Visualising Uncertainty in Geographic Data using Hierarchical Spatial Data Structures

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Biography

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1. Introduction

This paper presents the use of hierarchical spatial data structures to visualise uncertainty in spatial information. This is exemplified using geographic data from the New Zealand 2001 Census. Of interest here are questions regarding the use of hierarchical tree structures as an improvement over conventional geovisualisation of uncertainty techniques. Three such structures will be compared: the region quadtree, the hexagonal *heptree* (seven descendants in a tree structure) and the *hexagonal or rhombus* (HoR) quadtree. A major question is: can an uncertainty measure be effectively communicated using tree structures? It is argued that the use of horizontal and vertical lines generated by region tessellations is distracting and should be avoided. Standard hexagonal tessellations rotate during each recursive level of the tree, and therefore are more complex when creating geovisualisations to the HoR quadtree structure. The HoR structure is simple and visually effective to use for geovisualisation. Determining if an accuracy measure can be effectively communicated using tree structures is still being researched.

2. Uncertainty

2.1 Statistics New Zealand 2001 Census

The New Zealand 2001 Census was the dataset chosen to generate an uncertainty measure from. This was chosen partly because of easy access to data and existence of accuracy figures. The accuracy information arose from a Post Enumeration Survey designed to provide information on the completeness of census coverage (Statistics New Zealand. 2002).

2.2 Uncertainty Measure

The Monte Carlo statistical technique was chosen to generate an uncertainty measure; its use has been well established in the GIS community in the past (Burrough and McDonnell 1998; Fisher and McGwire 2001; Longley et al. 2001).

3. Geovisualisation Of Uncertainty Techniques

3.1 Current Techniques

There is a number of current geovisualisation of uncertainty techniques to view spatial data. MacEachren (1992) demonstrates the use of a metaphor or map overlay to show uncertainty. Some metaphors include: fog cover to hide the uncertain parts of the map, the blurring of uncertain parts in a map and restricting particular spatial resolutions and therefore accuracy of a map. Other techniques include, pixel mixture (De Gruijter et al. 1997), colour mixture (Hengl et al. 2002), animation (DiBiase et al. 1992), sound (Krygier 1994), blinking pixels (Fisher 1993), texture overlay and adjacent maps (MacEachren et al. 1998).

3.2 Proposed Tree Structure

A display of accuracy could be achieved using a tree structure to enable geographic visualisation by tessellations of varying resolutions. This structure provides the ability to impose coarse tessellations where the uncertainty is high and finer tessellations where the uncertainty is low. Current research is focused on using a tree structure to show geographic information at its appropriate accuracy level.

4. Region Quadtree

The region quadtree derives from a single root node that gets divided into four ordered nodes representing four equal quadrant regions. These nodes can also be divided in turn if the quadrant region is non-homogeneous and continues to be divided until each node has homogeneity. Once each node has homogeneity then that quadrant is stored as a leaf node with its corresponding attributes (Worboys 1995). The region quadtree takes advantage of raster data, homogenous spatial regions and has a variable resolution.

5. Hexagonal Heptree Or 7-Shape

From a geovisualisation point of view, Carr et al. (1992) state that hexagons have two advantages over squares, visual appeal and representational accuracy. Also, the horizontal and vertical visual lines created by region tessellations can have a strong effect on humans due to our internal sense of gravitational balance. Therefore the horizontal and vertical lines generated by region tessellations in standard orientation are irritating to view and should not be used. The region quadtree structure does have the advantage of being a regular set of tessellations, meaning that the region can be divided evenly and still maintain the same regular shape. The hexagon is irregular, because hexagons cannot fit together to create a larger one. Seven hexagons arranged in a “rosette” (Laurini and Thompson 1992) approximates to the unit hexagon shape. In turn, seven of these rosettes can be arranged to create recursively larger hexagon approximations. This structure is called the hexagonal heptree in this paper.

6. HoR Quadtree

The hexagonal heptree has limitations for a geovisualisation point of view. When the conventional hexagonal heptree is divided, each recursive child is rotated by an unjustified angle in relation to its parent (Holroyd and Bell 1992). The HoR structure was designed by Bell et al. (1987) to remove the dividing limitation of a standard hexagon. After amalgamating the centroids of 4 hexagons or 4 rhombi, the HoR quadtree forms an identical pattern. Boots (2001) states that the HoR addressing system has advantages over the heptree system. Thus, the HoR quadtree can be divided as needed without rotating, and when homogeneity is reached a new leaf node can be created. The HoR quadtree is a simple and visually appealing structure to use for geovisualisation.

7. Communicating Uncertainty Using The Hor Quadtree

After reviewing the literature, the HoR quadtree promises to be the most effective technique to view uncertainty in spatial information using a tree structure. In summary, a possible example of how the HoR quadtree could be used to view geographic data at an appropriate level of certainty is explained below. By using a technique such as the Monte Carlo simulation, an uncertainty measure can be derived. This information would then be fed into a HoR tessellation generator and based on the accuracy of a particular feature; an appropriate granularity is output in the spatial location of the feature. This provides the viewer with a map of spatial features created from tessellated HoR structures at the correct accuracy level.

8. References

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