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Seismic Phases Recognition Based on Long Short Term Memory Networks and Anomaly Detection

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In recent years artificial intelligence methods for detecting anomalies and abnormalities in time series have been successfully employed due to good performances in terms of high accuracy and speed. The aim of this paper is to exploit a dataset of small earthquakes recorded by a temporary, local network of 10 seismic stations located in an area of 10 km^2 in central Italy. During one year of observation about 600 earthquakes with 0 < ML < 2 have been localised by an highly optimised picking routine and also verified by experienced analysts. The resulting dataset consists of 4300 waveforms with labelled seismic phases together with a series of 4300 randomly chosen waveforms containing seismic noise. The first step of our approach is to apply rolling mean and Savitzky-Golay filters to seismic waveforms in order to improve the signal to noise ratio in the dataset. In the second step Long Short Term Memory (LSTM) networks are trained to learn the seismic noise contained in the waveforms recordings so that seismic phases can be recognized as anomalies. The LSTM model is able to detect seismic phases with an efficiency of about 90%. An error vector is computed subtracting observed and LSTM predicted values, respectively. Then a multivariate Gaussian distribution is used to fit the error vector providing an improvement to the seismic phases detection. A final test is performed exploiting a subset of the original dataset where we combine 1000 seismic and 1000 noise waveforms. The designed anomaly detection algorithm is able to identify more than 98% of the seismic waveforms.