 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. We consider this approach as semi-automatic as the current implementation requires the earliest arrival at the closest station to be picked. 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.
A drawback of the proposed approach is the fixed station geometry. We discuss an alternative approach which allows to apply this method independent of station configurations.

Keywords: Deep learning, Machine learning, Earthquake Swarm

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