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Local Probability Density-based 3D Edge Detection Applied to an Electromagnetic Inversion of the Kevitsa Ni-Cu-PGE deposit, Finland

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Introduction: Three-dimensional physical property models and geophysical inversions are difficult to interrogate, with common approaches relying on visualising cross-sections ('slicing') or altering the opacity of voxels in the outer shell of the model or by voxel value. Typically the objective of such interrogations is to identify edges between homogeneous regions within the 3D model, which can then be used for further region-based analyses in resource estimation and mine planning. Manually searching for edges in a physical property model is time-consuming, and is especially difficult with 3D inversions due to the smoothness constraints implemented in the inversion algorithms. We present a new computationally efficient 3D edge detection algorithm based on probability estimation which performs well on such smoothly changing models.

Case Study: The edge detection algorithm was applied to an airborne electromagnetic inversion of Kevitsa, a Ni-Cu-PGE mafic-ultramafic intrusion located in Finnish Lapland [1]. The airborne time-domain electromagnetic survey was flown in 2009 using the VTEM system [2] with 100 m line spacing, and inverted by First Quantum Ltd using UBC's EM1TDM inversion code with voxel dimensions of 30 m x 30 m x 15 m deep. The algorithm was also evaluated on mass density and magnetic susceptibility inversions (not shown here for space reasons).

Method: The proposed algorithm detects edges in two steps. First, the probability density at each voxel is estimated given its neighbour's (within a user-selected radius) voxel values. These probability densities are estimated using kernel density estimation with a Gaussian kernel and a bandwidth calculated from the voxel's neighbours using Silverman's rule of thumb [3]. Second, a low-pass filter is applied to the resulting voxet of local probability densities to highlight regions that are highly dissimilar to their neighbours. This dissimilarity is an indicator of edges or outliers within the data. The time-complexity of the algorithm is *O(N*n)*, given a total of *N* voxels and considering *n* neighbours for each voxel.

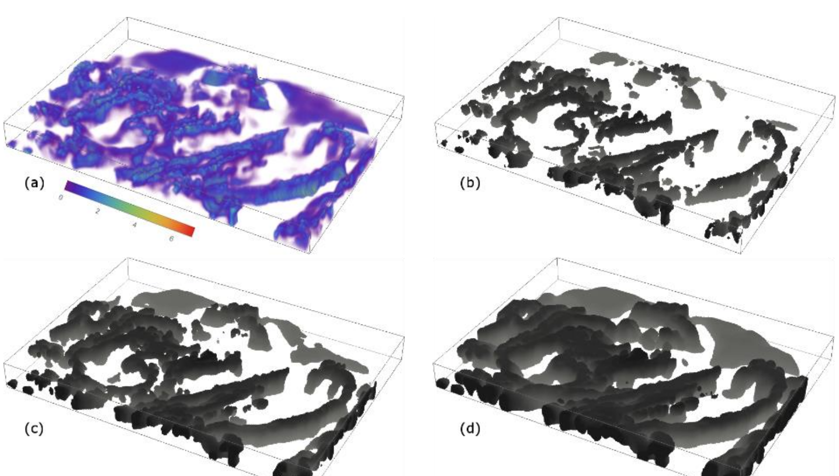

Figure 1: UBC AEM inversion of the Kevitsa mine: (a) log transformed with linearly increasing transparency, (b)-(d) edges detected by thresholding the local probability density estimate of each voxel at 0.05, 0.1, and 0.5 respectively.

Results: The edge detection algorithm was applied to a log-transformed version of the electrical conductivity voxet (i.e. EM inversion) to facilitate kernel density estimation. Figure 1 shows the results of the local probability density voxet thresholded to three values

(0.05, 0.1, and 0.5), where the higher-valued thresholds correspond to softer edges.

References:

[1] Yang S-H, et al. (2013) Contrib Mineral Petrol 166:81-95

[2] Witherly K, et al. (2004) ASEG Extended Abstracts 2004 1:1-4

[3] Silverman, BW (1986) In: *Density estimation for statistics and data analysis*: Chapman and Hall