A toolbox of algorithms for polygonal subdivision generalization

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Although the drawbacks of such an approach are well known and documented in the literature (Saalfeld 1999), algorithms based on the principles of line simplification are still commonly used for the generalization of categorical data in the vector model (polygon generalization)[1]. Instances of research dedicated exclusively to polygon generalization are rare until now, algorithms for only a small number of needed operations are available. Thus, this paper first states the requirements on algorithms especially designed for polygon generalization. Then the toolbox of algorithms is presented that is used at the University of Zurich in research and experiments related to the generalization of polygon maps. Finally, some ideas and concepts for the orchestration of these algorithms, i.e. the automation of the polygon generalization process, are discussed.

While operators designate abstract transformations in the generalization process algorithms put the geometric and semantic transformation of the data set into execution. The basic operations of categorical data generalization and a review of existing algorithms for polygon generalization are found in (Galanda and Weibel in press). The specific topologic and semantic structure of polygonal data and the long-term objective concerning the automation of the generalization process determine some requirements on the algorithms design and implementation, namely algorithms:

- need not any interactive input;
- balance computational costs and possible benefit;
- ensure consistency of the data set according to the formal definition of a categorical coverage[2];
- propagate every change of an object's geometry or semantics to those objects connected to the transformed object;
- preserve object characteristics (e.g. shape);
- hold well defined interfaces to measures and constraints;
- support a global generalization approach, i.e. several conflicts of the same kind are solved at once;

[1] A categorical data set represented by vectors is termed a *polygon map, polygonal subdivision* or *polygon mosaic*.

[2] A categorical data set visualizess the variation of a single variable by a finite number of discrete, nominal categories, that is, the mapped area is covered by mutually exclusive and collectively space exhaustive regions (Goodchild et al. 1992).

- produce predictable results;
- be robust;

Some of the above specifications are in conflict with one another. In practice, algorithms compromise between these different requirements. The main part of the paper concentrates on the presentation and discussion of a comprehensive set of algorithms exclusively designed for the generalization of polygonal subdivisions.

The generalization of a categorical coverage often starts with a semantic transformation of the polygon map, that is a reduction of the number of categories shown (*reclassification*). The algorithm changes the polygon's category and possibly performs a geometric combination with neighboring objects of the same class. The same algorithm may realize a simple *elimination* operation (the freed space is then assigned to only one new category). Semantics are of overriding importance to produce meaningful aggregations of categories and objects.

The basics of vector geometry can be used to implement algorithms for *displacement* and *exaggeration* operations. That is, a displacement vector is applied to every vertex or some vertices of a polygon's outline. The amount and the direction of the shifting may result either from the shortest distance between map objects or the availability of free map space. The *enlargement* operation is implemented by a scaling algorithm emanating from the polygon's center of gravity. An enhanced convex hull algorithm (vertices of the objects' outlines are included within a defined threshold) enables the geometric aggregation of categorical objects. A polygon object's skeleton derived from a Conforming Delaunay Triangulation is used as a basis for the implementation of an *elimination* algorithm and the *collapse* operation (Bader 1997). All these algorithms are easy to implement and demand relatively low computational resources, but require additional methods to validate the provided solution according to consistency and to propagate an object's changes to the polygon mosaic.

Conversely, algorithms based on optimization techniques (OT) support a global generalization approach and are well suited to handle complex situations, but they involve high computational cost. (Galanda 2001) described the application of snakes[3], one OT, for the *displacement*, *exaggeration* and *enlargement* of polygon objects and pointed up how polygon generalization may benefit from the use of OT.

As *typification* can be understood as a combination of algorithms for aggregation, elimination, displacement and enlargement, no specific algorithms are proposed for that generalization operation. For a discussion of the *simplification* and *smoothing* operation references to the literature on line generalization are given.

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[3] An introduction on the snakes method in cartographic generalization is given in (Burghardt 2000) and (Bader 2001).

Every single algorithm was successfully tested on land use data of the landscape model VECTOR25 and VECTOR200 of the Suisse Federal Office of Topography and geological data of the Swiss National Park at a scale of 1:25,000. But the availability of this toolbox of (independent) algorithms is only a first step in order to enable automated polygon generalization. The algorithms' integrated orchestration in an automated generalization process especially designed for polygonal subdivisions requires a good deal more. Only few approaches (e.g. Müller and Wang 1992) are known from literature until now. Thus, a framework for automated polygon generalization is currently under development at the University of Zurich. Extending previous work on road networks and urban settlements done by the AGENT-consortium (Barault et al. 2001) a constraint-based approach to generalization modeled within a multi agent system is proposed. The design and preliminary results of that branch of our work is discussed in a paper at SDH 2002 (Galanda and Weibel 2002).

Keywords

Polygonal subdivision generalization, algorithms, automated generalization, framework;

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