Generating Multiple Scale Model for the Cadastral Map using Polygon Generalization Methodology

Woojin Park, Kiyun Yu

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Abstract

Cadastral map has high importance for the administration and urban planning because it contains the boundary of land ownership. To use cadastral map in web or mobile environment, construction of the multiple scale model (MRDB) can be useful. In this study, the methodology for generating multiple scale model of cadastral map using by overlaying with network data and applying polygon map generalization techniques is proposed. The generating process is composed three steps: selection of network data of topographic map, parcel polygon merging according to the network data, and line simplification. Proposed methodologies are applied to the cadastral map in Suwon area. The result map was generalized into 1:5,000, 1:25,000, 1:250,000 scale.

1. Introduction

Cadastral map is composed of a large number of parcel lines which is the boundary of the land ownership. Cadastral map has high importance for the administration and urban planning. In these days, as LBS industry is being grown up, the needs for using cadastral map is increasing in public and private area. Several attempts to use cadastral map in web or mobile environment is made. To use cadastral map in web or mobile environment, construction of the multi-representation database (MRDB) that is compressed into multiple scale from the original map data is recommended(Sajajoski, 2007).

Methodologies for generalization of the urban polygon map have been studied since 1980s. Galanda and Weibel (2002) outline a framework for the automated generalization of polygon data based on a multi agent system. Li et al (2004) proposed the hierarchical reconstruction of urban spatial structure into enclave, block, superblock and neighborhood using urban morphology and Gestalt theory. Chaudhry and Mackaness (2008) studied the automatic identification of urban settlement boundaries for multiple representation databases using concept of 'citiness'. These studies have similar ideas to that of this paper and show good performances for each specific circumstances. However, these methods do not suggest appropriate solution for generalizing cadastral map.

This study aims to provide the public with cadastral map data in internet or mobile service by generating a multi-scaled model of cadastral map. Moreover we intended to enhance the legibility and service efficiency of map by aggregating parcel polygons in accordance with various scale levels. Road network data of topographic map is used as the auxiliary to implement this process more effectively. The reason of utilizing the road network data is due to Korean cadastral map which is not only unrefined but also too complicated to find out the relative location of each parcel. Accordingly, overlaying the road network on the cadastral map can enhance the legibility of the map

2. Methodologies

In this study, automatic generation of multi scale model of cadastral map by merging parcel polygons suitable to the multiple scale level and considering the hierarchy of urban structure. The shape of parcel line is affected by adjacent geographic objects, administrative boundaries and especially network data such as road or river. In addition, it contains many thematic attributes like land use or ownership. Thus, to merge parcel polygons in accordance with the scale level, it is highly significant to consider the geometric, topological, thematic attributes all together. For this reason, it is difficult to apply commonly used polygon generalization methodologies to the cadastral map. Also, in many cases, cadastral map have some of discrepancy of line shape or attribute information between the real world because of the non-real time update period problems. Therefore cadastral map itself is difficult to obtain sufficient information for generalization. For complement of this problem, the urban structure identified by road network of topographic map is used as the supplementary data. Although there are some researches on subdivision methodologies for urban areas using network data, there are quite a few studies over network generalization for polygonal subdivision generalization of categorical data such as land cover map or cadastral map.

The methodology proposed in this study is composed of three steps. First of all, the road centerline of topographic map is selected according to the scale levels considering attribute, structural and geometric properties of road network. Second, after overlaying the road network data on the cadastral map, parcel polygons are divided into two parts (network area and non-network area) and then, parcel polygons within each area are merged properly according to the scale level. Third, merged parcel polygons are simplified by using line simplification algorithms. Figure 1 is the flow diagram of this study.

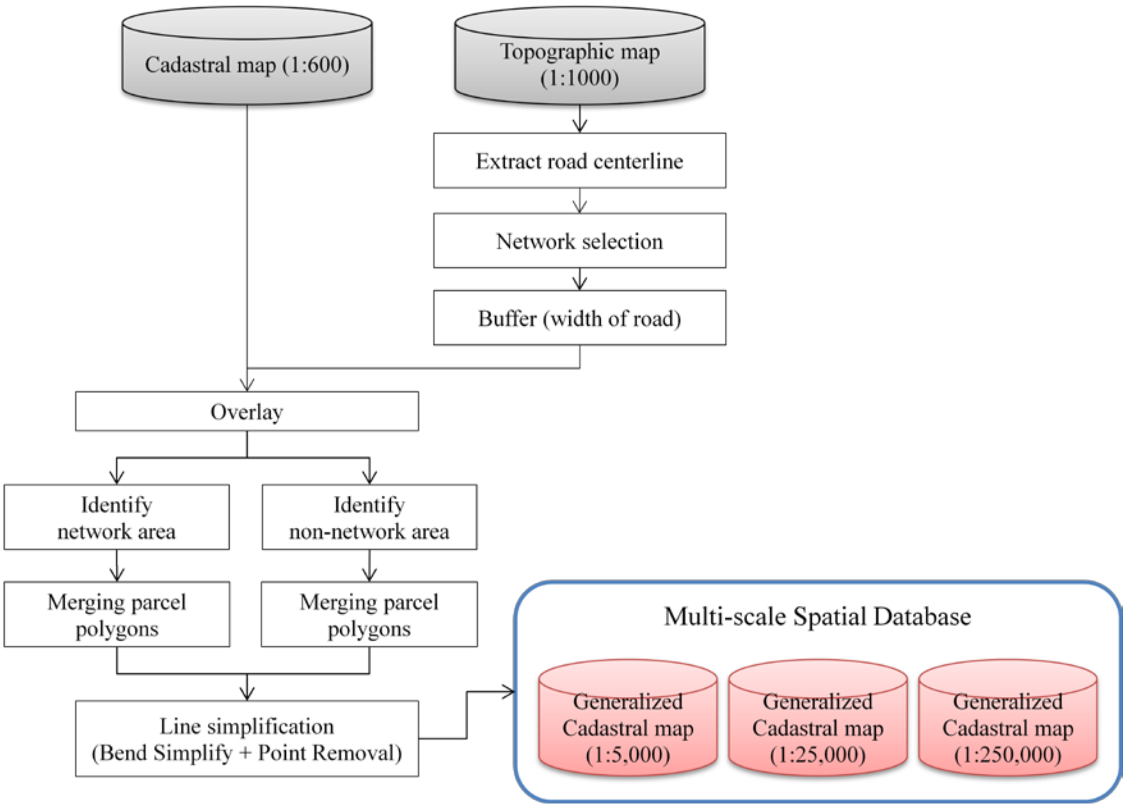

Figure 1. Flow diagram of this study

The proposed methodology in this study is applied to the cadastral map of Suwon city in Korea. The scale of cadastral map and topographic map is 1:600 and 1:1,000 respectively. The target scale level is 1:5,000, 1:25,000 and 1:250,000. Figure 2 is the cadastral map and road network data from topographic map used in this study. ArcGIS 9.3 and Matlab 7.0 were used for the implementation of the proposed methodologies.

Figure 2. The cadastral map and road network data from topographic map of test area (Suwon city, Korea)

2.1 Selection of Network data

For using the urban structure for criteria of parcel polygon merging, the block which is the surrounded area by road network should be identified according to each scale level. Therefore, in advance, road network data need to be selected and eliminated as to the scale level considering attribute, structural and geometric properties synthetically. In this study, the class and width of road centerlines is extracted from the attribute information of road data in topographic map. In addition, for extracting hierarchical and relational properties, road network is reconstructed using 'stroke' concept and stroke degree and stroke length values are extracted (Thomson et al. 1999).

An initial object is selected and a unique id is imposed to the object. Adjacent objects in two end points are selected and deflection angles with the adjacent objects are calculated at each end points. Among the adjacent object, the one which has the least deflection angle and less than 15˚ is found out and the same stroke ID with the initial object is imposed to this object. If the road width of the found object and the average width of the object group which have the same stroke id to the initial object show bigger difference than the standard deviation, the newly found object is considered as a different stroke. This process is repeated until the entire road objects have stroke IDs.

After the reconstruction of road network data, four properties: The average road width, length of stroke, degree of stroke, mode value of road class are calculated and saved as attribute information. These properties are used as the criteria of network selection. For quantification of importance for each network data, the weighted sum of standardized values for each property is used as the importance index (hereafter, II) of network data. The following equation is for calculating the II from four properties, where 'strk_deg' is the degree of stroke, 'strk_leng' is the length of stroke, 'width' is the average width of stroke and 'class' is the mode of road class in a stroke:

$$II = \frac{[strk\_\deg]}{\max(strk\_\deg)} + \frac{[strk\_leng]}{\max(strk\_leng)} + \frac{[width]}{\max(width)} + \frac{[class]}{\max(class)}$$

After calculating II for road network data, edges with the low index are eliminated successively. For fitting the numbers of remained edges in network data to the scale level, Töpfer's radical law was applied (Töpfer et al, 1966). In other words, all strokes are aligned in descending order of II and the stroke with the least index is eliminated iteratively until the ratio of result line density and original line density satisfy the Töpfer's law(Liu et al., 2010, Chen et al., 2009). The above procedures are executed for each scale of 1:5000, 1:25000 and 1:250000.

Table 1 shows the total length of network and threshold of Importance Index for each scale level, and Figure 3 illustrates the results of selection of road network for each scale. The first one is the raw road network data from topographic map and three other ones is the selected according to each scale.

Table 1. Total length of network and threshold of Importance Index for each scale level

Scale	1:1,000 (Original)	1:5,000	1:25,000	1:250,000
Total length of network (m)	92358.45	41284.23	18471.69	5818.58
Threshold of II	0.000	0.4085	0.4682	0.6754

Figure 3. Selection of road network for each scale level

2.2 Merging Parcel Polygons

In advance of merging parcel polygons, the cadastral map is separated into two parts: network area and non-network area. Network data selected in previous step is transformed into polygon data which is buffered by width of road. Network area is identified by overlaying network polygon data to cadastral map. In other words, clipped area of cadastral map by network polygon is identified to network area and each unclipped area is identified to non-network area. In most case, unclipped area is surrounded by network area and form a block. Figure 4 is an illustration of separation of cadastral map into network and non-network area according to the network data.

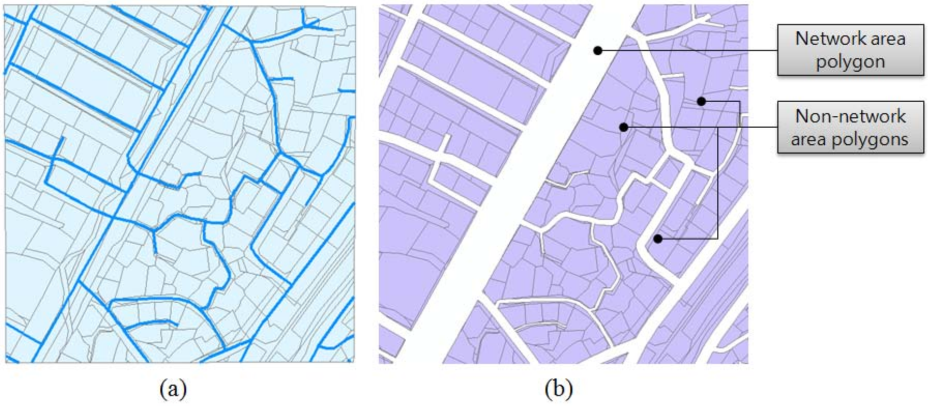

Figure 4. Separation of cadastral map. (a) cadastral map(background polygons) and road network (solid lines) (b) network area and non-network area polygons

Parcel polygons in network area are merged into one polygon. However, polygons in non-network area should be merged according to the scale level. In this study, rule-based merging technique is applied and these rules are determined empirically through repeated tests and intuitively by geometric inference. The rules of merging are as follows:

(1) Parcel polygon with the smallest area is merged successively.
(2) Polygon is merged to the neighbor polygon which has the same land cover.
(3) If there are plural polygons of same land cover, the target polygon is merged to the polygon which has the longest common edge with the target polygon.
(4) If there is no polygon of same land cover, the target polygon is merged to the polygon which has the longest common edge with the target polygon.
(5) The merging process is repeated until the ratio of the number of remained polygon and the number of polygons in raw cadastral map satisfies to the Töpfer’s law.

Figure 5 illustrates the merged results of parcel polygons in non-network area for each scale level. White area represents network area and grey area is non-network area. There are some differences among network area in each result because network area is determined as to network data of each scale level.

Figure 5. Merged results of parcel polygons in non-network area for each scale level

2.3 Line simplification

Parcel lines are expressed by unarranged line feature. Therefore, when the parcel data is generalized, unnecessary bendings or superfluous vertices can be occurred. For this problem, the merged result of parcel polygons is simplified by line simplification algorithms. By means of this process, the amount of data is decreased and readability of map can be enhanced. In this study, to eliminate both unnecessary bendings and superfluous vertices, bend simplify algorithm (Wang and Müller, 1987) and point remove algorithm (Douglas and Peucker, 1973) are applied in serial. The parameters for each algorithm are determined experimentally in range of avoiding geometric distortions and excessive positional error. The parameters for two line simplification algorithms are determined experimentally as the following table.

Table 2. the parameters for two line simplification algorithms

	1:5,000	1:25,000	1:250,000
Bend Simplify	5m	7m	25m
Point Remove	1m	1.5m	5m

Figure 6 illustrates the merged and simplified results of cadastral map for three scale level. The area of dark gray color represents road network area and other parcel polygons are colored differently according to the land use class.

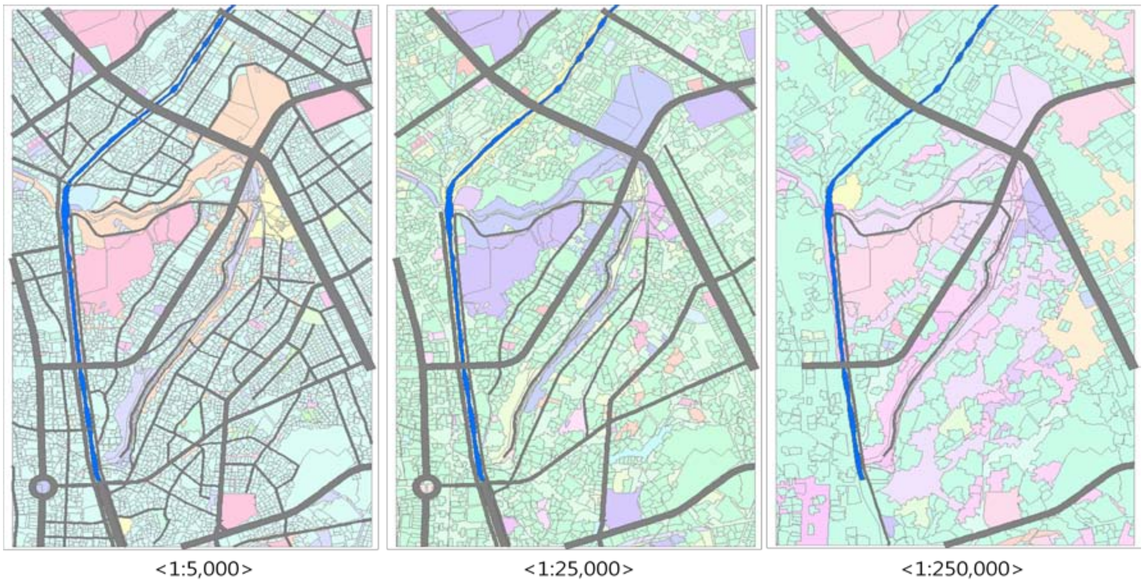

Figure 6. The merged and simplified results of cadastral map for three scale level.

3. Conclusion

In this study, the automatic merging methodology of parcel polygons in cadastral map for generating multiple scale model is examined. The road network data of topographic map is used for the auxiliary data of merging. The road network data is selected and eliminated according to several scale level. Selected road network is overlaid on the cadastral map for separating parcel polygons into network area and non-network area. Parcel polygons in each area are merged according to each scale level. For the last process, merged polygons are simplified by line simplification algorithms to eliminate unnecessary bendings and superfluous vertices. The generalization methodology composed of these processes can merge parcel polygons with insufficient attribute information using topological and geometrical properties from road network data. This methodology seems to be useful in generating multi scale model for cadastral map efficiently and automatically.

This study can be characterized as a case study for it makes the cadastral map in Korea region an object of the study. However, as criteria for aggregation of parcel polygon in polygonal generalization process, network data is used to consider the geometric, topological and thematic attributes of each polygon. Since there have been quite a few studies on this methodology, this research can be differentiated from other studies and it will somewhat contribute to an academic development in map generalization field. In addition, this methodology can possibly be applied to other categorical map generalization such as land cover data.

For the future works, multiple generalization operators and algorithms should be considered. The optimization approaches for each process and the orchestration of processes will also be examined. In addition, the quantitative and qualitative evaluation should be added in the near future.

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