On Quantitative Shape Analysis of Sliver Polygons Created by Line Simplification

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Abstract

Cartographers are simplifying lines by eliminating unneeded details or by exaggerating several characteristics when they are performing any generalisation task on the basis of their experience and knowledge. The results of manual simplification should preserve the shape or the visual character of any individual line although it is modified. Thus, it is difficult to integrate the process of manual line simplification in a digital environment because it is partially mental. In the past decades, many researchers with either cartographic or computer science background tried to develop a large number of simplification algorithms. Among these simplification algorithms, the most effective ones are eliminating the unneeded details - vertices along the line- by satisfying several local or global geometric criteria. In most cases, line simplification algorithms are controlled by a parameter (tolerance), which is usually expressed in length units. The more the tolerance size is increased the more simplified becomes the result. Thus, user should tune the tolerance size in order to achieve a desirable level of simplification. Furthermore, cartographers' research was directed towards evaluating line simplification either on the perceptual level [Jenks 1989, Wood 1995] or by analysing statistically several cartometric measures [McMaster 1986, João 1998].

The application of any line simplification algorithm eliminates those vertices of the line that are redundant for the given geometric criterion in combination with the selected tolerance size and finally preserves all the other vertices of the line. By overlaying the original and the derived line a number of polygons of narrow and elongated shape is created, usually called sliver polygons. The area of the sliver polygons expresses the areal distortion between the original and the derived line produced by line simplification. In studies related to line simplification evaluation [João 1998] a cartometric measure defined by the sum of the area of all sliver polygons divided by the total length of the original line, is used to express a global quantity of areal displacement, named "total areal displacement". The cartometric measure of "total areal displacement", as defined above, is useful for evaluating line simplification because it can be associated with the needed accuracy standards. Since, areal displacement gives only an overall estimation of the displacement magnitudes produced by line simplification, a more detailed view regarding the distribution of displacement magnitudes caused by line simplification would be useful. This may be expressed by the cartometric measure of "vector displacement", but it is very difficult to identify the same point on the original and the derived line especially for continuous lines without intersections, like coastlines. Thus, it is an interesting idea to estimate a more representative expression for areal displacement related to each individual sliver polygon and based on its shape, as a cartometric measure for line simplification. By analysing the shape of sliver polygons created by line

simplification and classifying them into different categories according to their shape, the magnitude of "sliver polygon displacement" can be estimated more reliably. More specifically, sliver polygons can be identified as having three kinds of shapes: a rounded polygon, elongated strip, and a crooked strip [Franklin and Wu 1987]. The shapes of the sliver polygons are mainly related to the tolerance size rather than to the geometric criterion of the selected algorithm. If the tolerance size values are kept small the derived line is close to the original one and the significant majority of the created sliver polygons have the shape of an elongated strip.

The perimeter of a polygon (L) is related to its area (A) by the expression [Maling 1989]:

$L = k\sqrt{A}$, where k may describe the shape of the polygon.

For example k=4 for a square, k=4.5590 for an equilateral triangle and k=3.5449 for a circle. For the cases of shapes having the form of an elongated strip, like a sliver polygon, the coefficient k has a significantly high value. Thus, the coefficient k can be used for the shape analysis of sliver polygons created by line simplification. Based on the estimated shape number (k), sliver polygons are modelled –normalised- as having rectangular shape with sides ratio 1:n. The normalized sliver polygons are used to estimate the magnitude of displacement of line simplification.

In this paper the cartometric measure of "sliver polygon displacement" is estimated for the simplification of a coastline, characterised as having a high degree of complexity, by applying Douglas and Peucker algorithm over a range of tolerances. The Douglas and Peucker algorithm was selected since it is widely used by cartographers and produces small displacement during line simplification. The estimated "sliver polygon displacement" has been associated to the shape of sliver polygons created by the simplification tasks according to the performed shape analysis described above. Data consist of a coastline located in the central part of Greece, digitised from 1:50,000 scale paper maps and having a length of approximately 800km. The raw data were cleaned from all the unwanted redundant vertices, by applying the same algorithm with a very small tolerance size (0.01mm on map). The cleaned lines formed the original data set, which was subjected to successive simplifications by applying Douglas and Peucker algorithm over a range of different tolerances. All derived lines were overlaid with the original one by applying a typical GIS function. The proposed "sliver polygon displacement" measure was compared with "total areal displacement" suggested in literature. The results of the comparison are regarded as promising in the direction towards overcoming the underestimation degree of "true" displacement present in "total areal displacement" measure.

Finally, the shape analysis carried out in this study may be useful for segmenting cartographic lines when performing simplification tasks, by examining the locations along the line where sliver polygons produce high magnitudes of displacement and their shape is rounded.

References

FRANKLIN, WM.R., and P.Y.F. WU, 1987. "A polygon overlay system in Prolog". Proceedings of *AutoCarto 8*, Baltimore, Maryland, 97-106.

DOUGLAS, D.H., and T.K. PEUCKER, 1973. "Algorithms for the reduction of the number of points required to represent a digitized line or its caricature". *The Canadian Cartographer*, 10(2), 112-122.

JENKS, G.F., 1989. "Geographic logic in line generalization". *Cartographica*, 26(1), 27-42.

JOÃO, E.M., 1989. *Causes and Consequencies of Map Generalisation*. Taylor & Francis, London.

MALING, D.H., 1989. *Measurements from Maps. Principles and Methods of Cartometry*. Pergamon Press, Oxford.

McMASTER, R.B., 1986. "A Statistical Analysis of Mathematical Measures for Linear Simplification". *The American Cartographer*, 13(2), 103-116.

WOOD, C.H., 1995. "Perceptual responses to line simplification in a task-oriented map analysis experiment". *Cartographica*, 32(1), 22-32.

Biography

The author graduated from the Department of Rural & Surveying Eng., National Technical University of Athens in 1979. Since 1990 he holds the degree of Doctor Eng. from the Department of Rural & Surveying Eng., National Technical University of Athens. Currently, he serves as Associate Professor in the same University. His research interests are: map generalisation, maps and atlases for children, 3-D cartographic modelling and visualisation. He is member of ICA Commission of Map Generalisation.