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Note About Resolution

Appendix E

Roughness Extraction

E.1 Summary and Purpose

The purpose of this appendix is to report the method and findings of a set of analyses attempted to try to extract roughness patterns from DEMs. The intention was to used spatially variable roughness maps as one of the inputs into the Fuzzy Inference System (FIS) used for quantifying DEM surface representation uncertainty in Chapter 4. A facies map well calibrated to field measurements, spatially distributed profilemeter measurements, image classification techniques, or more sophisticated roughness retrievals from higher resolution terrestrial laser scanner data (Vericat *et al.* 2007, Brasington *et al.* 2007, e.g.) would all be suitable alternatives to use. However, recall from § 3.3, that the aim of the DoD uncertainty analysis (of which the roughness extraction is just one component) was to develop a tractable method of quantifying surface representation uncertainty from raw topographic survey data alone (i.e. point cloud).

The analyses reported here were not able to produce consistent, coherent or reliable estimates of surface roughness. The fundamental reason is that the resolution of the topographic data collected is too coarse to resolve surface roughness due to grain size. They were therefore not used in the FIS Rule system in Chapter 4. However, the results may be helpful to readers considering similar analyses and are therefore provided here.

E.2 Background

Surface roughness is one of the primary components of surface representation uncertainty. In some instances, the roughness height can be of a similar magnitude to that of the elevation change being detected from a DoD (e.g. depositional gravel sheets); thus complicating the distinction between what changes are real and what changes are just a reflection of surface roughness. Given that surface roughness varies spatially, its influence on surface representation uncertainty will also vary spatially. As such, if coherent spatial estimates of surface roughness can be derived, it would be prudent to include such estimates in the estimation of surface representation uncertainty. In the absence of a tractable method highlighting spatial patterns of roughness, a more conservative isotropic estimate of roughness may suffice (e.g. based on a D_{84} or D_{90} for the reach).

Surface roughness in the fluvial environment is primarily a function of three factors: 1) composition, 2) organisation and 3) relative protrusion (above a mean surface) of the material that comprises the surface. The materials that typically comprise fluvial surfaces are sediments (alluvium), vegetation, detritus and other forms of organic and inorganic matter.

Various methods exist for producing spatially distributed estimates (i.e. a map[1]) of surface roughness. All methods involve some form of spatial averaging. This may be based on a field interpretation (e.g. facies map classification) or on a computational spatial model between point values (e.g. Kriging, TIN, Nearest Neighbour, etc.). On a cell by cell basis, roughness maps can either be classified into various discrete categories or a continuous measure of roughness height Lane (2005).

E.3 Roughness Extraction Methods Explored

Three approaches to retrieving roughness from topographic elevation data were explored based on a local neighbourhood analysis of surveyed points using: 1) the standard deviation of elevation; 2) the range of elevation; and 3) the difference of elevations between surfaces derived directly from TINs of the actual elevations, versus a surface derived from the mean elevation of points locally. In all three approaches one variant was attempted that modelled the roughness estimates spatially so as to preserve the exact roughness estimates where they were estimated; whereas a second variant attempted to smooth the spatial model through some combination of low-pass filtering and Kriging modelling. Both variants involved interpolation and spatial averaging, but the first variant seemed to produce more reasonable patterns. The steps eventually decided upon in each of the above three methods were as follows (Using ArcGIS 9.2):

1. Filter point cloud of raw survey data for areas of high slopes ($>$ 10 percent) using a slope analysis of a one meter resolution TIN-Derived DEM of the original survey data.[2] This was done so that local statistics on elevation captured primarily a local roughness signal instead of a macro-morphology roughness signal.
2. A discontinuous raster representing a roughness signal was produced using 'Neighbourhood Point Statistics' (in ArcGIS's Spatial Analyst). The desired local statistic (e.g.

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[1] For the purposes of the input requirements for Chapter 4,the map can originate as a vector (polygon), but ultimately needs to be a raster of either roughness values or classes.

[2] The original survey data was already filtered to remove erroneous points and those failing to meet minimum precision tolerances.

mean, range, standard deviation) of the elevation values for the filtered points was calculated in a 3x3 rectangular moving windows.[3]

3. In the case of the mean elevation statistic, this 1 m resolution raster was subtracted from the actual DEM and the absolute value taken to give an estimate of roughness. In the case of the standard deviation and range, these statistics were preserved as an estimate of roughness.
4. The 'Extract Values to Points' feature was used to extract the estimated roughness values at the same locations as the original filtered survey points (step 1)
5. The new point cloud was filtered to remove values with zero roughness height or no data.
6. To produce a continuous surface between points with estimates of roughness height, a natural neighbour interpolation scheme was used to produce a roughness raster
7. The final roughness surface was clipped by the original extent of the survey data.

The roughness analyses were conducted for all GPS surveys (2002, 2003, 2004, 2005, 2006), but not for the 2000 photogrammetric DEM as original point data was not available to perform neighbourhood points statistics. The patterns from the results shown in Figure E.1 are largely incoherent, and the magnitudes did not show a reliable relationship to grain size distributions from 17 pebble counts in 2006 and 3 bulk surface samples in 2004.

Ideally, the selection of an appropriate roughness extraction method would be based on a direct comparison of derived roughness values with field measurements of roughness height. However, 'direct' measurements of roughness height are rarely available. Profilemeters can give estimates of roughness height along a transect, but statistics and spatial averaging along a profile will differ from similar statistics calculated in 2D space. Although not entirely correct, surface roughness is sometimes equated to grain roughness alone and in such cases grain size might be a proxy for surface roughness. Such a simplification is convenient in that numerous methods exist for measuring grain size distributions in the field. These include pebble counts, bulk sampling, ... etc. (Bunte & Abt 2001). However, even if alluvium dominates the surface composition, the relationship between grain size and surface roughness is certainly not simple or unique.

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[3] Various window sizes and shapes were experimented with. Point density was high enough to enable small local window.

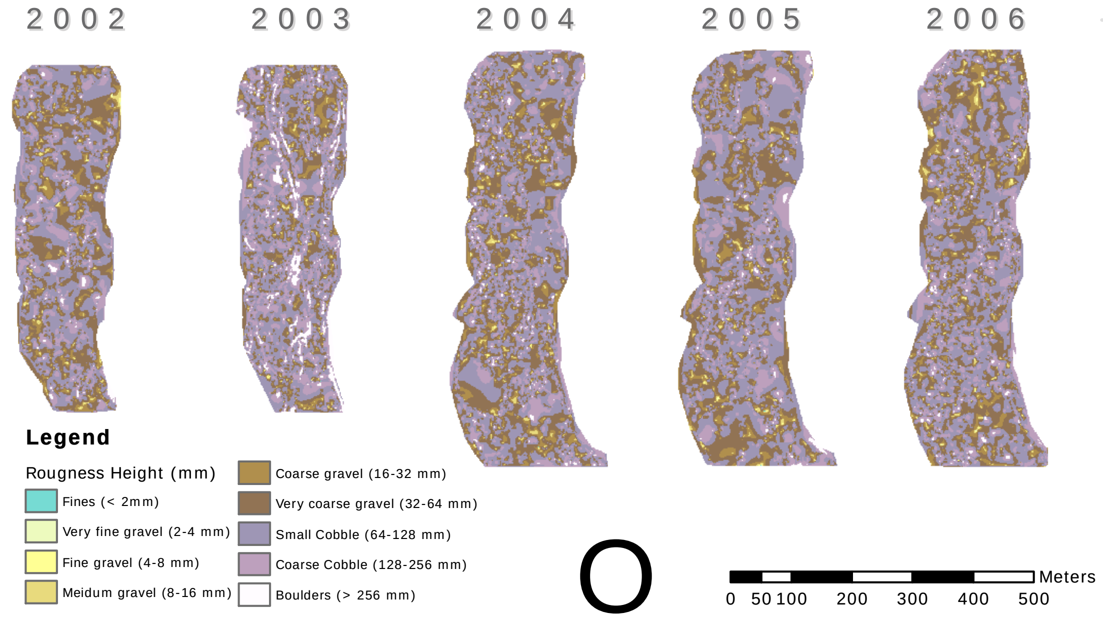

FIGURE E.1: Roughness surfaces derived from a moving window analysis of elevation range (see text for description). Note the roughness heights are classified using ϕ classes; the descriptive labels shown in the legend correspond to Wentworth scale grain size descriptions, but may differ considerably from actual grain sizes.