Terrestrial laser scanner and infrared thermography in rock fall prone slope analysis - Preliminary results

C. Squarzoni (1), A. Galgaro (1), G. Teza (1), C.A. Torres Acosta (2), M.A. Pernito (2), N. Bucceri (3)

(1) Dipartimento di Geoscienze, Università di Padova, Italy - contact: cristina.squarzoni@unipd.it
(2) International Institute for Geoinformation Science and Earth Observation (ITC), Enschede, The Netherlands
(3) Land Technology & Services s.r.l., Treviso, Italy

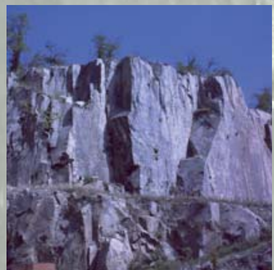
Introduction

The stability of a rock slope is strongly conditioned by its geomechanical characteristics, mainly by the discontinuity distribution within the rock mass. Discontinuities, such bedding planes, joints and faults, are planes of weakness cutting the intact rock, so failure tend to occur preferentially along these surfaces. Most of the discontinuity properties are determined in the field. To collect information on the discontinuities' properties, observations are typically carried out with a traditional geomechanical survey, in which the direct access to the rock mass is necessary for a detailed investigation.
Recently, the 3D terrestrial laser scanning (TLS) technique has been proposed as an alternative technique to perform geomechanical analysis in a remote way. The data provided by a TLS survey can be used in order to obtain information about the discontinuities geometry.
In order to obtain information about the fracturing condition of the rock mass, the transient infrared thermography (IRT) can be used to determine time variation of heating and cooling on the rock surface, allowing improving the quality of the 3D rock mass geometry obtained by TLS.

The test site

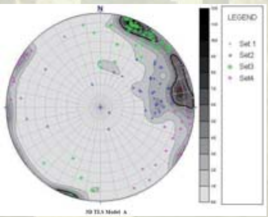
The test site is a trachyte quarry located in the Euganean Hills, 15 km far from Padova (north-eastern Italy).

The quarry's walls were observed with TLS (Optech ILRIS 3D), considering two different viewpoints, 60-m mean acquisition distance and 3-cm mean spatial sampling. The georeferencing of the TLS data was performed using a GPS-based topographic network with high-reflectance artificial targets, in order to obtain a a valid positioning of both the discontinuity planes and exposed surfaces.

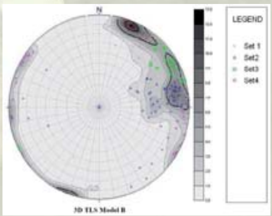


Discontinuities orientation extraction

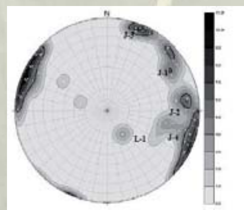
The TLS point cloud data were processed in order to obtain discontinuity plane orientations of the rock mass. The segmentation of the discontinuity planes was performed using the Hough Transform method (Vosselman et al., 2005). After the segmentation, the orientation of the plane was computed and then classified into their corresponding discontinuity sets using the Fuzzy K-mean clustering.
The result of discontinuity extraction contains several outliers, due to vegetation or loose slope material and natural or blasting induced fractured rock mass. Outliers removal was mainly based on the interpretation of plots of discontinuity sets and visual observation of the results of the segmentation, as well as on the analysis of the scattered poles.
The results of the discontinuity orientation extraction from TLS data, obtained by Matlab scripts, was compared with the discontinuity measurements conducted by traditional scanline method, showing in general a good correlation, with fair correlation in case of low dipping discontinuities presents in the higher part of the slope, detected by the TLS and not by scanline measruements (reaching only 3 m high).



Plot of 160 individual planes extracted from the point cloud after segmentation and



Plot of the same planes after removal of the presumed outliers.



Traditional scanline measurements of the same slope face.

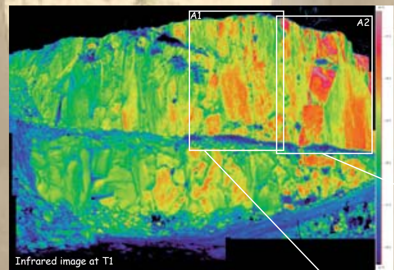
The discontuities layout show a typical fracture systems mainly related to tectonics events (rhomboidal) and a less important effects due to trachyte rocks cooling processes (hexagonal).
L1 corresponds to a low angle discontinuity plane, recognizable in the traditional survey; it is only fairly detectable by TLS analisys (Model A) and not reported in Model B due to low statistical representativeness.

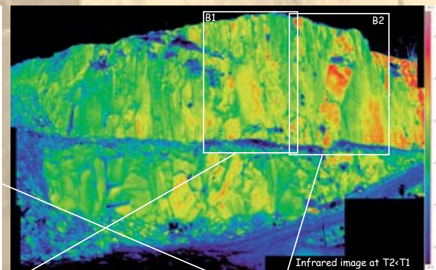
Infrared thermography

IRT is able to track the evolution of the temperature pattern of a surface. A series of thermal images acquired at different solar illumination conditions (e.g. sunrise, midday, sunset, as well as intermediate times) provides information about the thermal transfer efficiency of the rock. Since the thermal inertia of a sound rock if larger than the one of a highly fractured rock, the presence of discontinuities, voids or fracturing can be detected.

The IRT data processing is a complex task because the signal-to-noise ratio is relatively low and the orientation of the facets must be taken into account in order to allow a comparison between homogeneous data.

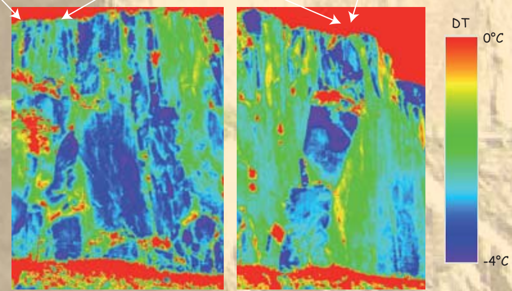
The preliminary tests were performed using a FLIR ThermaCAM SC640, with a 640x480 pixel matrix. Since the mean acquisition distance was 50 m, the thermal images have about 3-cm spatial resolution, similar to the one of TLS data.





IRT processing preliminary results:
- red: vegetation and sky (no thermal variation);
- green-yellow: open joints;
- blue: large face sound rock.

The higher thermal transfer processes charachterise the wider and most exposed rock surfaces. The rock mass discontinuities show lower thermal tranfer capacities.



DT = T(A2) - T(A1) DT = T(B2) - T(B1)

Concluding remarks and further investigations

TLS: fast and accurate contactless geometrical and geomechanical characterisation of the discontinuities, with large number of data for a good statistical analysis.
Problems to solve: lack in discontinuities detection caused by occlusion or orientation bias; errors in outliers removal.
IRT: provide information about the rock mass (joints aperture, infilling materials, water presence).
Problems to solve: definition of data acquisition protocol; normalisation against the differential orientation respect to the solar radiation.
TLS and IRT: by combining and integrating the two techniques, it will be possible to create rockfall prone maps of rock cliffs.

Acknowledgements

References