



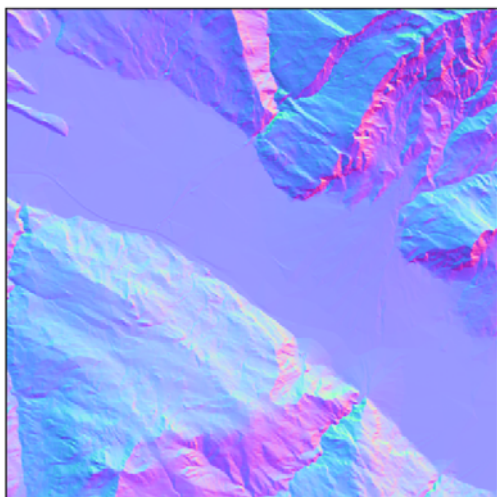
PROJECT - 01

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QUANTERRA

INTERNATIONAL INDEPENDENT CENTER OF CLIMATE CHANGE IMPACT ON
NATURAL RISK ANALYSIS IN MOUNTAINOUS AREA

Project Proposal



Design of a pseudo-
3D topographic
analysis computer
program:

COLTOP-3D

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Abstract:

*The design of a program of topographic analysis based on digital elevation model (DTM) is presented here. This software **COLTOP-3D** can be used to analyze the structures, especially faults, shaping the morphology.*

Maps as well as stereonets displaying colors depending on the orientation will be implemented. Histograms of topographic surface are planned. The design of tools useful to analyze topography in a structural way is planned. Faults tracing will be implemented based on orientation and surface points.

The functions and the main points of the project are presented.



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1. Aims of the project proposal

This proposal has to be accepted by the different partners. Please let M. Jaboyedoff know if you agree with this project or if major remarks have to be made.

For a long time we have been looking for a program that is able to analyze the topography based on digital elevation model (DTM) files. Several functionalities such as slope derivatives, slope aspects etc... are available (Fig. 1) (Burrough and McDonnel, 1998), especially in GIS environment. Despite those functions, 3D analyses of topographical structures are not really available. The present project will partly fill this gap by writing the program **COLTOP-3D** based on a pseudo 3D representation and a 3D analysis.

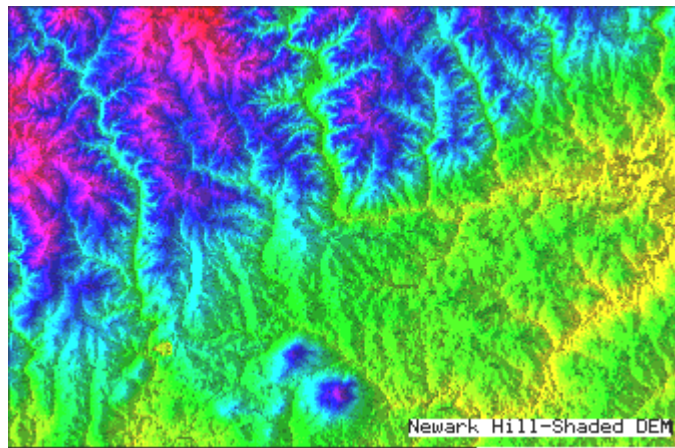


Fig. 1: Example of standard DTM GIS treatment combining elevations colors and shading under grass environment.
(From: <http://www.udel.edu/johnmack/frec682/682syll.html>).

Its main goal is to create a tool to visualize the topography, with colors indicating the orientations of the cells of the DTM combining in one attribute strike and dip, a kind of 3D shading. Starting from this orientation analysis on the image, histograms etc... functionalities will be developed.

Additional tools will be introduced dedicated to the faults and joints structure analysis.

The project is designed to realize the software in two or three steps, with intermediary results. The first version of the program resulting from the first phase will be written by M. Jaboyedoff in GSC (Ottawa) with R. Couture and P. Bobrowsky during March 2003.

2. Previous works

Other works

Looking at different computer programs (Envi, Ilwiss, PCI...), asking different people and searching on Internet (<http://pubs.usgs.gov/of/2001/of01-223/paradis.html>, http://rst.gsfc.nasa.gov/Sect11/Sect11_5.html), we did not find any traces of such a program. It seems that the 3D colors exists in topographic representations, but it is not used for structural purpose (<http://geopubs.wr.usgs.gov/open-file/of02-282/>).

Standard GIS and computer programs performed many DTM analysis such as watersheds, floods level estimations, etc...

Previous programming works in geology of the author

Two programs have already been written on this topic. The first, *Matterocking* was written for the CREALP (Research Center on Alpine Environment) and can be found on the web at www.crealp.ch. This program permits to compare topography with structural data, in order to detect the areas where rock discontinuities can favor instability by sliding mechanisms. A probabilistic approach is proposed (Rouiller et al., 1998).

The second software, *CONEFALL* is dedicated to the cone method (Evans and Hungr, 1993) and will be soon available on Internet (www.quanterra.org). It was written in collaboration with the EPFL (Ecole polytechnique fédérale, Lausanne, Suisse). It allows producing grid files of propagation areas, based on the idea that a rockfall can only propagate within a cone centered on its source point.

The structure of the program *Mattercliff* was designed by M. Jaboyedoff, but written by the CREALP (Research Center on Alpine Environment) by J.-Y Delèze. The program is dedicated to the simple geometrical characterization of discontinuity sets (Jaboyedoff et al., 1996). It is also available on the website www.crealp.ch.

3. 3D representation

The pseudo-3D representation requires that each orientation of topographic cell possesses a unique color. To be useful, several choices of colors must be offered by the program. Furthermore, the orientations have to be quantifiable to analyze the structures shaping the morphology. For that purpose, tools have to be added to the two basic functionalities maps and color canvas.

Color

Representation of color orientation in 3D will be performed using Schmidt stereonet (canvas). It can be achieved by using projections of the poles of



the cells of topography on the vectors of the RGB colors (Red, Green, Blue).

A function must be created using the principle illustrated in Fig. 2, using the change in orientation of the vectors and their lengths.

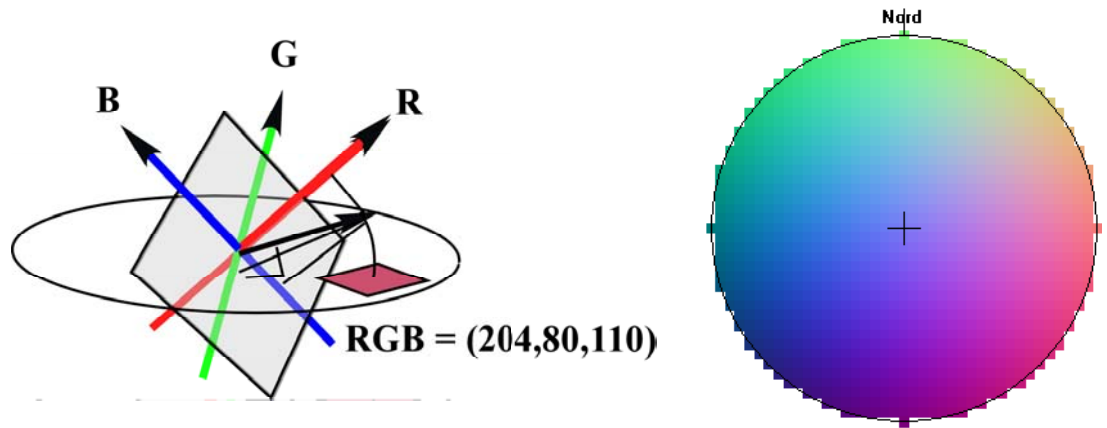


Fig. 2: (left) One solution to use RGB and Schmidt projection, RGB vectors are in color and the vector perpendicular to the topographic cell is black. It is projected on RGB vectors. (right) Example of results of colors defined using orientations (this colors does not correspond to the one used in Fig. 3).

Maps

Maps are simply used to display the cells of the DTM using the colors defined by the canvas (Figs. 2 and 3). An inverse function of that underlying Fig. 2 must be developed to obtain orientations when the mouse is displaced on the colored map. The display of selected orientation alone will also be implemented.

Orientation definition using points, canvas or spreadsheet

By clicking on the map, the dip and direction will be displayed on the map. Such results will be either printed on a canvas or printed in a list file that can be stored in a text file (Fig. 4).

Mean orientation

Selecting graphically an area of interest, the orientation canvas or files previously described will also be obtained for all cells located within the selected area.

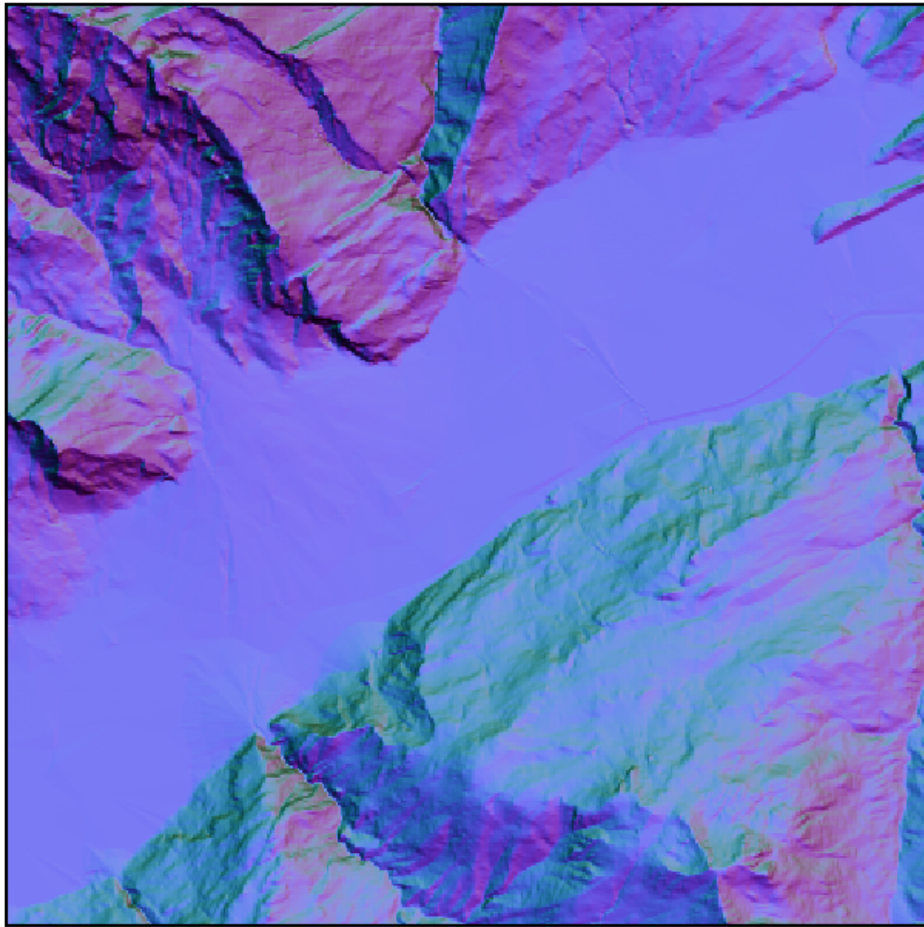


Fig. 3: Example of map that can be obtained from a DTM with a mesh size of 25×25 m. Note the similar orientation on both sides of the valley (DHM25, reproduce with the authorization of Office fédéral de la topographie BA034918).

4. 3D analysis: Histogram of topographic DTM cells orientation

Analysis of topography is also based on simple statistics. Histogram of slopes and strikes will be implemented as well as 3D histograms (Fig. 4).

3D histograms can be compared to Schmidt density stereonets, but cells orientations replace measurements of dip.

In number

Histograms are built by counting the number of cell orientations that make an angle smaller than a given limit with the orientation density to estimate. This is performed using scalar product. Results are divided by the surface area of the sector of sphere defined by the range of angle around the direction to estimate, that is a cone.

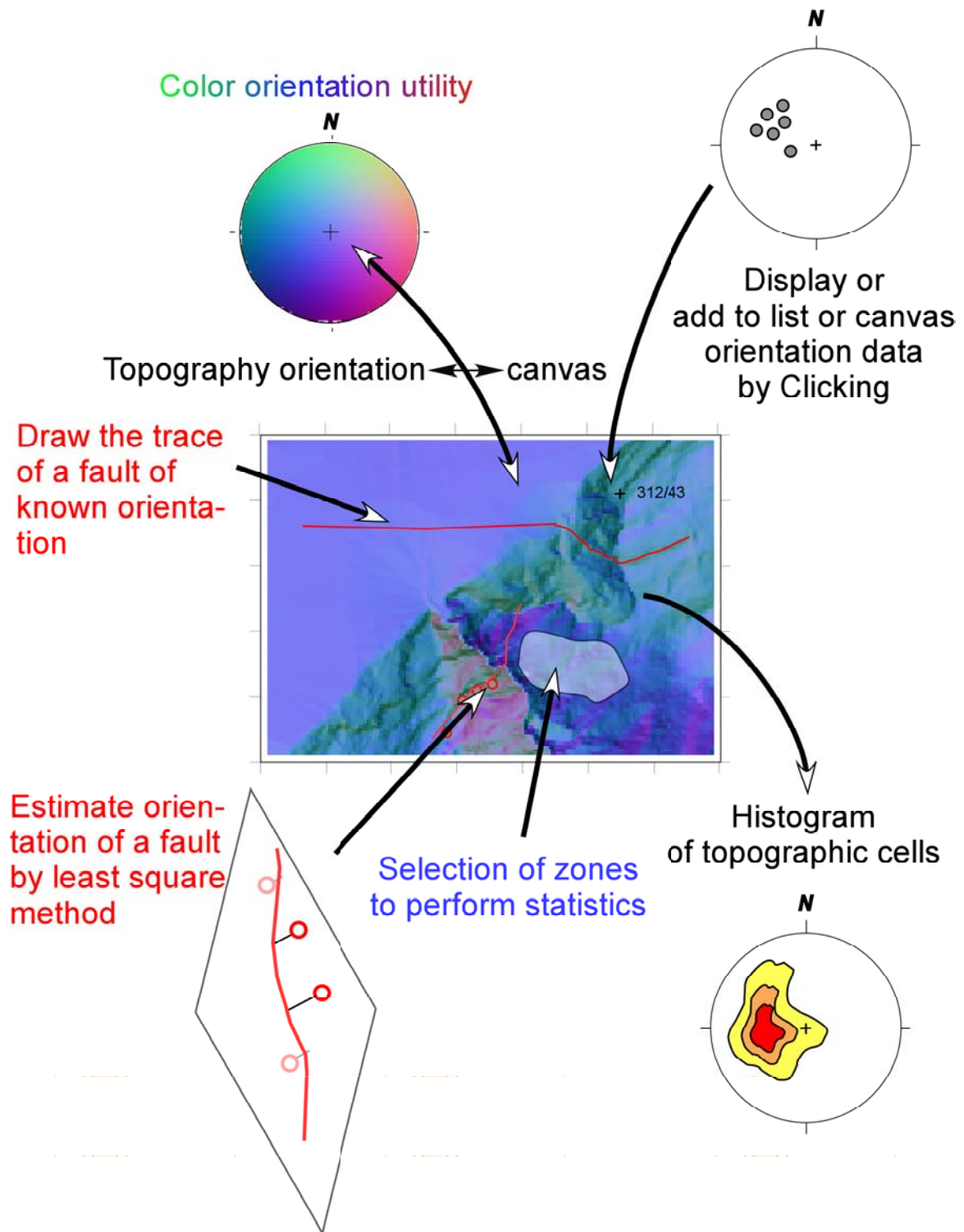


Fig. 4: Illustration of the different functionalities of the program COLTOP-3D.

Weighted

The 3D histogram can be weighted by the surface of the topographic cells. Instead of using simple counting of each orientation, they are multiplied by the surface. The results have to be normalized.

Local estimation

Histogram will also be possible within a sector of topography contoured manually.

5. 3D fault tracing

The analysis of the images and the statistic produced by COLTOP-3D leads notably to put hypothesis about large-scale structures such as faults and large joint sets (Fig. 4).

Traces

Knowing one point of a fault and its orientation, a function will be developed to obtain its trace on the topography. Spatial limits will be implemented too.

Least square fault traces using points

Sometimes a fault is suspected, but no orientations are clearly visible on the topography. Thus by placing points on the topography belonging to the supposed trace of the fault, the trace will be obtained using least square method to define a planar surface.

3D Fault buffer

The "buffer" function usually implemented in GIS permits to create a buffer around an object with a constant distance horizontally (Burrough and McDonnel, 1998). If a fault is oblique to the topography, this buffer should vary depending on the angle between the topography and the fault. A function that produces such buffers will be implemented.

Simulation

The function of fault tracing allows tracing a lot of faults. Using this function, simulations of fault display on the topography will be developed.

6. Stereonet of fracturing density

Joints sets can shape rock slopes. The analysis of the frequency of the main joint sets, compared to histograms of topography will be a tool to analyze the effect of fracturing on landforms development.



Fracturing density canvas

Following the theory of Hudson and Priest (1979 and 1983), the density of fracturing can be calculated in all directions of the space using the frequencies and orientations of the pole of the discontinuity sets (Fig. 5).

Comparing the results with small area of topography will be a test for the effect of fracturing on geomorphology.

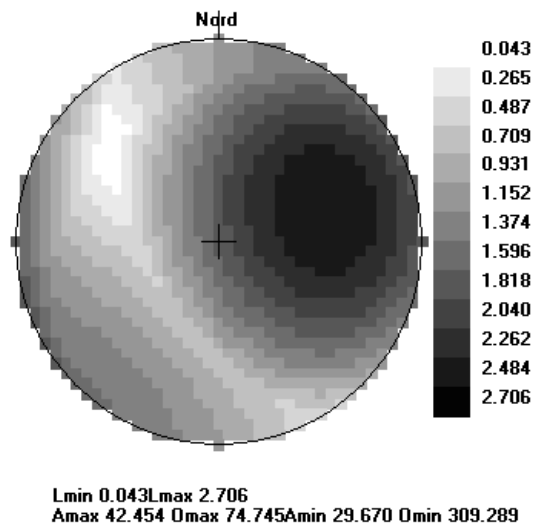


Fig. 5: Example of frequency canvas of two discontinuity sets 130/30 and 60/60, assuming frequency of 1 and 2 respectively.

7. Programming

The programming will be performed in Visual basic 6.0 using API functions (Stephens, 1999). The application will be a multi windows application (Mdi). Several types will be produced; some of them will be dependent on each other's. A function of color in 3D will be developed.

The colors will be displayed as bitmap, but they will be defined in a grid array of RGB colors using API. A function of map coordinates will be refined, in order obtain high quality outputs.

8. Planning

As usual, it is difficult to establish a planning for computer programming. But because some routines partly exist, some stages will not be too difficult to reach.

The continuation of this project depends on the success of this first stage and on the results obtained using COLTOP-3D

Travel	1'500 CHF
Accommodation	1'000 CHF
Salary	7'500 CHF
Expenditures	1'000 CHF
	<hr/> 11'000 CHF

Fig. 7: Approximative costs of the first stage of COLTOP-3D program. The change between \$CAN is approximtly 1/1 with the CHF, thus accomodation and expenditures are supported by GSC.

12. Perspectives

Depending on the advance of the project, the possibility to introduce a background image to pseudo-3D representation have to be implemented, this will be useful to compare mapping.

The development of laser DTM (Lidar) of high resolution will increase the potential utility of COLTOP-3D.

Collaborations with private companies have to be considered.

13. Preparation of Nice 2003

A presentation in the EGS-EUG-AGU congress in Nice 2003, has already been submitted, containing partly subjects linked to COLTOP-3D. The abstract is:

Rock instability hazard assessment based on detailed topographic analysis

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Assuming that rock instabilities are generated by the conjunction of particular structural and morphological settings, analysis of the topographic relief using DTMs (digital elevation model) provides essential results for the hazard assessment of rock instability. The accuracy of the results is dependent on the mesh size of the DTM.

Residuals obtained by the subtraction of a DTM and a smoothed topography allows the detection of either convex or concave morphologies. Depending on the smoothing parameters used, convex relief can correspond to potentially unstable spurs, and concave relief can correspond to thalwegs indicative of local areas affected by higher erosion rates. The combination of these two features and the use



of different smoothing parameters allows the detection of unstable spurs in local areas prone to high erosion.

Three-dimensional topographic analysis is performed by using the orientation of each single cell of the DTM, and provides a 3D shaded relief. This analysis allows the identification of the main structures that shape the landscape, especially from a tectonic perspective. This leads to the identification of the main potential rock slope failure mechanisms produced by discontinuities. Using these results, the area where potential plane or wedge sliding may occur can be detected, as well as the density of dangerous structures.

Combining residual analysis and structural analysis allows rock hazard instability assessment. This method can be refined by using other instability factors such as proximity to observed regional faults, observed scree slopes, or poor geomechanical properties. Depending on the data available, these instability factors must be classified.

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