Modelling Uncertainty in Spatial Data: A Natural Hazards Example

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UEA has a large multidisciplinary School of Environmental Sciences. GIS is used in a range of application contexts, including economics, catchment management, natural hazards, public health and environmental decision making. We use specialist 3D visualization facilities as part of our research.
“Uncertainties and errors are intrinsic to spatial data and need to be addressed properly, not swept under the carpet of fancy graphics displays”


- Much terrain modelling has been driven by data availability
- More attention need to be given to ‘fitness for purpose’
- This is particularly relevant for natural hazard management
- One example is lahars (a type of volcanic mudflow)
Assessing Uncertainty

Evaluating the uncertainty in different inputs and how this may propagate through modelling operations is central to evaluating the reliability of final results.

Two complementary methodologies

- *Uncertainty analysis* – propagation of error
- *Sensitivity analysis* – apportion output variation to sources

These techniques utilise simulation procedures and can help assess whether results meet the quality requirement for the application.
Montserrat Study Area

Belham Valley
November 2004,
Tourist bus stranded
Impact of Lahars in the Belham Valley

~3 m
Ground GPS Survey

Used to create Primary DEM
Creating a Secondary DEM

Photos used to add details of channels and vegetation terraces.
Flow Modelling Methodology

Resolution

Construction method

stdv of error

Spatial dependency

DEM

Perturbed DEM

Cost Distance

Cost Direction

Flow algorithm

Start point

End point

Flow modelling based on elevation change

5 or 10 m cells

Stdv = 0.1, 0.5 or 1 m

DEM

Error 'noise' field
<table>
<thead>
<tr>
<th>DEM</th>
<th>DEM + Random Error</th>
<th>Least Cost Path</th>
<th>Probable Paths</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="DEM Data" /></td>
<td><img src="image2" alt="DEM + Random Error Data" /></td>
<td><img src="image3" alt="Least Cost Path Data" /></td>
<td><img src="image4" alt="Probable Paths Data" /></td>
</tr>
</tbody>
</table>

- **DEM** values are: 8, 6, 5, 9, 7, 4.
- **DEM + Random Error** values are: 8.2, 6.1, 5.2, 5.1, 4.4, 3.4, 8.8, 7.0, 3.6.
- **Least Cost Path** values are: 0, 0, 0, 1, 1, 1, 0, 0, 1.
- **Probable Paths** values are: 0, 0, 0, 1, 1, 0.66, 0, 0, 0.33.
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Least-cost flow path

Probability surface
Impact of DEM Interpolation Method

- Rasterised TIN
- Spline
- Topogrid
Impact of DEM Construction Method
Impact of Changing Cell Resolution

Secondary DEM more robust to resolution change

Stdv = 0.5 m
Incorporating spatial dependency in errors had relatively little additional impact.
Implications

• In this application, **DEM construction method** and **elevation error** have the most significant impacts on model output.

• Primary 10 m DEM, stdv = 0.5, 45 % of area covered by some flow

• Secondary 10 m DEM, stdv = 0.5, 16 % covered

• Primary DEM not ‘fit for purpose’ in this study area

• Results highlight ‘key’ locations for monitoring terrain changes

• Spatial dependency of DEM errors doesn’t merit further investigation

• Adding ‘noise’ does not compensate for inadequate DEM creation.
Conclusion

There is no substitute for constructing a DEM that is informed by the terrain and evaluated as fit for the application to which it is put.

Forthcoming Publication
