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Data Exploration using Unsupervised Feature Extraction for Mixed Micro-Seismic Signals

Matthias Meyer (1), Samuel Weber (2), and Jan Beutel (1)

(1) Computer Engineering and Networks Laboratory, ETH Zurich, Switzerland, (2) Department of Geography, University of Zurich, Switzerland

We present a system for the analysis of data originating in a multi-sensor and multi-year experiment focusing on slope stability and its underlying processes in fractured permafrost rock walls undertaken at 3500m a.s.l. on the Matterhorn Hörnligrat, (Zermatt, Switzerland). This system incorporates facilities for the transmission, management and storage of large-scales of data (∼7 GB/day), preprocessing and aggregation of multiple sensor types, machine-learning based automatic feature extraction for micro-seismic and acoustic emission data and interactive web-based visualization of the data. Specifically, a combination of three types of sensors are used to profile the frequency spectrum from 1 Hz to 80 kHz with the goal to identify the relevant destructive processes (e.g. micro-cracking and fracture propagation) leading to the eventual destabilization of large rock masses. The sensors installed for this profiling experiment (2 geophones, 1 accelerometers and 2 piezo-electric sensors for detecting acoustic emission), are further augmented with sensors originating from a previous activity focusing on long-term monitoring of temperature evolution and rock kinematics with the help of wireless sensor networks (crackmeters, cameras, weather station, rock temperature profiles, differential GPS) [Hasler2012].

In raw format, the data generated by the different types of sensors, specifically the micro-seismic and acoustic emission sensors, is strongly heterogeneous, in part unsynchronized and the storage and processing demand is large. Therefore, a purpose-built signal preprocessing and event-detection system is used. While the analysis of data from each individual sensor follows established methods, the application of all these sensor types in combination within a field experiment is unique. Furthermore, experience and methods from using such sensors in laboratory settings cannot be readily transferred to the mountain field site setting with its scale and full exposure to the natural environment. Consequently, many state-of-the-art algorithms for big data analysis and event classification requiring a ground truth dataset cannot be applied.

The above mentioned challenges require a tool for data exploration. In the presented system, data exploration is supported by unsupervised feature learning based on convolutional neural networks, which is used to automatically extract common features for preliminary clustering and outlier detection. With this information, an interactive web-tool allows for a fast identification of interesting time segments on which segment-selective algorithms for visualization, feature extraction and statistics can be applied. The combination of manual labeling based and unsupervised feature extraction provides an event catalog for classification of different characteristic events related to internal progression of micro-crack in steep fractured bedrock permafrost.

References

Hasler, A., S. Gruber, and J. Beutel (2012), Kinematics of steep bedrock permafrost, J. Geophys. Res., 117, F01016, doi:10.1029/2011JF001981.