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CENTRALITY BASED HIERARCHY FOR GENERALIZING AND LABELLING STREET FEATURES IN MULTI RESOLUTION MAPS

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Abstract
This paper presents a methodology to extract a new hierarchy to effectively generalize and label street features in intermediate multi scale street networks. The hierarchy uses two main parameters as criteria for ordering the street features; their centrality measures, i.e., betweeness, reach, straightness and closeness, and their functional classes attribute. The measures are integrated using fuzzy-AHP to yield proper coefficients in the hierarchy creation process. The hierarchy is applied for the thinning process to reduce the complexity of the network. Later, the proposed hierarchy is implemented as a priority value to label street features in intermediate scales.

Keywords: *Generalization; Labeling; Multi-resolution; Street Network; Functional Class; Hierarchy; Centrality*

INTRODUCTION

A multi-resolution map is a tool that uses a small space to represent a large space while zooming into the map, thus its contents often compete for the map space leaving little space for features and labels. The main consideration of multi-resolution map design is to make its features more comprehensible, accurate, legible, complete and aesthetic which are the basic needs for the map users. A certain amount of street features appear at the users' sights in each zoom level while surfing a multi-resolution map of the network. The map readers use some common information about the streets' functionality to browse the map efficiently, i.e. they use important classes of the streets to navigate to other less important streets. Several important streets can aggregate within a limited area at small scales and overlay each other as well as their labels. Therefore, proper generalization and labeling processes for the street network is necessary to apply at these scales.

Map generalization is the name of the process that simplifies the representation of geographical data to produce a map at a certain scale with a defined and readable legend. To be readable at a smaller scale, some objects are removed; others are enlarged, aggregated and displaced one to another, and all objects are simplified (Ruas, 2008). One common applied generalization process is the thinning process where insignificant features are omitted from the network. However, eliminating all insignificant FC streets from the network is not a realistic solution for intermediate level of details multi-resolution maps; because the number of these features is the flooding majority of the total street number within a map, and they have important role in providing the connectivity of the network.

Map labeling is a visual process of assigning the best positions for texts of the graphical features of a map. The main aim of this process is to find a good configuration for labels (Kakoulis and Tollis, 2006). Determining which streets to be labelled is one of the difficult decisions to be made in labelling process. Street hierarchies, which rank the network features according to levels of importance, are implemented to ease the application of generalization and labelling processes. The importance of each street feature in the network is distinguished based on its functional class (FC), by which streets and highways are grouped into classes according to the character of traffic service that they are intended to provide. However, this classification is not valid to differentiate between features from the same FC within a limited area. To promote this, spatial geometric properties beside FC of the street features are considered in the proposed hierarchy. It distinguishes the spatial importance of each feature and ranks them in a sequence order by calculating their centralities in the network. Centrality values change in each scale by calculating (1) a convenient distance from the users' eyes to the laptop's screen, and (2) the radius in which the users capture the street features in the screen in their focus states.

THE PROPOSED HIERARCHY

In this study, the four centrality measures are extracted from the primary graph of the network using Sevtsuk and Mekonnen (2012)'s formulas in a test area. Betweenness is a measure of how often a street feature is located on the shortest path between other street features in the network. Reach illustrates the density of the features because of its position close to other near features. Straightness signify directness and connectivity of tracks amid the street feature and it's adjacent. Closeness simply indicates to which extent a feature is near to all the other neighbor features (Crucitti et al., 2006). Those measures are derived using the mid-points of street features and the appropriate radius in each scale. Each of the centrality measures marks different patterns of the street network as significantly important; however these patterns alter in their practicality for the generalization and labelling processes.

Centrality measures for each street feature in the network are calculated, then normalized and recorded in the geodatabase. Tests for each measure are applied to evaluate the capability of each measure in capturing relevant important street features in the network at each scale. By considering the authors cartographic judgments with information obtained from the operated tests; the importance of the measures is categorized in descending order as follows: 1. Betweenness, 2.Reach, 3.Straightness and 4.Closeness.

Ranking and giving priorities to the various centrality measures in an equation are constructed by using multi-criteria decision methods. One of the most utilized methods in the multi-criteria decision approaches is the Analytical Hierarchy Process (AHP), which is a theory of the measurements through pairwise comparisons and relies on the judgments of experts to derive priority scales (Saaty, 1980). In fuzzy-AHP approach, the linguistic variables of human feelings and judgments are represented by a triangular fuzzy numbers to conduct the pairwise comparisons, and extent analysis method is employed to decide the priority of alternatives (Chang 1996; Chan et al., 2008 and Tyagi, 2015). The weights for each of the centrality measures are computed and normalized from Chang's (1996) fuzzy priority method. Equation 1 is generated to extract the priority value for each feature, within the same FC, by multiplying each measure's value with its assigned weight. Equation 1 is used to rank all street features in the network in distinct class as shown in Figure 1

$$\text{weight of the street feature} = \begin{array}{ll} \text{normalized betweeness value of the feature} & \times 0.5223 + \\ \text{normalized reach value of the feature} & \times 0.3252 + \\ \text{normalized straightness value of the feature} & \times 0.1129 + \\ \text{normalized closeness value of the feature} & \times 0.0396 \end{array} \quad (1)$$

STREETLIST	Reach_no	Closs_nor	Between_n	Straigh_no	Priority	Class	HierarchyG
167142	0.000104	0.00000015	0.000442	0.000108	0.027702	1	9601
150162	0.000107	0.00000018	0.0004	0.000106	0.025564	1	9600
150162	0.000107	0.00000018	0.000394	0.000105	0.025253	1	9599
122484	0	0.00591028	0	0	0.023406	1	9598
167142	0.000104	0.00000016	0.000354	0.00011	0.023099	1	9597
122484	0	0.00580808	0	0	0.023001	1	9596
167142	0.000104	0.00000016	0.000352	0.000109	0.022989	1	9595
167142	0.000104	0.00000016	0.00035	0.000109	0.022879	1	9594
167142	0.000104	0.00000015	0.000348	0.000109	0.022786	1	9593
150162	0.000107	0.00000018	0.000346	0.000106	0.022735	1	9592
150162	0.000107	0.00000018	0.000343	0.000103	0.022575	1	9591
150162	0.000107	0.00000018	0.000342	0.000104	0.022489	1	9590
150162	0.000107	0.00000018	0.000341	0.000102	0.022464	1	9589
150162	0.000107	0.00000018	0.000341	0.000102	0.022423	1	9588
122484	0	0.00398108	0	0	0.015766	1	9587
122484	0	0.00390474	0	0	0.015464	1	9586
122484	0	0.00390012	0	0	0.015445	1	9585
122484	0	0.00383992	0	0	0.015207	1	9584
130539	0.000106	0.00000014	0.000179	0.000105	0.013983	1	9583
188781	0.000103	0.00000013	0.000176	0.000102	0.013695	1	9582
195235	0.000107	0.00000014	0.000154	0.000107	0.01272	1	9581
141192	0.000104	0.00000015	0.000153	0.000106	0.012549	1	9580
195235	0.000107	0.00000014	0.000144	0.000107	0.01221	1	9579
141192	0.000104	0.00000015	0.000142	0.000107	0.012007	1	9578
127556	0.000104	0.00000016	0.00014	0.000109	0.011924	1	9577
185853	0.000105	0.00000014	0.000113	0.000103	0.010462	1	9576
169422	0.000101	0.00000015	0.000111	0.000104	0.01024	1	9575
169422	0.000103	0.00000016	0.000105	0.000107	0.010052	1	9574
120448	0.000107	0.00000014	0.000105	0.000095	0.010048	1	9573
169422	0.000101	0.00000015	0.000107	0.000103	0.010035	1	9572
151159	0.000101	0.00000015	0.000107	0.0001	0.009987	1	9571
109399	0.000107	0.00000014	0.000102	0.000094	0.009886	1	9570

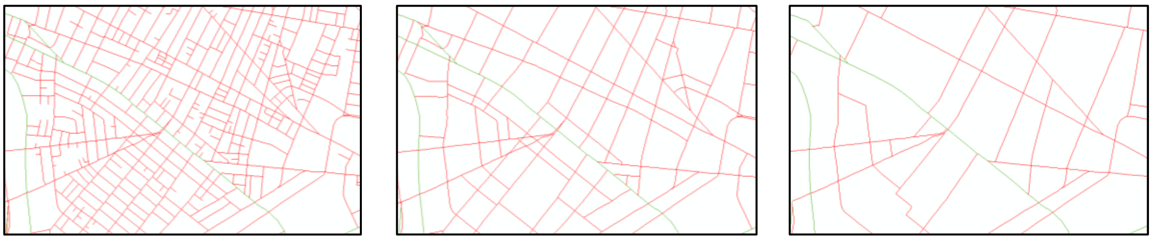
Figure1. Part of the attribute table of the geodatabase displaying the proposed hierarchy.

The hierarchy ranks street features from the same FC, which all have "1" in Figure 1 represented in *Class* field, by their extracted priorities, represented in *Priority* field. Features which have the same label also receive different priorities thus different orders in the hierarchy, i.e. street with id 167142 in the *STREETLIST* field pick up different priority values for its features.

GENERALIZATION AND STREET LABELING PROCESSES

In this paper, three generalization processes, merging, collapsing and thinning, to reduce the geometric complexity of street features are deployed. Merging followed by collapsing is deployed using FC attribute as input hierarchy in the merging process. Later, thinning is applied for the scales (1:8K, 1:16K, 1:32 and 1:64) and the proposed hierarchy is employed as a priority input.

Part of the test area is displayed in Figure 1.a. before the thinning processes is applied. Features colored in green illustrate vital streets while features colored in red illustrate other less significant streets in the network. For the scale 1:64K, the thinning process is applied using the FC hierarchy (Figure 2.b), and using the proposed hierarchy (Figure2.c). The proposed hierarchy in thinning process provides more space for labels and other symbologies between the street features in the map.



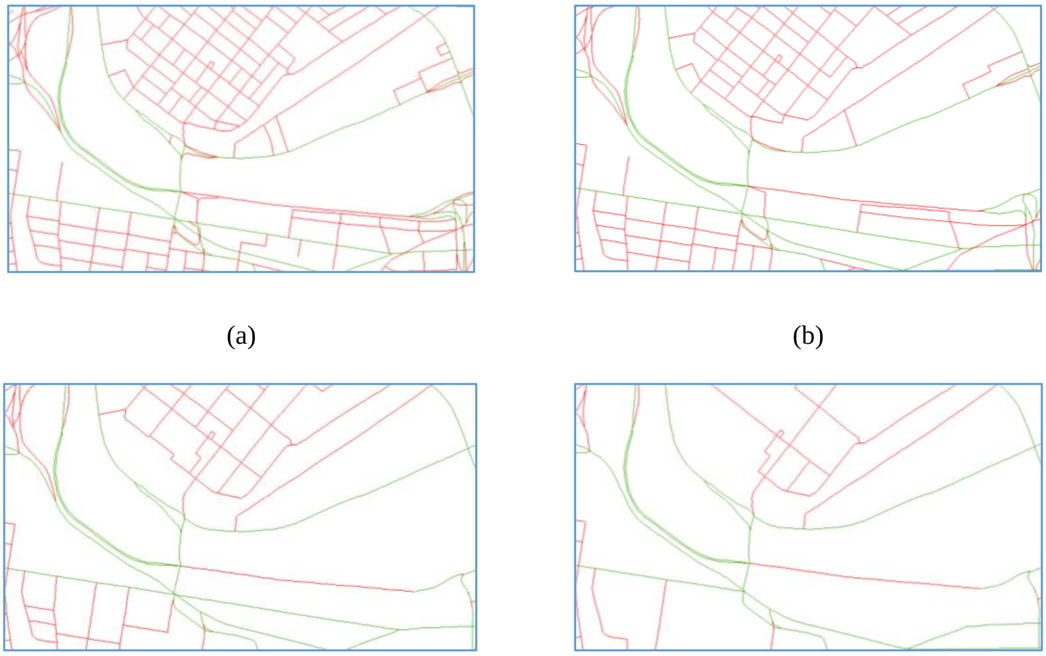
(a) (b) (c)

Figure2. Part of the sample area at 1:64K a) before thinning b) after thinning using functional class hierarchy b) after thinning process using the proposed hierarchy.

Using the proposed hierarchy, a boxed part of the test area in each scale is shown in Figure 3. The percentage of the remaining number of features in important FC streets using the proposed hierarchy and street FC hierarchy for the same area are given in Table 1. The proposed hierarchy gives priorities for important street in the network, thus maintain more visuality of them.

Table 1. Percentage of remained important street features number at each scale

		1:8K	1:16K	1:32K	1:64K
	Using functional class hierarchy	25.71%	28.73%	35.76%	48.70%
	Using the proposed hierarchy	24.68%	26.21%	28.88%	36.92%



(a) (b) (c) (d)

Figure 2. Part of the sample area after the thining process is applied using the proposed hierarchy at scale a) 1:8K b) 1:16K c) 1:32K d) 1:64K.

Four quality constrains for the labeling process are maintained to ensure best interpretation of multi-resolution street map as follows:

1. The association of a street feature and its label.
2. The visibility condition.
3. The aesthetic condition.
4. The priority for labeling (using the proposed hierarchy).

Multi-resolution street network generalized at intermediate level of details is labelled using Styled Layer Descriptor (SLD) in GeoServer. To control the overlaps between labels, priority labeling option is used, during the rendering of the layer. The proposed hierarchy is specified as a priority value in the SLD to calculate relative spatial importance for each feature in GeoServer. Figure 3 displays a sample area at scale 1:8K and 1:16K using the proposed hierarchy as a priority value in GeoServer, streets in green are streets of most important while streets in red are of less important.

(a) (b)

Figure 3 displays sample labeled areas using the proposed hierarchy as a priority value at scale a)1:8K and b)1:16K

CONCLUSION

Generalization and labelling processes using the proposed hierarchy is implemented to best represent important streets at intermediate level of details. Centrality measures help identifying important features in the street network by capturing various patterns of streets that differ in importance according to the used scale. By implementing the proposed hierarchy in the thinning process, more spaces between street features are available to display and interpret the multi-resolution map with less legibility problems while maintaining the most important street features in the network. The mentioned quality constrains, with the proposed hierarchy as a priority value, maintain display of important street features in their top priority by considering their streets spatial significance. However, developing proper model is essential in the application of the quality constrains, because some issues of improper label placement occur more often as scales get smaller that are not referenced to the hierarchy.

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