A new automated technique within ArcGIS to compute the attitudes of planar topographic features.

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Introduction

Common methods of visualizing topographic data such as contour maps or shaded relief do not yield a clear and quantitative representation of the full 3D orientation of a surface. ArcGIS® contains built-in tools (the Surface toolset in Spatial Analyst® toolbox) that can determine the Aspect and the Slope via nearest neighbor algorithms [1], but lacks the capacity to use kernel sizes larger than 3x3 pixels, or to provide goodness-of-fit estimates (Fig. 1: A-D).

A New ArcGIS Tool

Herein, we present our in-house developed ArcGIS add-on that computes surface derivatives using Least Squares Regression (LSR) which is similar to the approach used in the manual planar attitude calculations used within the software Orion [2, 3]. The new approach allows more flexibility by enabling the use of larger, user-defined kernel sizes, and the ability to calculate Mean Squared Error (MSE) (Fig. 1: E, G). Unlike ArcGIS built-in tools, our software has a capacity to generate parameters for Cartesian plane equations, thus making it possible to distinguish parallel surfaces from coplanar. We also demonstrate a new, Augmented Visualization of Attitude (AVA) presentation for displaying attitude data in RGB format, wherein strike is encoded as hue and dip as saturation (Fig. 1: F, H).

Advantages of the New Tool

The ability to use larger kernel sizes becomes useful where surface roughness is an issue, or where the Digital Elevation Model (DEM) is subject to other noise. Increasing the kernel size minimizes the effect of small (e.g., single pixel size) surface undulations, without sacrificing data quality. As long as the kernel size is markedly smaller than the features of interest, the quality of fit will increase as more points are available for regression analysis.

The MSE parameter provides a cleaner, less noisy representation of surface irregularities then can be obtained using ArcGIS® Curvature tool. Points with high values of MSE are indicative of either invalid pixels in the parent DEM, exceptional roughness, or bends. Estimating surface roughness using MSE is superior to doing the same via the neighborhood standard deviation, as the latter does not take into account the slope of the surface.

AVA provides a much crisper and more detailed display of surface attitudes than Aspect, Slope or Hillshade. The appearance of AVA is similar to that of colored hillshading. However, while hillshading is unidirectional, AVA highlights features similarly in all directions, providing a clear view of planar features of similar attitudes that are otherwise too subtle to be noticed from the DEM rasters alone.

Where topography follows geological features such as faults or bedding planes, these features can be automatically located and data extracted for use in other software. This reduces the demands on the operator when processing large data sets in search for exposed geological surfaces.

The outputs of different kernel sizes were tested against planar surfaces measured with the Orion software, which fits a plane to a set of user-defined points [3]. Results indicated that the distribution of attitudes, calculated for every pixel within the DEM over a set region of interest compared well with the manually calculated best-fit plane using Orion.

Applications and Future Work

The automated determination of surface attitudes has a wide range of potential applications, from tectonic feature and crater identification to surface roughness estimations, boundary location and error elimination. Depending on the size of the DEM the actual time of computation is short, making it an ideal tool to examine large DEMs and rapidly locate features of interest.

Future work on this project will expand on current abilities by focusing on optimization for outlier (error) pixels elimination, using variable kernel sizes within a scan to compensate for variations in surface roughness, developing a procedure for surface reconstruction from partially incomplete data sets by approximation, and applying this software to the study of morphology of outflow channels and streams.

Upon completion of final coding, this tool will be made freely available to interested parties, who are encouraged to contact either M. Minin or F. Fueten.

References: [1] ArcGIS Help 10.1 (2012), http://resources.arcgis.com/en/help/main/10.1/index.html#//009z000000tw000000 [2] Fueten, et al. (2005), *Icarus*, 175, 68-77. [3] Pangaea Scientific, http://pangaeasci.com/index.php?page=orion

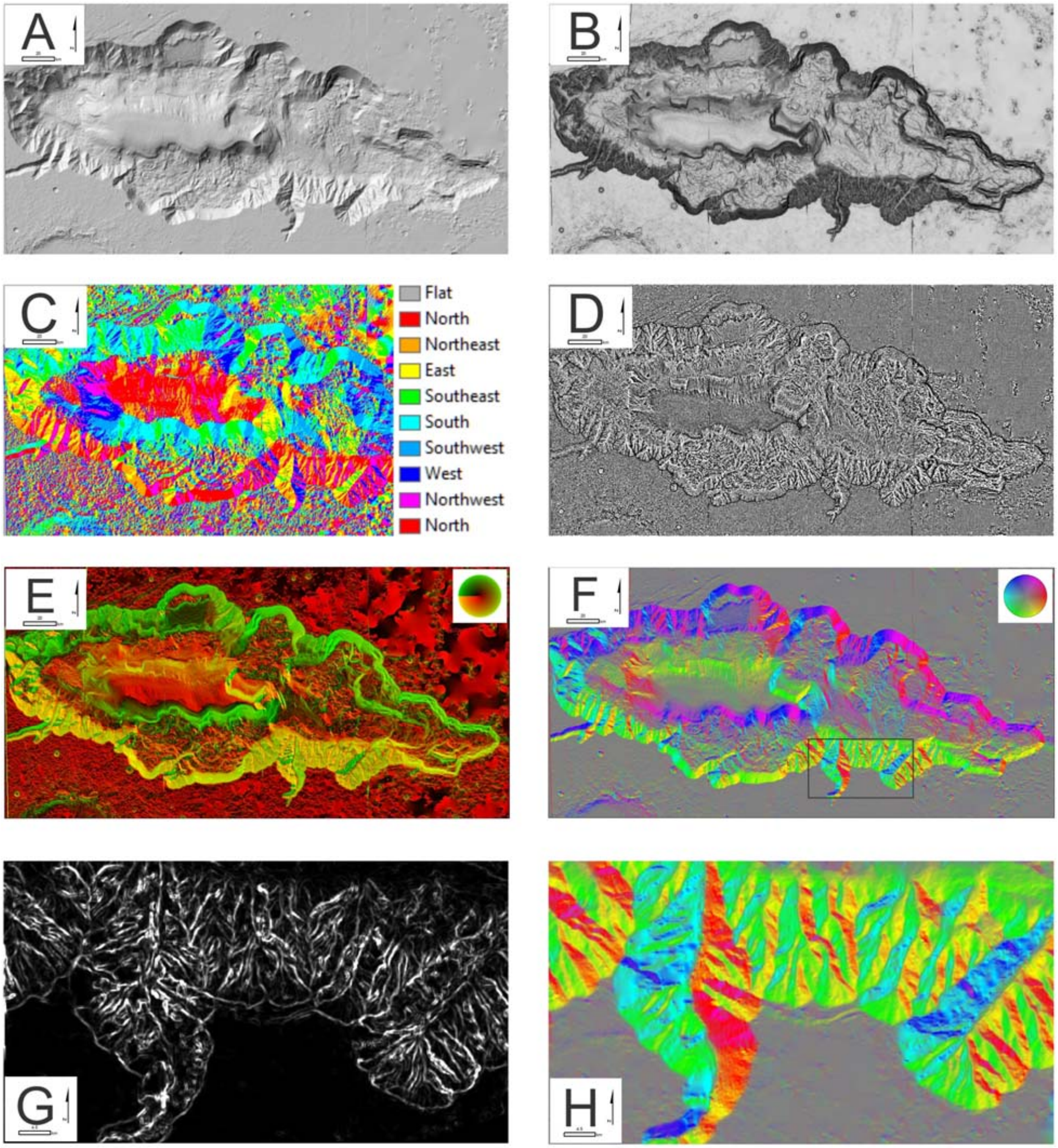

Figure 1: Attitude visualizations options illustrated on HRSC composite DTM (100 m/pixel) of Hebes Chasma, Valles Marineris, Mars.
Figs 1A-D) produced using ArcGIS built-in tools provided with Spatial Analyst extension: A) Hillshaded DTM; B) Surface slope; C) Aspect, the equivalent of strike; D) Curvature, illustrating deviation from planarity.
Figs 1E - H were produced using in-house developed extension: E) Strike (R), Dip (G) and Error (B) as bands of RGB raster; F) Augmented Visualization of Attitude (AVA) with Strike as hue and Dip as saturation. The small circle in the top right corner of E and F corresponds to coloring of a perfect half-sphere indent. Fig 1G and H indicate a zoomed in area corresponding to black rectangle within 1F. G) Mean Square Error of best fitting plane found by Least Squares regression using 5x5 kernel, H) AVA of section of a chasm illustrating detailed variation of wall attitude.