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Coltop3D: A New Software for Structural Analysis with High Resolution 3D Point Clouds and DEM

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Summary

Coltop3D is a software that performs structural analysis by using digital elevation model (DEM) and 3D point clouds acquired with terrestrial laser scanners. A color representation merging slope aspect and slope angle is used in order to obtain a unique code of color for each orientation of a local slope. Thus a continuous planar structure appears in a unique color. Several tools are included to create stereonets, to draw traces of discontinuities, or to compute automatically density stereonet. Examples are shown to demonstrate the efficiency of the method.

Introduction

The increasing precision of terrestrial laser scanners (TLS) makes possible to perform more detailed systematic structural and morphological analyses than ever reached before. Using the orientation of each single collected vertex, a point cloud data set can be represented by a 3D image where each single point has a color defined by the local dip and strike direction, which allows a very simple slope analysis. This can also be applied to any surface reconstructed through the data set, making the detection of planar structures within a cliff, i.e. in the presence of overhangs, possible, which is not with classical 2D digital elevation models. Such simple analyses applied to 3D clouds of points make it possible to quickly identify structural features affecting topography, such as the main joints set shaping rock face leading to the identification of the main structural features shaping a relief. They open new perspectives in relief analysis.
Although the principles of the analysis are well established, the post-treatment and the standard operating use of such large data sets may impair an in-depth analysis for specific applications, such as landslide or rock fall analysis and structural analysis, since modern devices such as TLS allow for capturing dense 3-dimensionnal data set (up to tenth of millions points) on the surface of an object, within a few minutes.
Coltop3D software aims at solving these shortcomings by allowing geologists to focus on their main task.

This is illustrated with two case studies. The first one is the Hegguraksla rockslide study site in Western Norway), whilst the second is an ongoing structural analysis near the Cinque Torri site in Northern Italy (Dolomites).

Coltop3D Method

Classical GIS tools permit a mathematical analysis of topography using slope, slope aspect, second derivative, curvature, flow paths, etc. (Burrough and McDonnell, 1998). But very few are dedicated to the analysis of the relief structure. An attempt was made by Brewer and Marlow (1993) which led to a particular color representation of topography using color dependent on both slope angle (i.e. dip) and slope aspect (i.e. dip direction), but none were used for structural analysis.

Coltop3D extends the idea of having a unique color for both dip and dip direction by adapting a computer graphics classical Hue Saturation Value (HSV) wheel to a lower or upper Schmidt-Lambert projected stereonet (figure 1, left).

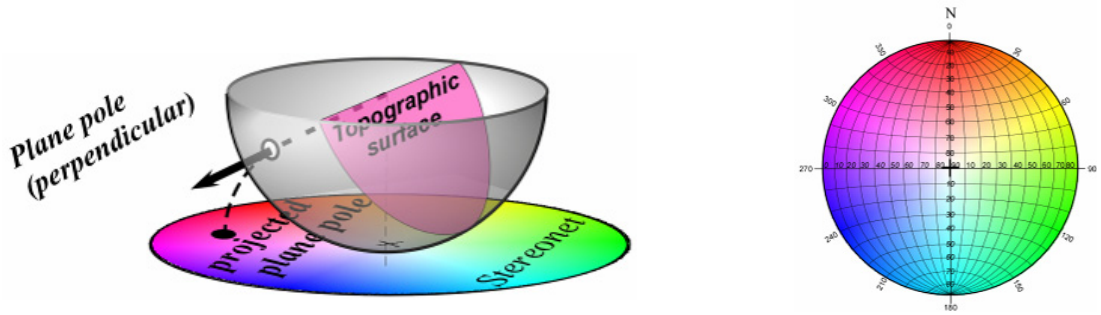

Figure 1: Relationship between Schmidt-Lambert projection and HSV wheel (left). The HSV wheel plotted on a steronet (right).

The local dip direction of the surfaces is represented by the hue (H) value of the wheel ranging from 0 to 360° and the dip of the pole using the saturation value of the wheel (S). Thus, the rendering mode of a terrain range from white for a perfectly flat area to a purer color when the dip increases (figure 1, right). The Value or Intensity value (I) can be changed for representation purposes. The link with Red Green Blue (RGB) value is performed using the method proposed by Gonzalez et al. (2004).

Using this color scheme (figure 2), a geologist can easily visually detects terrain features and use other Coltop3D tools to narrow his analysis.

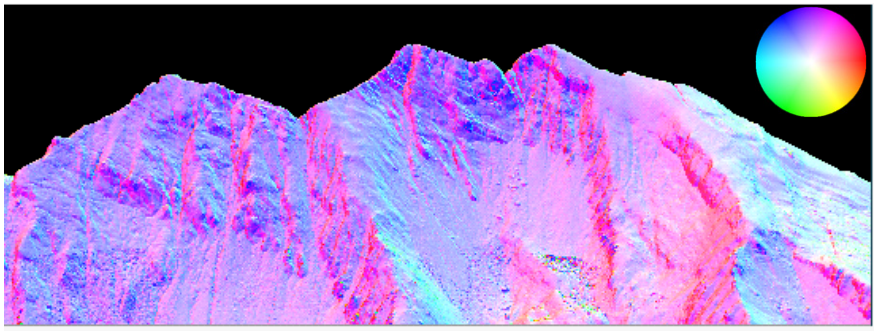

Figure 2: A typical rendered view with Coltop3D (Les Diablerets, Swiss Alps)), the violet indicated regional faults that are cutting the entire rock mass.

Hegguraksla rockslide case study

The Hegguraksla study site in the Western Norway fjords. The study site is formed by an up to 250 m high, vertical and sometimes even overhanging cliff in thin-bedded gneisses and augengneisses with a generally well developed foliation and several very persistent discontinuity sets (figure 3, left).

Four major discontinuity sets were determined by field mesurements (figure 4, right) (altough not directly made on the cliff itself due to limited accessibility). Coltop3D unique color rendering mode allowed for quickly determining these four major discontinuities, as well a other minor ones (figure 3, right, and figure 4, left).

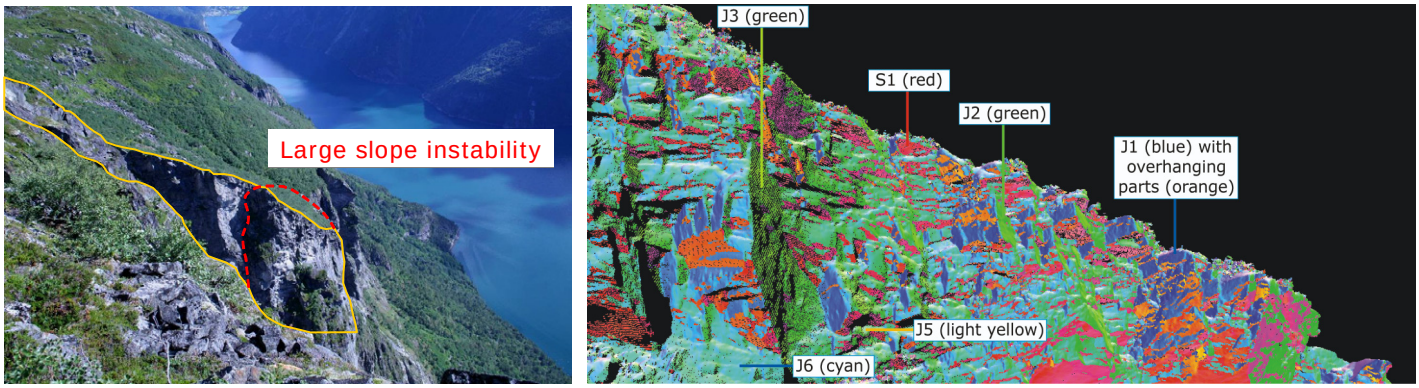

Figure 3: Picture of the study area (left). Coltop3D view of the study area and localisation of the discontinuities (right).

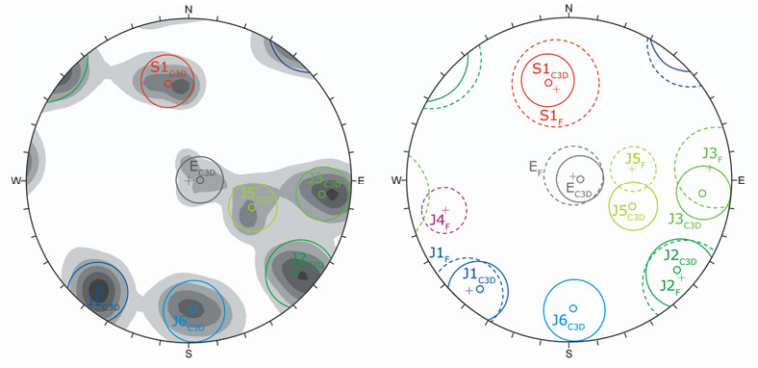

Figure 4: Density stereonet made with Coltop3D (left). Field measurments (“F” suffix) versus discontinuitie determined with Coltop3D (“C3D” suffix) (right).

Cinque Torri site structural analysis case study

The Cinque Torri is a group of dolomitic pinnacles covering an area of about 40.000 m2 placed on the Eastern Dolomites (Italy). The tectonic influence combined with stratigraphical setting are the main causes of the actual fragmentation and deep ground deformation. In the late spring of 2004 a dolomitic pinnacle of about 11,400 cubic meters sudden collapsed in a zone with high tourist frequentation. Major concerns for tourism safety raised up immediately after the event and monitoring program was then undertaken.

TLS and Aerial laser scanner (ALS) were applied to create a detailed model surface of the area and for the control of a particularly unstable pinnacle (the “Torre Inglese”).

Coltop3D software allowed the structural analysis of an area around the Cinque Torri of about 3,5 km2 by means of ALS original point cloud data computation, while a combination of both ALS and TLS data was undertaken for the local group analysis.

These investigations led to the identification of two main discontinuity sets directly link to the regional tectonic and the fragmentation of the Cinque Torri group (250°/49°, 303°/42°), the top stratification (005°/33°), and local systems of fractures (171°/36°, 210°/15°) that cross almost perpendicularly the stratification.

Despite the lower resolution of the ALS datum compared to the TLS datum, it is appreciable the quality of the point cloud render view and the versatility of Coltop3D software on selecting and filtering data sets. This last function results very useful where rock outcrops confine with uncorrected data points such as land covering.

Future research topics will concern the analysis of relations between the regional tectonics and specific area showing critical geomechanical conditions.

This results represents a fundamental data input for future numerical modelling of the unstable pinnacles inside the Cinque Torri group.

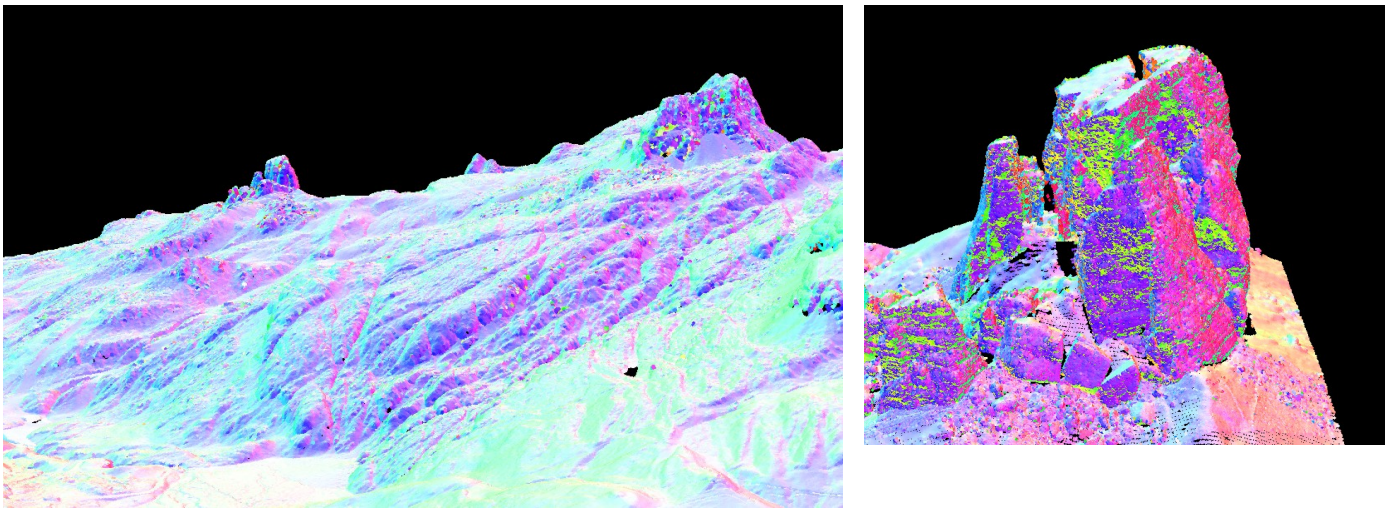

Figure 5: A render view with Coltop3D of the North-Western part of the ALS acquired area (Cinque Torri, Dolomites, Italy) (left) and the Western side of the Torre Grande (left).

Conclusion

The efficiency of a unique colour representation for both dip and dip direction was illustrated with two case studies. 3D point clouds acquired with TLS devices permit a rapid structural analysis. This is useful as joints and instabilities are often in inaccessible zones, that will never be reached by any geologist.

Coltop3D software offers to geologist other capabilities, such as:

- Ability to handle huge data sets (up to 150 millions points);
- Coloring the surface not only with a colour scheme linking conmputer graphics HSV wheel and Schmidt-Lambert stereonet projection, but also with height field, return signal intensity and RGB true color
- Ability to select a subset of a point cloud with complex geometric shapes;
- Ability to select a subset of a point cloud with dip and dip direction values;
- Creating density stereonets with selected subset;
- Easely import from or export point cloud data to third party software.

References

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Brewer C. A. and Marlow K. A. 1993, Color representation of aspect and slope simultaneously. Proceedings, Eleventh International Symposium on Computer-Assisted Cartography (Auto-Carto-11), Minneapolis, 328-337.

Gonzalez R.C., Woods R., Eddins S. 2004. Digital Image Processing Using Matlab. Prentice Hall, pp. 624.