New insight of geomorphology and landslide prone area detection using DEM

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The increasing precision of digital elevation models (DEM) makes it possible to perform more detailed and systematic morphological analysis. Using the orientation of each single cell, a DEM can be represented by a kind of 3D shaded relief map having one color for each dip and strike direction, thus permitting a very simple slope analysis.

Three-dimensional histograms represented on density stereonets make it possible to analyze and identify the main structures of a rock slope. From such a representation, it is easy to detect the main features of a relief such as the main joints set shaping a slope, a fault scarp limiting an unstable rock mass, or a landslide scarp. Large-scale fault analysis helps the interpretation with respect to the location of some rockslides.

Such an approach applied to rock slopes leads to the identification of the main potential failure mechanisms produced by discontinuities. Using these results, the areas where potential planar or wedge failure may occur can be detected by comparing sliding directions and relief orientations. The density of dangerous structures can be also estimated if the average discontinuity spacing and trace length are known, or determined using a DEM.

Volumes of rock instabilities can easily be determined using the discontinuity traces on the DEM that shaped the relief delimiting unstable rock masses. For soil slopes, the scarp as well as the bottom of the slope can be determined, making it possible to estimate the sliding surface and thus the volume of the unstable mass, using simple functions.

In the basement rock of the Swiss Alps, the fracturing is developed enough to define in certain locations around 50% of the slope orientation directly. Often the entire slope is dependent on the 2 or 3 main fractures sets. Active rock instabilities are often located in the neighborhood of the intersection of large faults, as it is suspected in the Cretaux rock-fall area (VS, Switzerland). In many cases, a depression of the relief is associated with such an intersection. These depressions can be detected by the subtraction of a smoothed upper level of topography from a DEM. Identification of spurs within depressions indicates the presence of an important mass within a highly erodible area.

The comparison of streams locations and directions – calculated using GIS routines, or mapped – with the orientations of faults shows a very good agreement in the gneissic rocks of the Mattertal and of the Rhône valley (VS, Switzerland). The streams 3D directions often belong to the plane defined by the main discontinuities shaping the relief.

The histograms of DEM orientation performed by rock types are different for one hill slope. The slope angle is dependent on both an apparent friction angle of the rock, as demonstrated in the Lourtier area (VS, Switzerland), and discontinuities. However, the discontinuities play different roles depending on the peak strength of rocks.

Such simple DEM analyses make it possible to quickly identify unstable or potentially unstable rock masses. The increasing availability of DEM will make such methods very useful.