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Towards an automatic real-time seismic monitoring system for the city of Oslo

Erik Myklebust, **Andreas Köhler**, and Anna Maria Dichiarante
NORSAR, Solutions, Norway (erik@norsar.no)

Global estimates for future growth indicate that city inhabitation will increase by 13% due to a gradual shift in residence from rural to urban areas. The continuous increase in urban population has caused many cities to upgrade their infrastructures and embrace the vision of a "smart-city". Data collection through sensors represents the base layer of every smart-city solution. Large datasets are processed, and relevant information is transferred to the police, local authorities, and the general public to facilitate decisions and to optimize the performance of cities in areas such as transport, health care, safety, natural resources and energy. The objective of the GEObyIT project is to provide a real-time risk reduction system in an urban environment by applying machine learning methodologies to automatically identify and categorise different types of geodata, i.e., seismic events and geological structures. The project focusses on the city of Oslo, Norway, addressing the common need of two departments of the municipality, i.e., the Emergency Department and the Water and Sewage Department. In the present work, we focus on passive seismic records acquired with the objective to quickly locate urban events as well as to continuous monitor changes in the near surface. For this purpose, a seismic network of Raspberry Shake 3D sensors connected to GSM modems, to facilitate real-time data transfer, was deployed in target areas within the city of Oslo in 2021. We present preliminary results of three approaches applied to the continuous data: (1) automatic detection of metro trains, (2) automatic identification of outlier events such as construction and mining blasts, and (3) noise interferometry to monitor the near sub-surface in an area with quick clay. We use a supervised method based on convolutional neural networks trained with visually identified seismic signals on three sensors distributed along a busy metro track (1). Application to continuous data allowed us the reliably detect trains as well as their direction, while not triggering other events. Further development of this approach will be useful to either sort out known repeating seismic signals or to monitor traffic in an urban environment. In approach (2) we aim to detect rare or unusual seismic events using an outlier detection method. A convolutional autoencoder was trained to create dense features from continuous signals for each sensor. These features are used in a one-class support vector machine to detect anomalies. We were able to identify a series of construction and mine blasts, a meteor signal as well as two earthquakes. Finally, we apply seismic noise interferometry to close-by sensor pairs to measure temporal variations in the shallow ground (3). We observe clear seismic velocity variations during periods of strong frost in winter 2021/2022. This opens up for the potential to detect also non-seasonal changes in the ground, for example related to instabilities in quick clay deposits located within the city of Oslo.