An Empirical Mode Decomposition Method for Automated Line Generalization

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1. Introduction

With the developing requirement of geography information system (GIS) and booming data, different levels of data will be needed in geographical observation and analysis. As one of three basic types in GIS graph system, line generalization for different levels became a hotspot and has lots to do.

For line generalization, Douglas and Peucker (1973) propose the most popular Douglas-Peucker (DP) algorithm, Visalingam and Whyatt (1990) re-evaluated DP algorithm through visualization, Li and Openshaw (1992) simplify the line depend on scale. Peng and Muller (1995) simplify the urban road network by dynamic decision tree structure. The method of Wang and Muller is (1998) based on analysis of shape characteristics. These methods are mainly based on geometrical feature constraint. Other methods such as adaptive lattice model (Doihara and Wang, 2002), genetic algorithms (F Wu and H Deng, 2003), ontology-driven (L Kulik et al, 2005) are not available for the real application so far. Line generalization is a contradiction between information and map accuracy and structure. Among the above algorithms, the DP algorithm is considered a good compromise between compression and shape preservation. In the comparison experiment (2007) conducted by K P Zhu et al, they found the DP algorithm is fit for topological constraint while not for geometrical constraint.

In past two decades, some frequency domain techniques have also introduced to cartography like Fourier transform (Fritsch and Lagrange 1995, Lawford 2006) and wavelet (Balboam and Lopez, 2000 and Saux, 2003) which consider more about line feature. The frequency domain algorithms are becoming more and more popular. EMD (Empirical mode decomposition) method is a new promising frequency domain method in signal processing method which was proposed by N E Huang (1998). After that, EMD method has been used in many fields such as meteorology, tide, earthquake, medicine and signal processing. EMD method is widely used because it is data driven and adaptive. In signal processing sight, line can be regard as one or two dimensional signal. So this method is also available and meaningful to line generalization. Eric Guilbert (2009) firstly tried to use this method in line generalization and discussed the principle. The research in this area is at the initial level and our work is also based on this.

2. Methodology

Empirical mode decomposition (EMD) is a method for analysing nonlinear and non-stationary data (Huang et al, 1998).The method does not need to know priori knowledge, according to the input signal characteristics, adaptively decomposed into a number of intrinsic mode function (IMF). It decomposes a signal into low frequency components high frequency components.

The method is therefore data driven. For bivariate signal, Rilling (2007) develops a bivariate empirical decomposition method and Tanaka (2007) develops a complex empirical decomposition method. In our paper, line will be bivariate empirical mode decomposed, through that we get different levels of line component. The algorithm first finds the extreme points in the curve. Generate an average signal with upper and lower envelop which interpolated with b-spine interpolation from extreme points. Then we do the iteration and sifting procedure until the result satisfies the stop criteria. Finally we get the IMFs. For speed and effect optimization, we limit the number of intrinsic mode function to two and gain different level components by iteration procedure instead of sifting procedure.

After that, we extract the feature point based on visual curvature (Liu H et al, 2008) on each level component. Different with classical feature extraction method, visual curvature can represent line visual feature in different levels.

3. Discussion and Conclusion

Through above operations we have obtained line generalization result in different level. For better understanding, we conduct a quantitative assessment experiment between EMD line generalization method and DP algorithm in four kinds indexes namely shape similarity, geometric accuracy, run time and compression ratio. Hausorff distance is an assessment index for the shape similarity between two graphs through two points set match. Geometric accuracy contains both the ratio of line length and line sinuosity.

Result demonstrates that EMD line generalization method can gradually smooth the line correspond different level and keep generally same shape by removing the details. The method also depends on the feature point extraction. Comparison shows that there are no big difference between two methods in Hausdorff distance and the ratio of line length. EMD line generalization method is better than DP algorithm in geometrical feature. DP algorithm is better than EMD in speed and compression ratio.

We also see the simple form of line component obtained by EMD. It would be a great progress in line generalization and compression field and more meaningful if the components can be described as a simple mathematic function.

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