An Assessment and Categorisation of Quantitative Uncertainty Visualisation Methods for Geospatial Data

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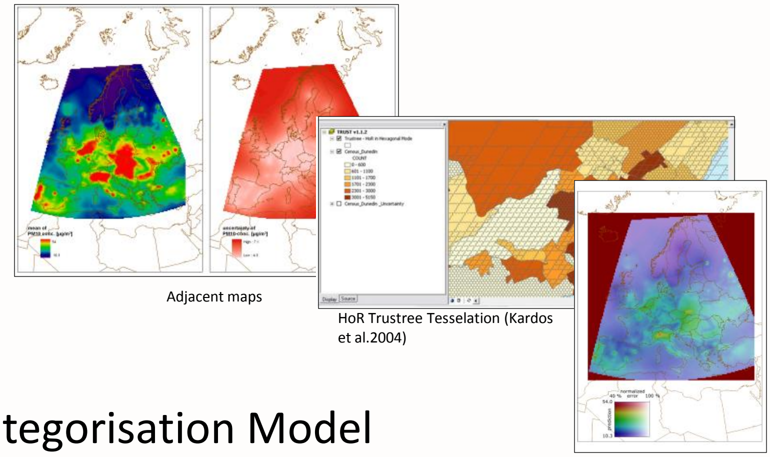
Introduction

Visualisation of uncertainties in geospatial data is important for thorough data analysis, information derivation, as well as for rational decision making. Many methods have evolved to cater to different data and user requirements such as the measurement scale of the phenomenon, format in which the data is encoded, type of uncertainty measured and the user interaction type. We present a review and categorisation of selected uncertainty visualisation methods according to their conformance with the parameters to provide users an ease of selecting applicable uncertainty visualisation method(s).



Adjacent maps

HoR Trustree Tesselation (Kardos et al.2004)

Whitening

Table1: Uncertainty visualisation methods

Name of the Method	Description
Adjacent Maps	Value and uncertainty are presented in two separate maps. (MacEachren 1992).
Animation	(1) Animation of different realisations of the uncertain attribute to emphasise the uncertainty (Ehlschlaeger et al. 1997). (2) Blinking Regions, where two images of data and uncertainty are overlaid on top of another and alternately displayed (Kardos et al. 2006). (3) Blinking Pixels where the displayed data is manipulated to blink through constantly changing colour of the pixels of more uncertain data with a rate of change proportional to the uncertainty (Fisher 1993).
Hierarchical Spatial Data Structures	Uncertainty is depicted through the granularity of a transparent tesselation (Kardos et al. 2003).
Colour Models	The colour hue represents data and saturation and intensity represents uncertainty (Hengl& Toomanian 2006).
Glyphs	Uncertainty and the data is represented in a bivariate depiction through pictorial symbols, known as glyphs (Pang 2001).
Contouring	Data is depicted through colour and uncertainty through intensity. Positional uncertainty is depicted through the gap widths in the dotted contour lines where higher uncertainty leads to wider gaps (Dutton 1992, Pang 2001).
Focus Metaphors	Uncertain data is depicted out of focus and more certain in focus. Another metaphor of this method is the Opacity method where less uncertain data is seen less opaque and more uncertain data is more opaque (MacEachren 2005, Drecki 2002).
Exceedance Probability Mapping	These maps depict the probability of exceeding a threshold in a certain pixel or area (e.g. Van de Kassteele & Velders 2006). A similar concept is giving confidence intervals.
Statistical Dimension in a GIS	The uncertainty of the data is represented by the cumulative probability functions for each pixel or vector object. The map colour scale shows the associated value or probability (Pebesma et al. 2007)

Categorisation Model

Figure 1 presents a UML class diagram which is a first version of a formalised model based on categorisation by the core parameters of uncertainty visualisation. This formalised model depicts the interrelation between the uncertainty visualisation methods and their supported parameters.

Once the model is implemented, it bears the ability to automatically select applicable visualisation method(s) based on the data and user requirements, which would be an input to the model. This could be used for visualisation of uncertainty of results within, e.g. web-service or model chains.

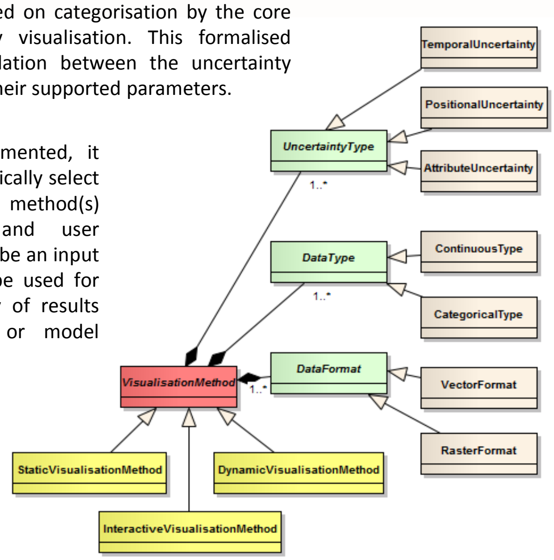


Figure 1: Model Draft

Application

Assuming a given scenario in visualising the uncertainty of the PM_{10} concentration in a given area, the user feeds in the requirements:

- *Uncertainty Type:* ***Attribute***
- *Data Type:* ***Continuous***
- *Data Format:* ***Raster***
- *Interaction Type:* ***Dynamic***

Upon these requirements the decision tree which can be followed by a program, ultimately leads to the consequent outcome of visualisation methods:

Animated Isolines
Animation
Blinking Pixels and
Blinking Regions.

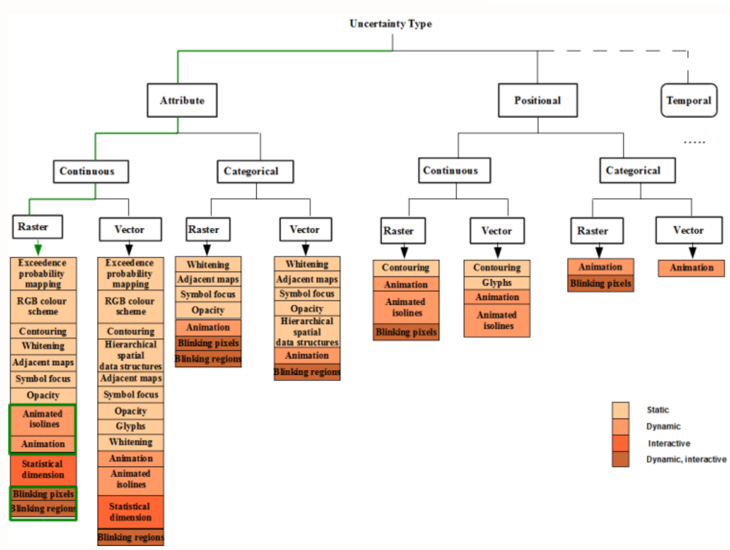


Figure 2: Decision tree

Outlook

In future, the model will be implemented to integrate with a web-based visualisation tool and tested for its performance. Also, future work will be to assess the usability of these methods, at different user experience levels. Through these evaluations the assessed methods can be categorised by their relevance and usability at different user groups. Thereupon, *usability* as another parameter for each method could be derived. This will allow novice users to choose methods according to their level of expertise.

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