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Methodology of the Cartographic Generalization Process of the Road Network

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Abstract:

Automation of the cartographic generalization process is the main subject of research in modern cartography but there is still no comprehensive method allowing for the transition from a map of a larger scale to a map of a smaller scale. This process is carried out by cartographers with use of various types of generalization operators, such as selection or aggregation, which leads to the simplification of the map image. The goal of automating generalization is to make this process independent of operator interaction and to improve the process of obtaining maps on smaller scales. This research develops and tests the methodology of automated generalization from the scale of 1:50,000 to the scale 1:100,000 of road network stored in Vector Map Level 2 (VML2) database. It is a spatial database that is corresponding in terms of detail to a topographic map in a scale of 1:50 000. The VML2 data structure is compatible with DIGEST (Digital Geographic Exchange Standard), which is used in NATO. The tests were conducted on the basis of road features located in central Poland near Lodz city – 51°47' N, 19°27' E.

Numerous authors have already been researching the road generalization in different aspects. In publication Pueyo et al. (2019) authors juxtaposed various generalization techniques for street networks. Lyu et al. (2022) showed the road network generalization method that is constrained by residential areas what provides some interesting results. Moreover, Wenhao et al. (2019) performed road network generalization on the basis of traffic flow patterns which differs from commonly used geometric approach and turned out to be very accurate.

The developed method is an algorithm written in Python programming language with use of ArcPy library, which is a special library compatible with ArcGIS software. Due to the small scale of the research, the algorithm focuses only on the selection of road features. Other geometric operations, e.g. smoothing, are not taken into account. The developed algorithm removes single road segments iteratively. The detection of the least matching segment is conducted on the basis of compactness factor value. A compactness value had already been used by Ruas (1999) to perform block aggregation. The whole process is presented in Figure 1 as a block diagram.

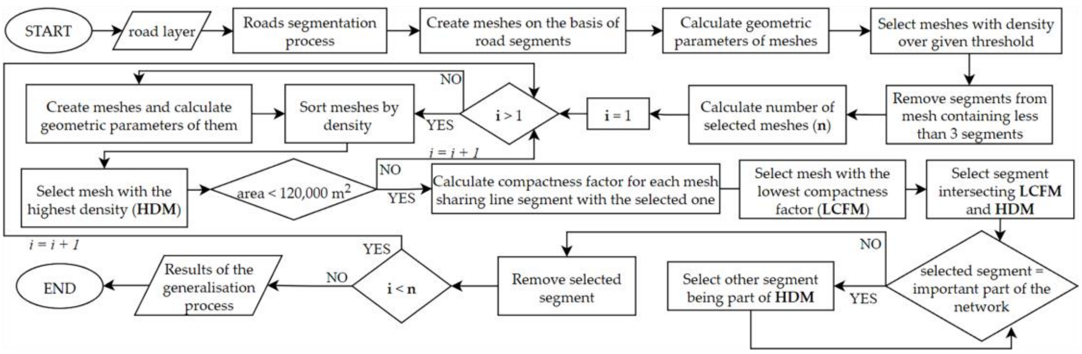

Figure 1. The algorithm of the developed method.

The crucial part of the algorithm is determining the road segment to be deleted. For this purpose, the compactness factor (CF) is calculated for each mesh that share a line segment with the highest density mesh (HDM). This is a parameter that determines segment that is most likely to be deleted from the mesh. It prevents from remaining irregularly shaped meshes on the map of 1:100,000. The CF can be computed by measuring a convexity of analysed meshes (equation 1).

$$\mathrm{CF} = (\mathrm{area(CH)} - \mathrm{area(HDM + SM)})/\mathrm{area(CH)} \tag{1}$$

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where CH is the convex hull of the HDM and SM (selected neighboring mesh). As a result we obtain a value which tells whether the removal of intersecting segment creates a regular or irregular mesh. The lower CF value is, the more regular created mesh will be. This situation is clarified in Figure 2.

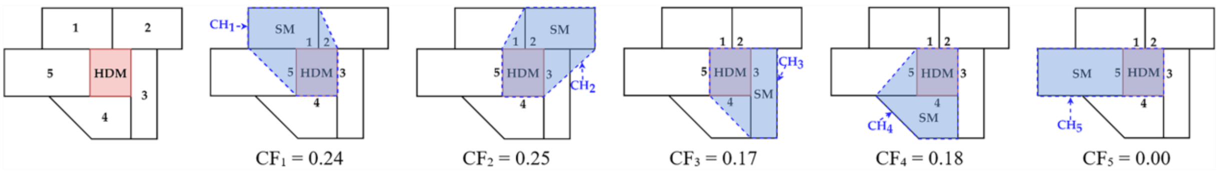

Figure 2. Computation of a compactness factor (CF).

In situation, when the selected segment is a part of the higher class route, the algorithm chooses another segment that is not an important road and has the least influence on the connectivity. This can be measured by a degree centrality – number of strokes that interconnect a given stroke. On the basis of this parameter the algorithm sorts remaining segments due to it and selects one with the lowest value. The accuracy of the developed method was calculated by comparing the generalization outcome with the military topographic map in a 1:100,000 scale which was taken as a reference material. Finally, the algorithm was able to select properly 80% of road segments on a tested area and the general accuracy of it reached 72%. The visualisation of exemplary results is presented in Figure 3.

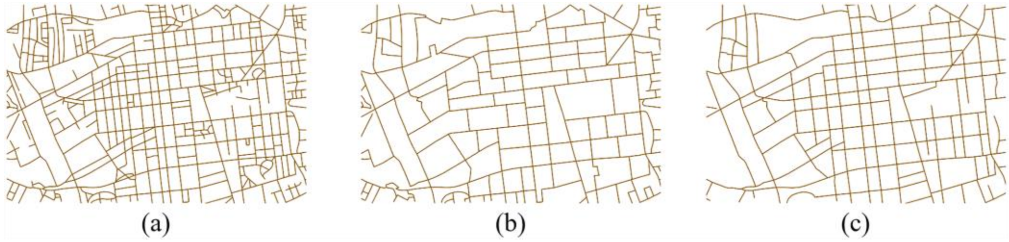

Figure 3. Results of generalization: (a) road network on 1:50,000 map; (b) results of generalization with use of the developed methodology; (c) road network on 1:100,000.

To sum up, the developed methodology gives satisfying results (accuracy is 72%) and, more importantly, its parameters can be adjusted to the needs of a user what makes the algorithm universal. It is worth noticing that by changing parameters, e.g. threshold mesh density or mesh area, we can obtain results in various degrees of generalisation. For the purpose of this research, the mesh density threshold was set to 0.018 and mesh area threshold was set to 120,000 m^2. Furthermore, the tests were conducted only on streets (roads in urban area) because their density is very high and a lot of selection operation must be performed. As far as the roads in undeveloped areas are concerned, they are distributed a way more sparsely and the algorithm can hardly find a mesh which density is below the given threshold. Besides, between military topographic maps of 1:50,000 and 1:100,000 scale the generalization of roads in undeveloped areas is inconsiderable. Moreover, the algorithm takes into account the importance of each road segment by checking their attributes before the removal from the mesh, what allows to maintain the connectivity of the higher class roads. Although the road network is not perfectly generalized, the tool can surely speed up this process and help the cartographers to make decisions which segment should be removed from the map.

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