Using machine learning and satellite radar to detect "silent" earthquakes in the Zagros Mountains, Iran

Project Abstract:

This research project aims to design deep learning based algorithms that can be trained on freely and abundantly available InSAR data in an unsupervised manner to identify, analyse and track deformation of the Earth’s crust. Whilst most medium-large magnitude earthquakes are detected by global networks of seismometers, many other tectonically important deformation events, for example aseismic/slow slip events or low magnitude earthquakes, often remain undetected. Since 2016 sentinel-1 is continuously recording movements across the globe and the change in movement is computed in the InSAR. A methodology is devised that is presented in this report with some preliminary results that show promising outcomes in terms of identifying movements caused by an earthquake. A fully convolutional autoencoder consisting of convolutional LSTMs (Long Short Term Memory) is trained on velocity patterns (calculated in radians/ days) of a location with respect to time. The model reconstructs these velocity maps with low error whereas when a synthesized anomalous time frame occurs in a sequence it identifies it with a high error. This unsupervised way of learning will not only identify movements caused by earthquakes but also will allow future scientists to take advantage from the semi-supervised labelled patterns which will be the output during the testing of our model.

The test case of this project is the Zagros region of Iran, focusing on continental convergent boundaries, but to train a diverse model that can be used on any part of the world with all types of movements, the methodology is designed and being tested on the data from Turkey that is highly covered by the satellite. The qualitative and quantitative results are presented in this report with an overview of existing methods. The proposed methodology is new in the field of earth sciences and a valid application of deep learning in the field of computer sciences.

Methodology:

In contrast to video data, where an individual image or frame contains information on the position of objects at a single acquisition time, an individual radar interferogram contains information on the difference in position between two acquisition times. If a satellite has Nt time acquisitions then, we can generate a maximum of NIFG interferograms, each containing the change in phase between a two acquisition times. Of these NIFG interferograms, only Nt are independent. So, we first converted these interferograms into a time sequence of consecutive velocities, using a modification of the SBAS algorithm [1]. When the data has spatial as well as temporal information that are both dependent on one another, this can assist in learning the pattern of the data. Long Short Term Memory cells (LSTMs) [2] are often used in
such cases to learn from time dependant data. In order to learn both colloquial/informal, the structure of the input data in the space as well as in time, these LSTM cells are applied with convolutions. These are called Convolutional LSTMs and can maintain the dimensions of the input data in case of an image or a video. Where there is no ground truth available and it is both expensive and time consuming to mark, label or caption abundant videos/images data, unsupervised or semi-supervised deep learning techniques involving convolutional LSTMs [4] are used to understand changes and track object movements [3] in them. Such techniques are often categorized as anomaly detection, either using CNNs and RNNs separately or using them together in a layer as one operation.

Anomaly detection techniques use reconstruction error as an indicator of sudden or prolonged changes in a sequence. No such anomalous movements are recorded on the location of frame that is used in the experiments. So the trained models cannot be tested in the case of an anomaly as the testing patch sequences are also generated from the same frame but were separated initially and not used in training. For this reason an earthquake like InSAR image is synthesized on the patch taken from the center location of the frame. The center location is selected because it exists in the training set of the model, so adding anomalies to some of its time frames will help in identifying abrupt alarming movements.

**Contributions to the Sustainable Development Goals**

The project addresses three UN Sustainable Development Goals (SDGs):

SDG 3: Ensure healthy lives and promote well-being for all ages-

- Improved seismic hazard information will strengthen Iran’s capacity for risk reduction and management of a national major risk to health and life.

SDG 9: Build resilient infrastructure and foster innovation-

- This project will enhance scientific research and innovation by training a student from a DAC nation and partner scientists in using innovative machine-learning approaches to analyse big-data.

SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable-

- Improved seismic hazard information has potential to reduce injuries, deaths and economic losses caused by earthquakes, and enable resilience to these events.
Conclusion & Future Work:

The experiments performed show that the generated velocity maps work better with the deep learning models as they give more understanding of a time sequence as compared to the change in movement recorded in multiple interferograms covering similar dates with varying time based overlaps. The system that generated the velocity maps is also tested and results show that it generates the predicted displacement covering all gaps as close as possible. The proposed deep learning based methodology is trained and tested on a small data set taken from single location of Turkey. The capacity of this model will be increased by adding more dataset and designing an efficient and more accurate network architecture by experimenting with previously mentioned GANs. In future we try to test the model with real earthquakes and try to train a globally diverse model that can be tested on all geographical locations including the Zagros region of Iran.

Project Information:

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References:

