SELECTION OF ROADS FOR CARTOGRAPHIC GENERALIZATION

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ABSTRACT:

Generalization is the task of producing multiple maps, of a different scale or purpose, from a single detailed data source. The field of generalization can be split into model generalization and cartographic generalization. Model generalization concentrates on the derivation of reduced databases from a source database, without changing the shapes of the remaining features. Cartographic generalization represents the process of deriving a graphic product or visualization from a source database. Cartographic generalization more complex than the model generalization, because providing clarity and logical consistency of graphic expression without using model generalization processes is usually difficult in cartographic generalization processes. In this study, our aims to show cartographic relationship between retained roads and scale change during the generalization, and to use the relationship as a measure how many roads should be retained and discarded. We have benefited from the road symbols covered with stippled areas in map space to decide *maximum reduction limit (MRL)* in generalized maps. The results can be evaluated in selection of roads in generalization process.

1. INTRODUCTION

Generalization is the process of deriving from a detailed source spatial database a map or database the contents and complexity of which are reduced, while retaining the major semantic and structural characteristics of the source data appropriate to a required purpose. It represents a process of informed extraction and emphasis of the essential while suppressing the unimportant, maintaining logical and unambiguous relations between map objects, maintaining legibility of the map image, and preserving accuracy as far as possible (Weibel and Jones, 1998). Transition from the manual techniques to automated generalization is difficult and complex. In a manual environment, generalization could often be achieved with a single stroke of the pen, through activities such as selection, collapse, smoothing, and displacement, despite each procedure needs to be addressed individually in automated generalization (Richardson and Mackaness, 1999).

In digital cartography and GIS automated generalization is separated two main branches, model generalization and cartographic generalization. (Weibel and Jones, 1998; Richardson and Mackaness, 1999; Weibel and Dutton, 1999; Jiang and Claramunt, 2004; Neuffer, et al, 2004; 1Spatial, 2007). Model generalization is not considered, though, as part of the cartographic generalization conceptually, these two generalization approaches are closely related (Jiang and Claramunt, 2004), and often model generalization is prerequisite to cartographic generalization.

Model generalization concentrates on the derivation of reduced databases from a source database (Weibel and Jones, 1998). The objective in model generalization is to reduce the resolution of the data by decreasing the number of features, without changing the shapes of the remaining features. As the geometry is not modified in the process, model generalization is often used in situations where aesthetics are less important than accuracy, such as with aeronautical charts or when the size of data storage is an issue (1Spatial, 2007). Model generalization is mainly oriented to structure-based filtering (Weibel, 1995; Jiang and Claramunt, 2004) in order to discard/eliminate some geographical features which are no longer relevant in the generalized map. In the literature, the selection which may also be seen referred to the elimination is the most important operator in model generalization process. However, precise mathematical relationships between features retained and scale change have not yet been clearly established (McMaster and Shea, 1992). Töpfer and Pillewizer (1966) attempt to provide a measure of how many features should be retained in selection process. Their motivation still helps the cartographers to decide how many features they should show at different scales (Joao, 1998).

Cartographic generalization represents the process of deriving a graphic product or visualization from a source database (Weibel and Jones, 1998). It is constraint-based process used by cartographers (Jiang and Claramunt, 2004), and involves displaying the geographical features required for a map's purpose or scale, while removing irrelevant detail that would clutter and confuse (1Spatial, 2007). The primary aim of cartographic generalization is for the resulting map to convey a clearly readable image which is aesthetically pleasing. Clarity and logical consistency of graphic expression is given priority over positional accuracy and completeness (Weibel and Jones, 1998).

Cartographic generalization has to deal with the specific problems of graphical symbology. When the scale of a map is

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decreased, there is less physical space in which to represent the geographical features of a region. At the same time, the features need to be exaggerated in size of the symbols to be distinguishable at a smaller scale. As the features fight for representation in the reduced map space, some features need to be discarded, and those remaining may be further simplified, smoothed, displaced, aggregated or enhanced (Joao, 1998). Providing clarity and logical consistency of graphic expression without using model generalization processes is usually difficult in cartographic generalization processes. This makes cartographic generalization more complex than the model generalization.

Improvements in computing power over the last ten years have allowed greater automation of cartographic generalization. By the first automated generalization project (AGENT, 1997 – 2000), generalization studies were departed from GIS and digital mapping software application. Scientists have benefited from Object-Oriented (OO) paradigm (Ruas, 1998; Ormsby and Mackaness, 1999) and agent-based systems (Lamy, et al., 1999; Barrault, et al., 2001; Duchene, et al., 2001; Duchene, 2004) to solve generalization issue. OO provides fundamental design capability and high performance in spatial applications with large volumes of complex data. They are all about managing complexity and a fundamentally new way of considering complex distributed systems, containing societies of autonomous cooperating components (Lamy, et al, 1999).

In this study, it is attempted to provide a measure that decide how many roads should be retained in a city centre. The selection process can be considered as part of the cartographic generalization, therefore cartographic transformations such as displacement of roads without discarding any segments may not be enough to provide clarity and logical consistency at smaller scales, particularly in built-up areas.

2. SELECTION OF ROADS

Roads are essential features on topographical maps and spatial databases. In the past decades, a lot of methods have been proposed to generalize road networks using selection process. Many of them are focused on Graph Theory (Mackaness and Beard, 1993; Thomson and Richardson, 1995; Mackaness, 1995; Mackaness and Mackechine, 1999; Jiang, 2004; Jiang and Claramunt, 2004; Jiang and Harrie, 2004; Kreveld and Peschier, 1998). It gives a lot of concepts and parameters, for instance, connectivity, minimum cost spanning tree, shortest path spanning tree, to facilitate structural analysis and road selection in road networks (Zhang, 2004).

Thomson and Richardson (1999) attempted to solve the selection issue using a good continuation principle which analyses the road network into a set of elements called strokes. A further analysis allows the strokes to be ordered, to reflect their relative importance in the network.

On the other hand, these studies are considered as a model generalization, oriented to structure-based filtering algorithms. They do not have any cartographic relationship between retained roads and scale change during the generalization. Our aim is to set up a relationship between them, and to use them as a measure how many roads should be retained and eliminated.

2.1 Test Area

We used a city map at scale 1:25K (Figure 1) as source data. Our primary test area is shown in a rectangle in the centre of the city. There are two main road data in the area. In Figure 1, red colour roads connect the city centre to other neighbour cities, and blue colour roads connect the streets to each other. The red ones are evaluated as high degree roads, thus they are longer than the other roads, and have a lot of junctions in the network. They should be protected during the generalization. The blue ones are streets and have high density in the city centre. Many of them should be eliminated during the generalization.



Figure 1. Test area in a rectangle and nearby areas.

2.2 Material

Generalization software, Radius Clarity produced by 1Spatial, is used to select roads in generalization process. It enables to derive digital data at different scales from large scale source datasets. Radius Clarity has OO GOTHIC database and sophisticated algorithms, constraints and processes to achieve generalized results that are of high cartographic quality. Its developer interface is Java. (1Spatial, 2007).

The map figures are also presented in Radius Clarity's map interface.

2.3 Method

We used the graphical symbols of roads at different scales (i.e. 1:25K, 1:50K and 1:100K), and its area value on the map in order to decide how many road segments should be retained in generalization. Figure 2 shows the road symbols on which stippled area cover at scale 1:25K.

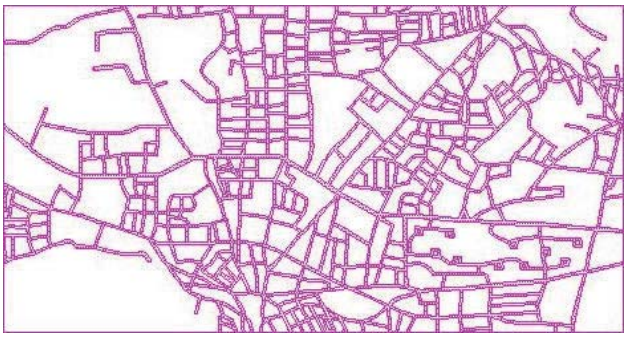

Figure 2. Stippled area at scale 1:25K.

The graphical symbols cover larger areas on the map space, while the scale of the map decreases. Similarly, as the scale is getting smaller, the map space decreases to represent the map

features because of the exaggeration of the symbols. This is an important issue particularly around the city centre.

Figure 3 and 4 show the exaggerated road symbols covered with stippled areas at scale 1:50K and 1:100K respectively without discarding any road segments.

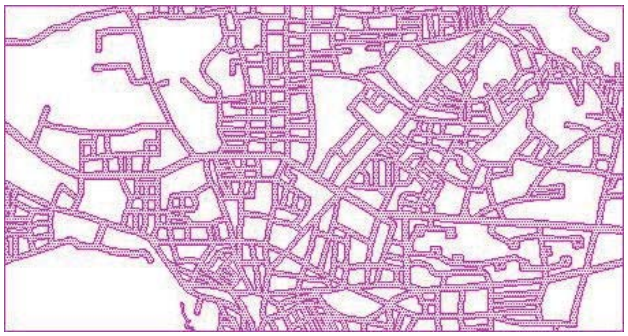

Figure 3. Stippled area based on exaggerated road symbols at scale 1:50K.

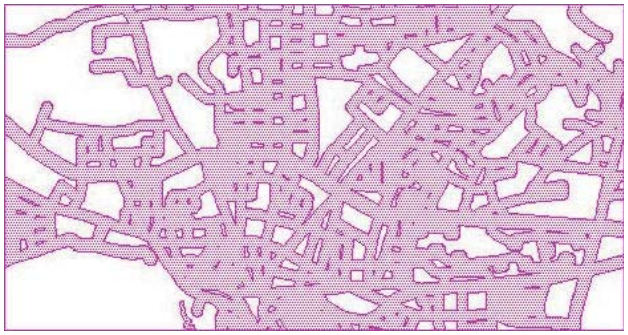

Figure 4. Stippled area based on exaggerated road symbols at scale 1:100K.

In Figure 3, some parts of the roads are greatly overlapping, and there is not enough space (white areas) to represent the other topographical features such as buildings which have to be shown in topographical maps at scale 1:50K. Moreover, Figure 4, in which road symbols are shown at scale 100K, is a good example to understand why the selection (referred to the elimination) is necessity in cartographic generalization. Road symbols cover too large areas unless some segments are discarded. It restricts the clarity and logical consistency of graphic expression on the map. However, it is impossible to get rid of overlapping segments using any cartographic transformation operators such as displacement in order to provide a clearly readable map at scale 50K and 100K in built-up areas.

Table 1 shows the area values covered with roads at scale 25K, 50K and 100K, and their percentages in map space (i.e. rectangle area in Figure 1). We suppose that the percentages are black/white (BW) ratios between road symbols and map space. It gives a significant clue how many road segments to be able to eliminate during the generalization process.

Scale	Area (ha)	BW ratio
1: 25K (source)	87.259	19.524
1: 50K (target)	163.038	36.479
1: 100K (target)	274.576	61.434

Table 1. Covered areas and their percentage in map space before generalization process.

We believe that the area covered with road symbols should be reduced to provide clarity and logical consistency at target scales. It means that we can discard some road segments until obtaining the BW ratio as in source scale (Formula 1). This is maximum reduction limit (*MRL*) in generalization (i.e. 16.973 at scale 50K and 41.910 at scale 100K).

$$MRL = BW_{target} - BW_{source} \quad (1)$$

Where MRL = maximum reduction limit

BW_{source} = Black-white ratio at source scale

BW_{target} = Black-white ratio at target scale

Figure 5 and 6 show the generalized road features covered with stippled areas at scale 1:50K and 1:100K. Some of the street segments (blue roads) are discarded using a road selection module, which is developed in SIBERCARTO – GIS and Digital Mapping Laboratory in Yildiz Technical University. The module aims to preserve road patterns such as grids and strokes in built-up areas. It is based on agent technology which has selection algorithms and constraints, and a gap parameter to prevent overlapped road symbols.

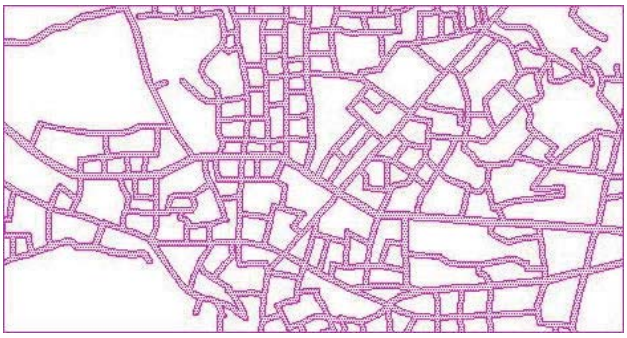

Figure 5. Stippled area at scale 1:50K, after roads are generalized based on selection.

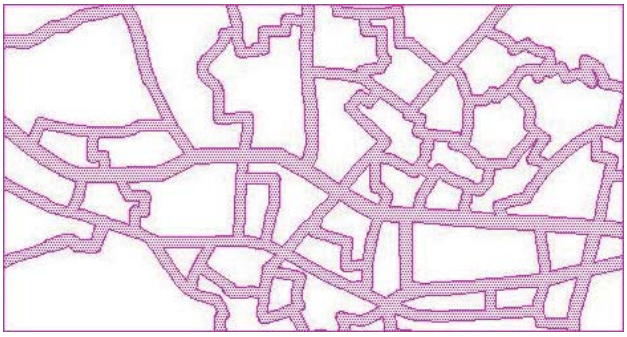

Figure 6. Stippled area at scale 1:100K, after roads are generalized based on selection.

Table 2 shows the area values covered with roads at source scale (i.e. 1:25K), and target scales (i.e. 1:50K and 1:100K), and their percentages in map space. These values show us reduction limits are %7.471 and %12.093 at scale 1:50K and 1:100K respectively. They are smaller than MRL described above.

Scale	Area (ha)	BW ratio
1: 25K (source)	87.259	19.524
1: 50K (target)	120.651	26.995
1: 100K (target)	141.311	31.617
1: 100K[1] (target)	139.952	31.313

Table 2. Covered areas and their percentage in map space after generalization process.

Figure 7 shows generalized results using 1Spatial's agent generalization technology in Radius Clarity at scale 1:100K. After the agent generalization, some road bends are edited and removed in order to make a readable map. It affects reduction limit reducing to %11.789.

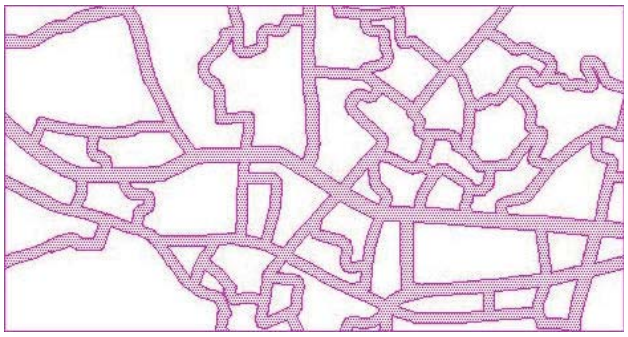

Figure 7. Stippled area at scale 1:100K, after roads are generalized based on agent technology.

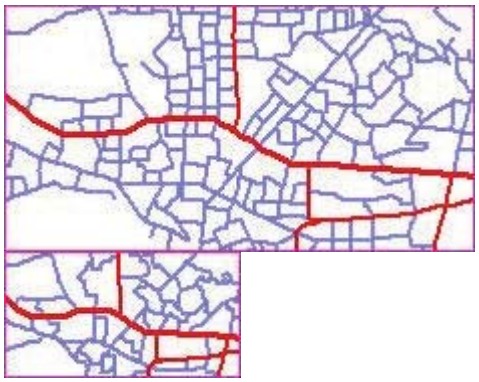

Figure 8. Generalized roads at scale 1:50K and 1:100K.

3. RESULTS

Selection is a necessity in cartographic generalization process, particularly in higher scale change such as from 1:25K to 1:100K. In this study, the limits in selection are evaluated according to symbol exaggerations in target scales, because exaggerated symbols cover larger area than symbols in source scale in generalization process. Generalized maps presented in Figures 8 provide clarity and logical consistency in the centre of the city at generalized scales. BW ratio of eliminated roads is smaller than MRL value described in section 2.

[1] Roads are generalized with 1Spatial's Radius Clarity based on agent technology.

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