EXPERIMENTS WITH A RIDGE AND CHANNEL DIGITAL ELEVATION MODEL

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ABSTRACT

The literature is rich with proposals to combine the advantages of the adaptability of the contour digital elevation model with the neighbourhood functions of the grid. Notable among these is the triangular irregular network model, or the (TIN). This paper will present another approach to digital elevation modelling based on traces of channels, and their dual, the ridges.

The conflicting demands of modelling phenomena with the minimum amount of data possible, with those of having data structured in such a way to make use of it with programs that are reasonably efficient and tractable to write is not a new problem in the application of computers. Nowhere is this conflict more evident than in the recording and storing of data to represent single valued surfaces such as a topographic surface.

Matrices have been used to record the height of grid lattice points since the early sixties, and perhaps even before. By contrast to this obvious way to record a surface in digital fashion, the contour map is practically the universal method for recording surface morphology in detail on paper maps, and contour maps have stood the test of time for commensurabiity, utility, interpretability, and economy (of symbolism required for the information conveyed). A surface may also be stored in digital form by line traces of the contours, where the economy mentioned in the context of paper map symbolism is even more evident. Boehm made this comparison in 1967 concluding that contour recording minimizes storage requirements whereas a regular grid matrix minimizes computing time necessary for several types of desired maniplations.

The reason for the economy of the contour method is related to adaptability. Where a surface is smooth few contours are necessary to record it, and these contours may be described by relatively small numbers of points, especially if the number of points have been filtered by an algorithm of the type described in Douglas and Peucker (1973). Where the surface is rough more contours are necessary, and since these will be more convoluted and wiggly in these regions more points are required to record the lines. This, therein, lies the unique advantage of the contour digital elevation model,... its exquisite adaptability to the morphology of the surface itself.

Digitized contours would therefore seem to be the ideal form of digital elevation model, but there are certain shortcomings related to what can be done with it in that form. On the other hand, a grid digital elevation model lends itself to many processes, operations, and to producing displays of all kinds. (Collins, Davis (1975), Douglas (1972), Mark, Sprunt) The reason for this obviously relates to its symmetry, but more especially to the implicit topological structure of the neighbourhood relations of each point. Nothing has to be searched to find which grid intersection point, or grid cell, or grid link is next to the current one, and data locations in storage are instantly calculable from the coordinate location in space. The obvious shortcoming of the grid is the redundancy of data required to store flat areas, since the grid resolution must be set small enough to capture the variability required in the rough areas. Although certain matrix compression techniques are useful the whole matrix must be regenerated every time a process of a type where a grid is useful is invoked.

There have been attempts to develop other structures for surface data which would combine the advantages of the grid and of the contour recorded surface. A noteable example is the development of methods for linking a relatively random (in the X-Y plane) distribution of points with an explict structure formed by a list of pointers attached to each point to replicate the implicit neighbourhood relation evident in a regular rectangular grid and yet maintain the adaptability of the contour by allowing the distribution of data points to adapt to the surface. Most of these methods revolve around the triangular irregular network model (Peucker, Peucker and Chrisman, Gold, Davis 1975). Much of the creative work has predictably been applied to the development of the intricate pointer structures, especially in generating the structure from the selection of points. One of the main objectives has been to find methods to avoid the possibility of the generation of non-unique triangular meshes. Applying the earlier work of Warntz, Peucker and Chrisman point to the information increasing capacity of the system by recording those points which have more surface information implicit in them. This applies to peaks, pits, passes, and break points.

It does not take long to find the limits of adaptability of any structure that is dependent on partitioning a surface into irregular triangles. The rate of transition in density of the distribution of triangles over a surface is severely constrained. Consider a flat surface such as prairie, (presumably possible to record with very large triangles), dissected with an incised meandering stream, where there is much relief along the banks of the stream valley. The valley would require a much higher density of smaller triangles to accurately record the relief. To join the flatter area with the large triangles to the rough area with the much smaller triangles, and still maintain the triangular structure required for the pointer list is impossible unless the transition is very gradual. It is possible that this may be an example of the mathematical difficulty of ajoining triangles described by White (1983).

As noted peaks, pits and passes represent points on a surface that contain by virtue of their definition much more information about the surface than other points. There are lines on a surface that are similarily information rich, namely the ridge and channel lines. Ridge and channel lines are slope lines that are in regions of relative higher convexity or concavity, respectively. They are local phenomena that may be identified locally. The substance of this paper is based on experiments with the recording of surfaces by these ridge and channel lines, recorded in three space with X-Y-Z coordinates reduced to the minimal number of points with a three dimensional filtering algorithm based on a concept of minimum offset, and expressed in the Douglas line reduction algorithm in the two dimensional case (Douglas and Peucker). The utility of the model is determined largely by the capacity to generate the ridge and channel network from a regular grid digital elevation model, and to recompose the grid from the ridge and channel model. The method to locate ridges and channels is that described in Peucker and Douglas, and clearly demonstrated in an operational setting by Mark. The method produces lines, but not necessarily of the simple path definition described in an image processing environment by Pavlidis. In other words lines are elongated clouds. There are, however, many techniques described the literature for thinning clouds and a number of these were tested.

The method for reconstructing the grid from the model is based on a contour to grid algorithm, modified for the three dimensional recorded lines. There are numerous approaches to convert digitized contours to a regular rectangular grid, (Douglas 1983, Yoeli 1967, Yoeli 1975). The process consists of two major components, a geometric one: that is the calculation of the value of a point from the values and locations of the contours near it, and an algorithmic one: the problem of finding those contours that apply, and the location along each contour to use for the interpolation, and further, to incorporate these in a tractable algorithm, given that for a problem of reasonably standard magnitude, 22,500 grid point values (ie. 150 by 150) might be calculated from a contour file comprised of as many, or more, than 150,000 points. A method based on a multi-rooted linear insertion list algorithm forms the basis of a system that converts a surface recorded by samples of any type of line on the surface to the regular grid digital elevation model.

REFERENCES

Collins, Stanley H., (1975), "Terrain Parameters Directly from a Digital Terrain Model", Canadian Surveyor, Vol. 29 No. 5, pp. 507-518

Davis, John C., (1975), Contouring Algorithms, Proceedings of Auto-Carto 2, A.C.S.M., pp. 352-359

Douglas, David H., (1972), "Viewblok: A Computer Program for Constructing Perspective View Block Diagrams", 'Revue de Geographie de Montreal', Vol. XXVI, No. 1, pp. 102-104.

Douglas, David H., and Peucker, Thomas K., (1973), "Algorithms for the Reduction of the Number of Points Required to Represent a Digitized Line or Its Caricature", 'Canadian Cartographer', Vol. 10, No. 2, pp. 112-122

Douglas, David H., (1983), The XYNIMAP Family of Programs for Geographic Information Processing and Thematic Map Production", in: Barry S. Wellar, Editor, Automated Cartography: International Perspectives on Achievements and Challenges, Vol. 2, Ottawa, Auto-Carto Six, pp. 2-15

Gold, C.M., (1977) "Practical generation and use of geographic triangular element data structures." Proceedings of an Advanced Study Symposium on Topological Data Structures for Geographic Information Systems, Harvard Laboratory for Computer Graphics and Spatial Analysis, Cambridge MA.

Mark, David M., (1983), "Automated Detection of Drainage Networks from Digital Elevation Models", in: Barry S. Wellar, Editor, Automated Cartography: International Perspectives on Achievements and Challenges, Vol. 2, Ottawa, Auto-Carto Six, pp. 288-295

Pavlidis, Theo, (1982), Algorithms for Graphics and Image Processing, Rockville MD, Computer Science Press.

Peucker, Thomas K., and Chrisman, Nicholas, (1975), "Cartographic Data Structures." American Cartographer, Vol. 2, No. 1, pp. 55-69

Peucker, Thomas K. and Douglas, David H., (1975), "Detection of Surface-Specific Points By Local Parallel Processing of Discrete Terrain Elevation Data", 'Computer Graphics and Image Processing', Vol. 4, 1975, pp. 375-387.

Sprunt, Brian F., (1975), "Relief representation in Automated Cartography: An Algorithmic Approach", in Davis, John C., and McCullagh, Michael J., eds., (1975), Display and Analysis of Spatial Data, London, John Wiley and Sons,

Warntz, William and Woldenburg, Michael, (1967), "Spatial Order: Concepts and Applications", Harvard Papers in Theoretical Geography, No. 4, Graduate School of Design, Cambridge