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MOI Toolbox – Version 2

Summary

This document provides a tutorial on the use of the MOI ArcGIS toolbox. The MOI toolbox provides a set of models to semi-automate the process of generating geological feature (e.g. bedding) dip and dip direction measurements from a high resolution Digital Elevation Model (DEM). Dip and dip direction measurements are estimated using the Moment of Inertia (MOI) algorithm (Fernández, O. 2005). The MOI algorithm requires a set of 3D points (X, Y and Z) to estimate, based on matrix algebra, the orientation of a plane that best-fits these 3D points. In addition to estimating the orientation of a plane, the MOI algorithm also provides an indication of the reliability of the fit of the plane with respect to the 3D points. These reliability metrics symbolise the distribution of the 3D points around the estimated plane (M) and the colinearity/coplanarity of the 3D points (K).

Extensive experimentation has indicated that curvature (profile, plan and average) DEM derivatives provide an optimal visualisation environment for the identification of small-scale (10-100 m) topographic features that represent the surface expression of geological features (bedding planes). High (and low) DEM curvature is used as a guide for digitising a set of vertices which are then converted into 3D geolocated points. It is from these 3D points that the MOI algorithm estimates best-fit plane orientation. Detailed information on the theory and practical considerations of this workflow can be found in Cracknell (2009) and Cracknell *et al.* (2013).

Software requirements and files

The MOI Toolbox was developed on a Microsoft Windows 64-bit operating system and uses a combination of ArcGIS 10.0 tools and Python 2.6 (32-bit) scripts. Testing with other versions of these applications has not been conducted although it is likely that later versions will work. The MOI script requires several modules which are supplied with the accompanying files (see below). ArcGIS current (MOI_template.gdb) and scratch (MOI_scratch.gdb) workspaces contain template and intermediate spatial data files in Projected Coordinate System GDA 1994.

The following files are provided in the MOI directory:

MOI

→ Python_modules (contains the Python 2.6 (32-bit) modules that must be installed)
- matplotlib-1.3.1.win32-py2.6

  - numpy-1.8.1-win32-superpack-python2.6
  - pyparsing-2.0.2.win32-py2.6
  - python-dateutil-2.2.win32-py2.6
  - scipy-0.14.0-win32-superpack-python2.6
  - six-1.6.1.win32-py2.6

→ MOI_template.gdb (ArcGIS current workspace)
  - GeoLines (polyline feature class)
  - GeoPoint (point feature class)
  - points3D (polyline vertices feature class)
  - MOI (toolbox)
    - DEM curvature (model to generate and display DEM derivatives)
    - MOI.py (link to MOI Python script)
    - MOI_V2 (model to generate 3D plane and display its properties)

→ MOI_scratch.gdb (ArcGIS scratch workspace)
  - DEM
  - Various files generated by the MOI Toolbox

→ references (reference documents)
  - Cracknell_2009.pdf (reference document)
  - Cracknell_etal_2013.pdf (reference document)

→ GeoPoint.lyr (point feature class symbology)
→ MOI.png (image displaying plane properties)
→ MOI_dat.csv (data file)
→ MOI.py (MOI Python script)
→ MOI_template.mxd (ArcMAP document)
→ vector.py and vector.pyc (required Python and compiled Python files)
→ MOI_Toolbox_Version2.pdf (this document)

Setup

Create a directory called ArcGIS on the C:\ drive of the computer you will be using (C:\ArcGIS\) and copy the MOI directory to this location. Install Python 2.6 modules starting with numpy, scipy and matplotlib followed by the others. Open the MOI_template.mxd using ArcMAP. If the MOI Toolbox is not available in the ArcToolbox window add the MOI Toolbox located in MOI_template.gdb. Open the MOI Toolbox and check that DEM curvature (model), MOI (script) and MOI_V2 (model) are available (Figure 1).

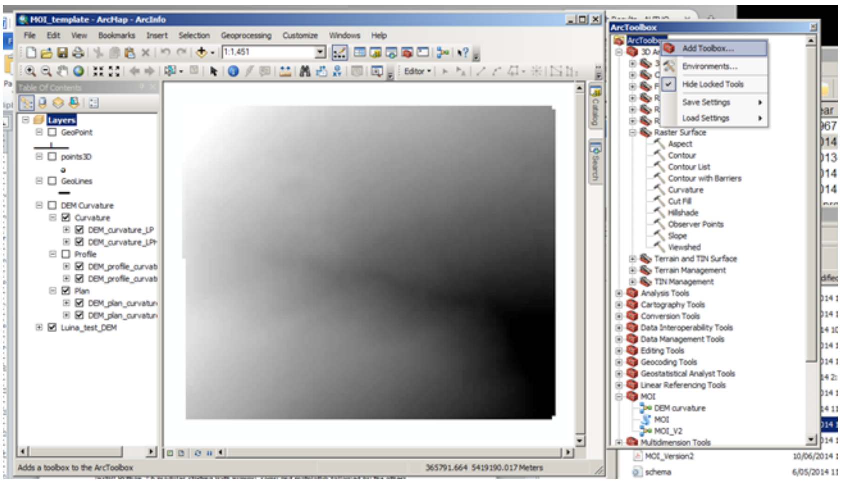

Figure 1. Screen grab showing ArcToolbox window (with MOI Toolbox installed). Add Toolbox … if the MOI Toolbox is not visible.

Tutorial

This tutorial is based on the Luina_test_DEM raster file located in MOI_scratch.gdb. This DEM was interpolated from LiDAR ground returns with a resolution of 2 m.

1. *Generating DEM curvature*

The *DEM curvature* model takes a raster DEM file and calculates curvature derivatives (profile, plan and average). Profile curvature is the curvature of the surface in the direction of slope and plan curvature is the curvature of the surface perpendicular to the slope direction. Average curvature is the average of these two curvature derivatives. Curvature derivatives are then smoothed using a mean spatial filter. Displaying these layers with red-blue (high-low) colour ramp and a sun angle filter is recommended. This visualisation aids the identification of topographic features representing the surface expression of bedding planes

Open the *DEM curvature* tool and set the following parameters:

- DEM – input DEM
(for all curvature derivatives)
- Neighbourhood (defaults to rectangular 3x3) –neighbourhood for mean spatial filter

2. *Digitising geological features*

It is easier to visualise the surface expression of a bedding plane as high curvature features indicating resistance to weathering and erosion (e.g. indurated siliciclastic sedimentary rocks - quartzite). However, low curvature features may represent faults or features that are less resistive to weathering and erosion.

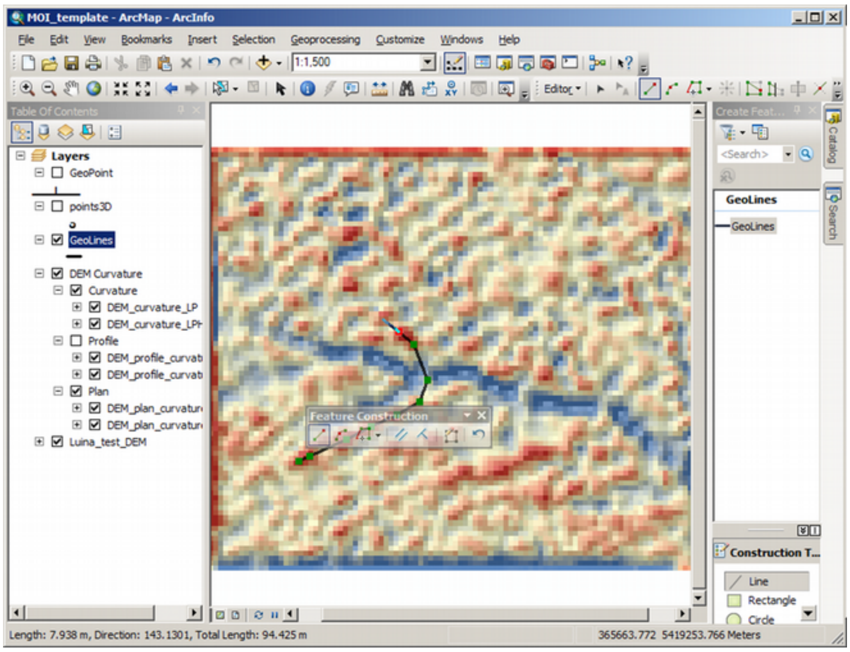

Figure 2. Digitising a GeoLines polyline feature from the DEM curvature (average) raster generated by the DEM curvature model.

Once a potential feature has been identified make the *GeoLines* feature class open for editing and delete the pre-existing line if present. Carefully place vertices in order along the feature of interest (Figure 2). Vertices can be deleted (or added) by Right-Click □ Delete Vertex (Add Vertex). Multiple features can be digitised. When you are finished be sure to Right-Click □ Finish Sketch and then Save/Stop Editing.

3. *Estimating and visualising MOI best-fit planes*

The *MOI_V2* model takes the polyline feature you have digitised in the previous step and appends X (Eastings m), Y (Northings m) and Z (elevation m) data, fits a plane using the MOI algorithm and then displays dip and dip direction information and associated reliability measures.

Open the *MOI_V2* tool and set the following parameters:

- *GeoLines* – input line feature class
- Scratch workspace (defaults to *MOI_scratch.gdb*)
- Current workspace (defaults to *MOI_template.gdb*)
- *INPUT_DEM* – DEM used to append elevation (m) data

NOTE – the *MOI_V2* model looks for an *INPUT_DEM* raster object in the *scratch.gdb* workspace. Therefore, to change the file that this raster object represents it is necessary to import the target DEM file into the *scratch.gdb* and rename this to *INPUT_DEM* (this will require deleting the existing *INPUT_DEM* file first).

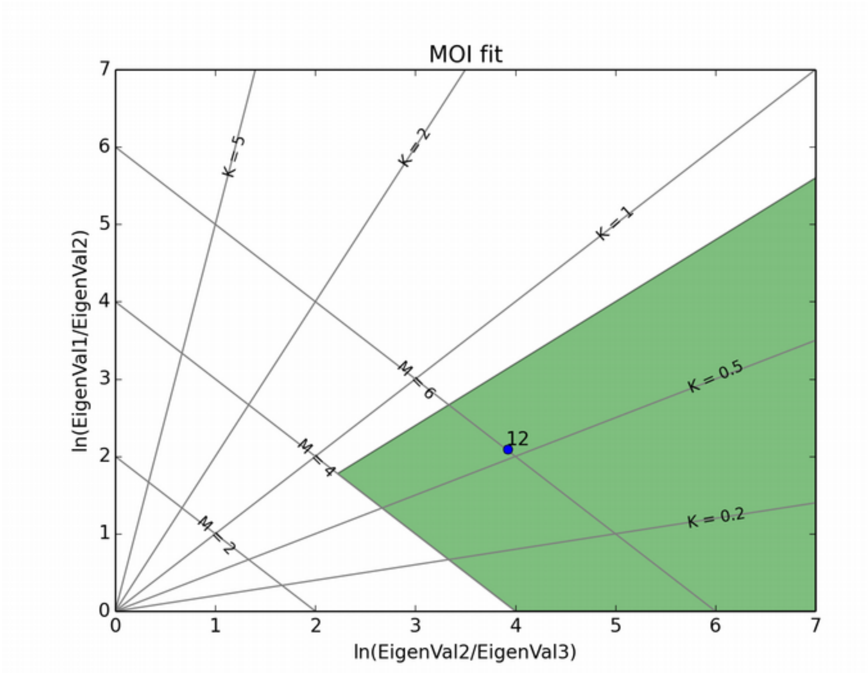

Figure 3. MOI.png showing the reliability of the distribution of 3D points used to estimate the best-fit plane using the MOI algorithm. High values of M indicate less dispersed 3D points. High values of K indicate increasingly colinear 3D points.

The *MOI_V2* tool should take about 1 minute to run and will work for multiple features in *GeoLines*. When *MOI_V2* has finished the ArcMAP display will have an updated set of *points3D* representing polyline vertices, *GeoPoint* plotted as dip (label) and dip direction (bedding symbol) at the midpoint of the *GeoLines* features. The *points3D* attribute table conats X, Y and Z coordinates and an Error field representing the distance from points to the MOI estimated plane. This information is useful for identifying points that are contributing to a poor fit to the MOI plane. In addition, an image will open showing a plot of the M and K reliability measures for each feature (marked with OBJECTID field) in terms of the log ratio of the three eigenvalues obtained when executing the MOI script (Figure 3). The green region indicates good M (≥ 4) and K (≤ 0.8) values. This image file is saved as *MOI.png* and will be overwritten during the next run of the *MOI_V2* model. All the information in the *GeoPoint* attribute table is written to *MOI_data.csv*. The fields in *MOI_dat.csv* are:

- **ID** = *GeoLines* feature ID
- **N_Points** = number of vertices used to generate *GeoLines* feature
- **Xmean, Ymean, Zmean** = mean X, Y and Z coordinates of *GeoLines* feature
- **M, K** = MOI reliability measures
- **RMSE** = Root mean squared error (distance) of all points to MOI estimated plane
- **A, B, C, D** = coefficients of plane
- **Dip, Dipdir** = Dip and dip direction of MOI estimated plane
- **eigen1, eigen2, eigen3** = Eigen Values of MOI estimated plane
- **Length** = Length (m) of *GeoLines* feature

These data can be loaded into other software for display and analysis. These data will be overwritten during the next run of the *MOI_V2* model.

References

CRACKNELL, M. J. 2009. Remote sensing geological structures using high resolution Digital Elevation Models. Honours Thesis (BSc.), School of Earth Sciences, University of Tasmania, Hobart, Tasmania, p. 165.

CRACKNELL, M. J., ROACH, M., GREEN, D. & LUCIEER, A. 2013. Estimating Bedding Orientation from High-Resolution Digital Elevation Models. *Geoscience and Remote Sensing, IEEE Transactions on,* vol. 51, no.5, pp. 2949-2959.

FERNÁNDEZ, O. 2005. Obtaining a best-fitting plane through 3D georeferenced data, *Journal of Structural Geology*, vol. 27, no. 5, pp. 855-858.