Automated schematization using memetic algorithms

Jerry Swan[1], Suchith Anand[1], Mark Ware[2], Mike Jackson[1]

[1]Centre for Geospatial Science, University of Nottingham, UK
[2]Faculty of Advanced Technology, University of Glamorgan, Wales, UK
Tel: +44(0)115 846 8411
Email: Jerry.Swan@nottingham.ac.uk ; URL: http://www.nottingham.ac.uk/cgs/

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1. Introduction

Mapping is a way of visualizing parts of the world and maps are largely diagrammatic and two dimensional. There is usually a one-to-one correspondence between places in the world and places on the map, but while there are limitless aspects to the world, the cartographer can only select a few to map (Dorling, 1996). Map generalization is required when there is a need to represent geographic information that is captured at large scale in a derived form at a smaller scale (Buttenfield and McMaster, 1989). The potential applications, and hence importance, of automated map generalization has increased tremendously with the advent of digital geographic datasets. Much work has been carried out in recent years, and considerable progress has been made. This is evidenced by the many academic papers published on the subject (e.g. Weibel, 1995; Weibel and Jones, 1998; Jones and Ware, 2005), the various working groups that have been set up (e.g. ICA Commission on Generalisation and Multiple Representation) and the increasingly advanced and useful generalization functionality now being found in commercial GIS software. However, many tasks associated with map generalization have proven difficult to automate and many research challenges remain.

Generalization by vertex displacement has been investigated using a number of metaheuristic techniques, including simulated annealing (Ware et al, 2003a), genetic algorithms (Ware et al, 2003b) and tabu search (Ware et al, 2002). Schematization by vertex displacement using simulated annealing is the subject of previous research (Anand,2007), In this paper, we examine the application of memetic algorithms to automated schematization in particular for water network modelling application.

2. Automated schematization

Manual generation of schematic maps requires considerable effort by a skilled cartographer, who must undertake an iterative labour intensive approach in generating the schematic output by hand. In computer assisted method, graphics software is used to undertake the schematic drawing by computer using raster maps scanned as input. Tools within the graphics package are used for drawing and editing etc. This again is an iterative process, though better quality results can be obtained much more quickly. In the automatic production of schematic maps vector based source datasets are simply input to suitable algorithm/software application, together within any control parameters that might be required. The basic steps for generating schematic maps are to eliminate all features that are not functionally relevant and to eliminate any networks (or portions of networks) not functionally relevant to the single system chosen for mapping. All geometric invariants of the network's structure are relaxed except topological accuracy. Routes and junctions are symbolized abstractly (Waldorf, 1979).

Elroi (1988) refined the process by adding three graphic manipulations, although implementation details and results were not given. First, lines are simplified to their most elementary shapes. Next, lines are re-oriented to conform to a regular grid, such that they all run horizontally, vertically or at a forty-five degree diagonal. Third, congested areas are increased in scale at the expense of scale in areas of lesser node density. Though Elroi in this paper has listed the theory on schematization, the actual real-life implementation was not given. The first step in the process is line simplification, which can be achieved using an algorithm such as that of Douglas and Peucker (1973). Care must be taken when performing this step to avoid the introduction of topological errors; this can be achieved most easily by making use of topology preserving variants of the Douglas-Peucker algorithm, such as that presented by Saalfeld (1999). Steps two and three are the key components of the process, and their automation has been the focus of previous work by several researchers.

3. The algorithm and software implementation

For a period in the late 1980s, Genetic Algorithms was perhaps the optimization technique of first choice. In (De Jong, 1993), it was shown that GAs were "satisficers" rather than "optimizers", i.e. they are useful for finding "near optimal" solutions, but cannot be relied upon to discover global optima. This finding was anticipated in practice by Grefenstette who augmented a GA by applying local search to each population member prior to evaluation (an analogous method can in fact be credited to (Kaufman, 1967). The results obtained in (Swan et al.,2008) for schematization by vertex displacement provide strong motivation for the application of Memetic Algorithms to the problem.

The generic memetic algorithm as presented below is essentially the same as that of (Grefenstette, 1987).For the schematization-specific genetic algorithm components, we adapt the Displacement Vector Template approach of (Ware et al.,2003) since we are only concerned with mapping vertices to a grid, we are able to represent the neighbourhood of a vertex by an integer value that maps to the grid coordinates. The local search component drives each population member to a local optimum by employing steepest-ascent hill climbing over the nine possible 1-ply grid positions of all the vertices (giving e.g. 900 operations for each iteration for a 100 vertex map).

```
Schematic MemeticAlgorithm():
Begin
Initialise population
Do
    Evaluate each member of the population
    Create new members by crossover and mutation
    Apply local search to new members
    Evaluate the new members
    Replace existing population members with new members
Repeat until termination condition is reached (e.g. time or #iterations )
Return the best population member ever generated as the solution

End
```

Based on the characteristics of a schematic map identified, the schematic map algorithm presented here considers seven constraints. Additional constraints can be added if required.

– Topological: The original network and derived schematic map should be topologically consistent;

– Orientation: If possible, network edges should lie in a horizontal, vertical or diagonal direction;

– Length: If possible, all network edges should have length greater than or equal to some minimum length (to ensure clarity);

– Clearance: If possible, the distance between disjoint features should be greater than or equal to some minimum distance (to ensure clarity);

– Angle: If possible, the angle between a pair of connected edges should be greater than or equal to some minimum angle (to ensure clarity).

– Rotation: An edge's orientation should remain as close to its starting orientation as possible

– Displacement: Vertices should remain as close to their starting positions as possible (Anand, 2006)

The software prototype has been implemented based on the memetic algorithm described. The algorithm is implemented in Java as a Web Feature Service. A Java-client application (Figures 1 and 2) has also been created to act as a workbench for demonstration and research purposes. Water pipeline networks are good examples of a practical application of schematic maps, where for example they can also a useful visualization tool for water engineers to help understand and analyze the hydraulic conditions of a network. Once connectivity details can be generated by the network modellers using this schematization technique it will give help water modellers to visualize mental maps of true connectivity from the derived schematic and this can knowledge can be used when carrying out analysis and design with network modelling. The datasets used for the study are water network datasets from DfID KaR Project R6872.

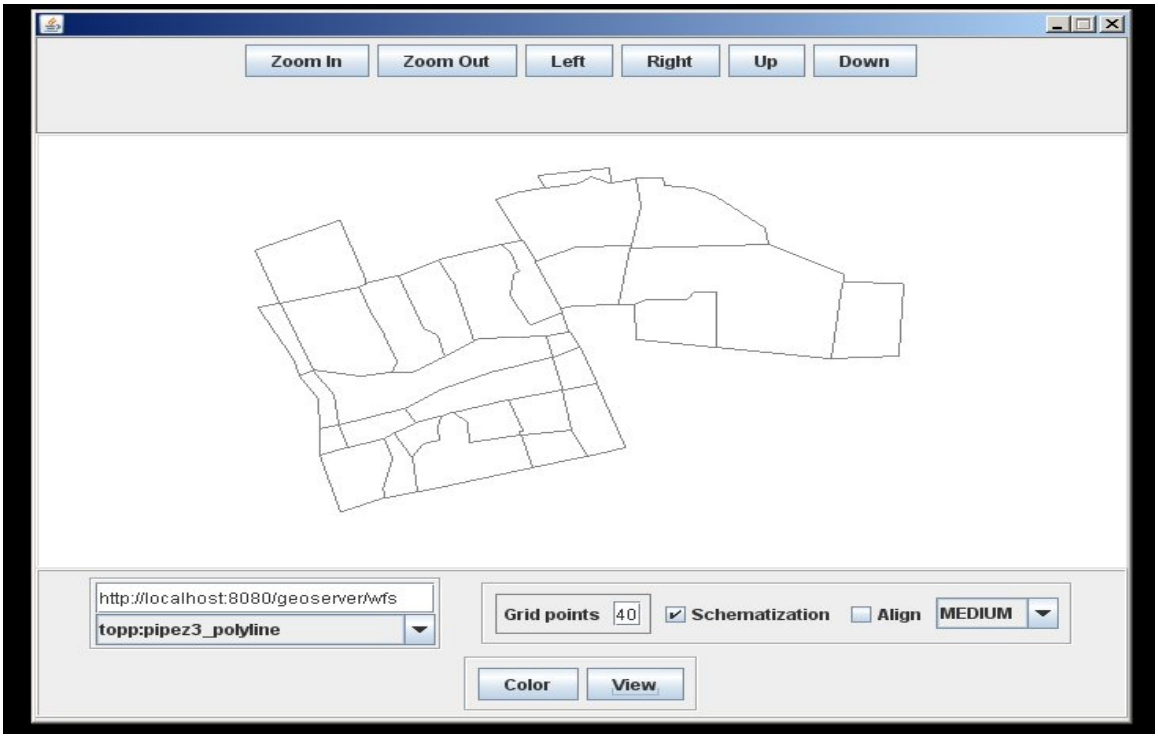

Figure 1: *Client application showing original water network feature set (Dataset Source: DfID KaR Project R6872)*

The client application allows a user to specify the URL of remotely-hosted data from an external WFS source. In the present implementation, input feature geometry is required to be of polyline format – an error message is displayed if the input data does not conform. The user can additionally select the number of grid points and the schematization quality. These parameters are then passed to the schematizing feature service, which obtains the feature collection from the remote data source and transforms them using the above algorithm. When optimization is complete, the schematized features are transferred to the client for visualization.

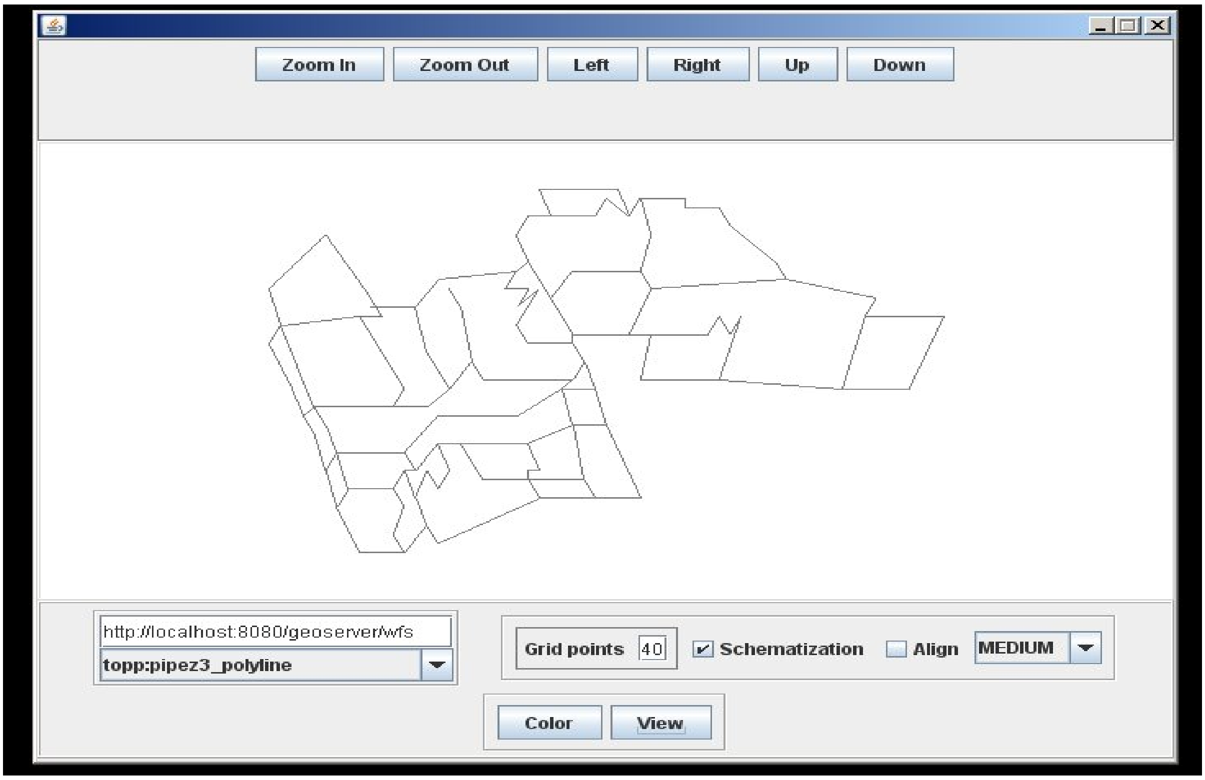

Figure 2: *Client application showing the results of schematized water network highlighting the true connectivity. (Dataset Source: DfID KaR Project R6872)*

4. Conclusions

This paper looks into the application memetic algorithms in generating schematic maps. The results are promising but more work need to be done in refining the process in consultation with water network modellers who are the key beneficiaries of this work. Future work will concentrate on refining the technique through the use of additional constraints to enhance visualization, usability and application in other domains.

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Biography

Jerry Swan is Research Fellow and interoperability test bed architect at the Centre for Geospatial Science, University of Nottingham
Suchith Anand is Research Fellow in mobile location based services at the Centre for Geospatial Science, University of Nottingham
J Mark Ware is Reader in the Faculty of Advanced Technology, University of Glamorgan
Mike Jackson is the Director of the Centre for Geospatial Science, University of Nottingham.