Enhancing landslide forecasting capability with machine intelligence: Deep Learning of optical and SAR multi-temporal image data stacks

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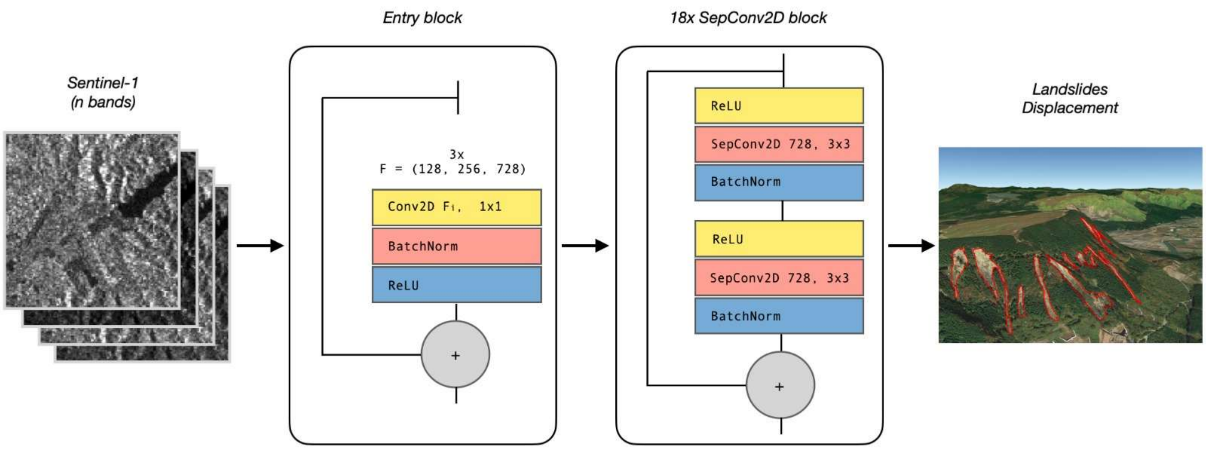
Background and rationale

In the context of basin-scale modelling and assessment of slope instability, there is a relevant gap of knowledge which concerns the time component. Most of the field information relative to mass movements is only spatial and the great majority of the existing databases and inventories refer to a single event or are neglecting the time component (the so-called historical inventories), the main cause being a lack of a consistent and applicable methodology for collecting, checking, selecting, and normalizing the complex, multi-source information in a common standard including time of occurrence, geographic position and intensity estimation (Chae et al., 2017). In this framework, emerging technologies making use of machine intelligence are at the forefront in research innovation and provide a novel support to access, measure, and exploit time-related data sources previously not usable such as raw real-time sensor acquisitions, social networks content, continuous or discontinuous streaming from news and online databases. Among them, the automation of data mining of quantitative information from satellite, aerial and drone surveys, by using deep learning methods (DL) and recurrent neural networks (RNN) to perform classification, interpretation and forecasting of time series derived from monitoring of slope processes is of notable importance in the geosciences. Despite being very fashionable and promising, though, such technologies are still scantly used in engineering geology, with the exception of classical machine learning such as multi-variate regression or classification (Ermini et al., 2005; Catani et al., 2013), and an important research gap is yet present in the knowledge transfer from fields where DL and RNN are being routinely used, such as automotive and defense, to the realm of geomechanics and geotechnics applied to natural slopes. A few recent examples address the issue and put the basis for a new approach, by proposing novel concepts to model or forecast slope instability at various scales, going from satellite data interpretation (Mondini et al., 2011; Forzieri et al., 2012; Liu and Wu, 2016), to slope scale time-series analysis (Turner et al., 2015; Yang et al., 2019), to the automated content extraction for the rapid alert and mapping of mass movements (Battistini et al., 2017; Catani, 2020).



Aim

The proposed PhD project builds on such recent advances related to the development of machine intelligence, to extend existing methods and techniques to the characterization of slope instability at the regional and basin scale for risk mitigation purposes. Concisely, the main objectives of the PhD project will be: i) to exploit and adapt existing Deep Learning tools used for autonomous vehicle guidance and automated content extraction towards the analysis of satellite data stacks for the development of rapid mapping techniques and towards data assimilation in numerical models for the spatial prediction of mass displacements, and, ii) to develop new methods based on Recurrent Neural Networks and time-series analysis for the forecasting of time-of-failure and the modelling and prediction of slope evolution in the short- to medium-term, both at the local scale and beyond.

To pursue the objectives, the project foresees the continuation of new and promising research that applies DL to the automated recognition of mass movements in both optical and SAR imagery, including combinations of them and data fusion with high-resolution topography, multi-temporal changes in the landscape morphometry and climate forcing.

Expected results

i) Development of DL libraries and convolutional neural networks to extract quantitative information on active slope processes from Sentinel-2 optical imagery;
ii) Development, as in (i), from Sentinel-1 SAR data stacks, including data fusion with optical;
iii) Development of algorithms based on RNN for the semi-automated analysis of multi-point InSAR time-series to model displacement patterns and generate time forecasts.
iv) Application of the methodologies on real cases in Italy, Sichuan (China), Hokkaido (Japan) and elsewhere.

Scientific cooperation

Most of the analysis and development of the PhD work will be carried out in cooperation with the CTTC (Centre Tecnològic de Telecomunicacions de Catalunya) (Prof. O. Monserrat) and the Sejong University of Seoul, Department of Geoinformation Engineering (Prof. S-E. Park), partially under the ESA Geohazards Exploitation Platform (GEP, https://geohazards-tep.eu/#!) project for the development of downstream products of Sentinel constellations. Drone SAR/Optical applications will be developed in cooperation with the Civil Protection Centre of the University of Firenze (Prof. N. Casagli and Dr. Guglielmo Rossi) and the Joint Research Centre of the European Commission (Dr. Dario Tarchi).

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