EGU23-13106, updated on 29 Feb 2024
https://doi.org/10.5194/egusphere-egu23-13106
EGU General Assembly 2023

An Unsupervised Anomaly Detection Problem in Urban InSAR-PSP Long Time-series

Ridvan Kuzu[1], Yi Wang[1], Octavian Dumitru[1], Leonardo Bagaglini[3], Giorgio Pasquali[4], Filippo Santarelli[4], Francesco Trillo[4], Sudipan Saha[2], and Xiao Xiang Zhu[2]

[1]Remote Sensing Technology Institute, German Aerospace Center (DLR), Weßling, 82234, Germany
[2]Data Science in Earth Observation, Technical University of Munich, Munich, 80333, Germany
[3]Space Technologies Lab, Leonardo S.p.A., Rome, 00156, Italy
[4]e-geos, Via Tiburtina 965, Rome, 00156, Italy

Interferometric Synthetic Aperture Radar satellite measurements are an effective tool for monitoring ground motion with millimetric resolution over long periods of time. The Persistent Scatterer Pair method, developed in [1], is particularly useful for detecting differential displacements of buildings at multiple positions with few assumptions about the background environment. As a result, anomalous behaviours in building motion can be detected through PSP time series, which are commonly used to perform risk assessments in hazardous areas and diagnostic analyses after damage or collapse events. However, current autonomous early warning systems based on PSP-InSAR data are limited to detecting changes in linear trends and rely on sinusoidal and polynomial models [2]. This can be problematic if background signals exhibit more complex behaviours, as anomalous displacements may be difficult to identify. To address this issue, we propose an unsupervised anomaly detection method using Artificial Intelligence algorithms to identify potentially anomalous building motions based on PSP long time-series data.

To identify anomalous building motions, we applied two different AI algorithms based on Long Short-Term Memory Autoencoder inspired by [3] and a Graph Neural Network version of it. LSTM Autoencoder is an unsupervised representation learning framework that captures data representations by reconstructing the correct order of shuffled time series. Its encoder part is used to extract feature representations of a time series, while the decoder part is used to reconstruct the time series. By assuming that most stable samples exhibit similar temporal changes, this algorithm can be used for anomaly detection (as the reconstruction loss would be high for anomalous time series).

The data used in this study were provided by the European Ground Motion Service over a rectangular area surrounding the city of Rome and includes approximately 500.000 time-series aggregated over more than 80.000 buildings. The time period covered is from 2015 to 2020.

In our proposed approach, we first extract deep feature representations for each timestamp of a non-anomalous time series. The feature sequence is then shuffled and passed through an LSTM encoder-decoder network. By learning to reconstruct the feature sequence with the correct order,

the network is able to recognize high-level representations of the time series. In the second step, the pre-trained network is used to reconstruct another time series. If the time series is non-anomalous, the correct order can be reconstructed with high confidence; otherwise, it is difficult to reconstruct the correct order. By selecting an appropriate threshold, anomalies can be detected with high reconstruction losses.

Overall, our proposed AI-based approach shows promising results for identifying anomalous building motions in PSP long time-series data. The use of unsupervised learning allows for more accurate statistical representations of the data and more reliable detection of anomalous behaviours. This approach has the potential to improve autonomous early warning systems for risk assessments and diagnostic analyses in dangerous areas.

This work is part of the RepreSent project funded by the European Space Agency (NO:4000137253/22/I-DT).

[1] https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4779025
[2] https://www.mdpi.com/2072-4292/10/11/1816/pdf
[3] https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9307226