Landslides in structurally complex formations: Geo-Mechanical characterization with Deep Learning models

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Background and rationale

In the context of slope-scale modelling and assessment of slope instability, there is a relevant gap of knowledge which concerns the structurally complex formations (sensu Esu, 1977). In fact, neither classical rock mechanic nor soil mechanics are directly applicable in those contexts. Complex geological units encompass a wide range of blocks in matrix rocks (so called Bimrocks) that are basically made up of a quasi-random mixture of rock portions (from the dimension of a few centimeters up to hundreds of meters) plunged in a (usually) ductile matrix of finer soil material. As an example, the Franciscan Complex in Northern California or the Basal Complexes of the Northern Apennines in Italy present similar characters.

Within such units, mass displacements and slope deformations are very common and produce important limitations in engineering applications, such as tunnelling, facility installation, building and foundation constructions, as well as quarrying. However, recommended laboratory testing on such materials are strongly hampered by the need of representing the structural variability at scales much greater than those available in lab machines.

It is necessary, therefore, to develop new operational methods that could help practitioners and geological engineers to understand the key parameters guiding rock slope behavior and to measure them. In particular, numerical FEM and FDM modelling, that are now evolved to a degree of accuracy more than appropriate, cannot be used on bimrocks unless such key parameters are known in the 3D space of the rock mass. Needed tools range from automated or semi-automated point cloud analysis, to 2D remote sensing with multi-spectral capability, to scaling laws able to overcome limitations in the upscaling of constitutive models and statistical geomechanical properties.

Aim

The proposed PhD project builds on the recent advances related to the development of machine intelligence, to extend existing methods and techniques to the characterization of bimrocks and their 3D structure, for geomechanical and geo-engineering applications. Concisely, the main objectives of the PhD project will be: i) to exploit and adapt existing Deep Learning tools to help extracting useful information from noisy data sources such as drone point clouds and multi-spectral images, and, ii) to develop new geometric models, based on fractal and self-similar 2D and 3D rick mass structures, that can be useful in bringing laboratory results at the slope scale and in simplifying the numerical models, and (iii) combining results of (i) and (ii) to produce a basic toolset for bimrocks geo-mechanical analysis.

To pursue the objectives, the project foresees the continuation of new and promising research that applies DL to the automated analysis of 2D photographs, 3D point clouds, and multi-spectral images (terrestrial or space-borne).

Expected results

Expected results include:

(i) A novel set of simplified models and rock mass indices based on fractal geometry to represent bimrocks.

(ii) An inversion model, based on the coupling of numerical simulations analysis tools (i.e. FLAC3D) with said fractal models and indices, able to provide quantitative estimations of the rock mass strength based on simple photographic or point cloud measures of the available outcrops.

Scientific cooperation

Most of the analysis and development of the PhD work will be carried out in cooperation with the University of British Columbia, Faculty of Applied Sciences, in the person of Dr. Davide Elmo, Professor of Rock Engineering and Associate Dean.

Funding and support

Funding will be provided by relevant connected projects now under evaluation over the Horizon Europe program. A specific fund from the Italian National Civile Protection Department is also foreseen to support the development of operational tools derived from the PhD results.