EGU22-4618
https://doi.org/10.5194/egusphere-egu22-4618
EGU General Assembly 2022

Supervised LSTM Modelling for Classification of Sinkhole-related Anomalous InSAR Deformation Time Series

Anurag Kulshrestha, Ling Chang, and Alfred Stein
Faculty of Geoinformation Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands

Recently, we have shown that sinkholes can be characterized at an early stage by precursory deformation patterns from InSAR time series [1]. These patterns are often related to sudden changes in deformations or deformation velocities. With such *a priori* information, accurate deformation modelling and early detection of precursory patterns is feasible. It is still a challenge, however, to scale up methods for classifying larger numbers of sinkholes over large areas that may contain tens of thousands of InSAR observations. To address this, we explore the use of Long Short-Term Memory (LSTM) Networks to classify multi-temporal datasets by learning unique and distinguishable hidden patterns in the deformation time series samples.

We propose to design a two-layered Bi-directional LSTM model and use a supervised classifier to train the model for classifying sinkhole-related anomalous deformation patterns and non-anomalous deformation time series. Samples for linear, Heaviside, and Breakpoint deformation classes are extracted by applying Multiple Hypothesis Testing (MHT) [2] on deformation time series and are used to compile the training dataset. These samples are randomly divided into a training set and a testing set, and associated with a target label using one-hot encoding method. Hyperparameters of the model are tuned over a broad range of commonly used values. Using categorical cross-entropy as the loss function the model is optimized using the Adam optimizer.

We tested our method on an oil extraction field in Wink, Texas, USA, where sinkholes have been continuously evolving since 1980 and a recent sinkhole occurred in mid-2015. We used 52 Sentinel-1 SAR data acquired between 2015 and 2017. The results show that the supervised LSTM model classifies linear deformation samples with an accuracy of ~98%. The accuracy for classifying Heaviside and Breakpoint classes is ~75% at the most. Temporal periodicity was observed in the occurrence of anomalies, which may be related to the frequency of oil extraction and water injection events. Heaviside anomalies were observed to be clustered in space, with a higher density close to the sinkhole location. Breakpoint class anomalies were much more uniformly distributed. Close to the sinkhole spot, we found that two InSAR measurement points were classified into the Breakpoint class, and have considerable changes in deformation velocities (~60^{o} velocity-change angle) shortly before the occurrence of this sinkhole. It is likely associated with the sinkhole-related precursory patterns. Through this study we conclude that our supervised LSTM is an effective classification method to identify anomalies in time. The classification map in terms of InSAR deformation temporal behavior can be used to identify areas which are vulnerable to sinkhole occurrence in the future and require further investigation. In the future, we plan to further develop methods to increase the classification accuracy of anomalous classes.

References:

[1] Anurag Kulshrestha, Ling Chang, and Alfred Stein. Sinkhole Scanner: A New Method to Detect Sinkhole-related Spatio-temporal Patterns in InSAR Deformation Time Series. Remote Sensing, 13(15), 2021.

[2] Ling Chang and Ramon F. Hanssen. A Probabilistic Approach for InSAR Time-Series Postprocessing. IEEE Transactions on Geoscience and Remote Sensing, 54(1):421–430, 2016.