Street Networks Generalizing and Labelling

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Abstract

This paper presents a methodology to extract a new hierarchy for 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; Labelling; Multi-resolution; Street Network; Hierarchy.

1 Introduction

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 (AASHTO 2001). 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 of this paper. It distinguishes the spatial importance of each feature and ranks them in a sequence order by calculating their centralities in the network. Four centrality measures were calculated and implemented for all street features, however, their 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.

2 The Proposed Hierarchy

In this study, the four centrality measures are extracted from the primary graph of the network using Sevtsuk and Mekonnen's (2012) formulas in a test area. The area is selected to be in Boston (USA) and contains street network for Cambridge and Somerville containing classified in five FC. The four centrality measures used in this study are explained shortly as follow (Porta et al. 2006). 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 signifies 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 neighbour features.

The values of the four 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 according to (Shoman and Gulgen 2016) in descending order as follows: 1. Betweenness (bet), 2. Reach, 3. Straightness (str) and 4. Closeness (clos). 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 number 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. It is used to rank all street features in the network in distinct class as shown in Figure 1.

$$\text{Weight of the street feature} = \begin{array}{l} \text{normalized bet. value of the feature} \times 0.5223 + \\ \text{normalized reach value of the feature} \times 0.3252 + \\ \text{normalized str. value of the feature} \times 0.1129 + \\ \text{normalized clos. value of the feature} \times 0.0396 \end{array} \qquad (1)$$

Figure 1: Part of the attribute table of the geodatabase displaying the proposed hierarchy.

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

3 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.

Using the proposed hierarchy, a boxed part of the test area in each scale is shown in Figures 2, 3, 4 and 5. 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 visualising of them.

Table 2: Example of table with title above

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%

Figure 3. Part of the sample area after the thinning process is applied using the proposed hierarchy at scale 1:8K

Figure 3. Part of the sample area after the thinning process is applied using the proposed hierarchy at scale 1:16K

Figure 4. Part of the sample area after the thinning process is applied using the proposed hierarchy at scale 1:32K.

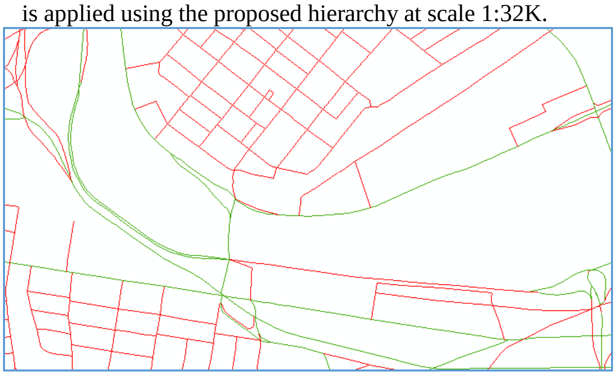
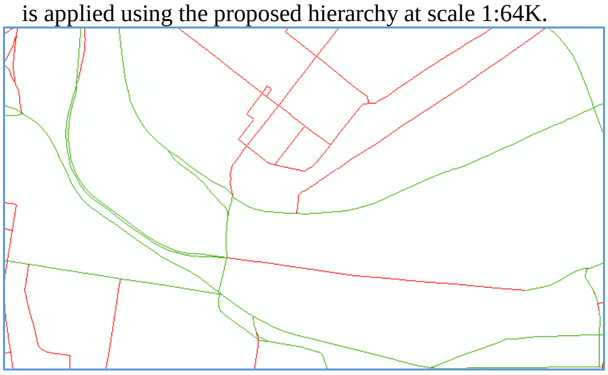


Figure 5. Part of the sample area after the thinning process is applied using the proposed hierarchy at scale 1:64K.



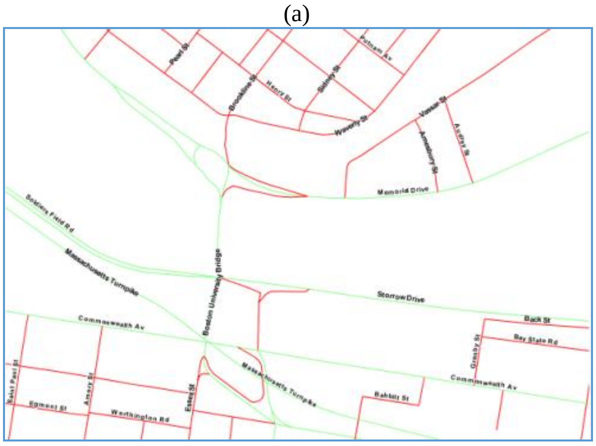
Four quality constrains for the labelling process are maintained to ensure best interpretation of multi-resolution street map as follows (Fan et al. 2005):

- The association of a street feature and its label.
- The visibility condition.
- The aesthetic condition.
- The priority for labelling (using the proposed hierarchy).

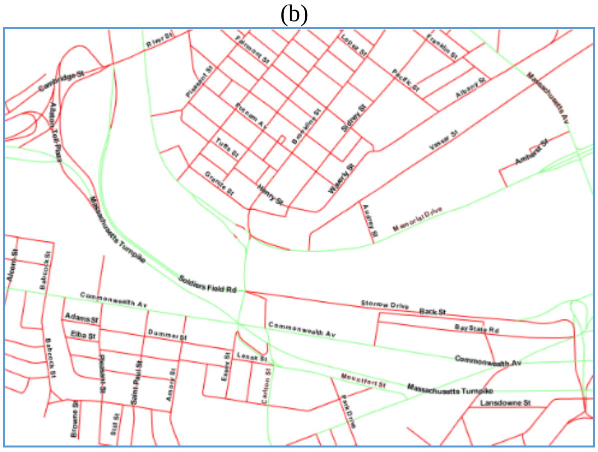
Multi-resolution street network generalized at intermediate level of details is labelled using Styled Layer Descriptor (SLD) in GeoServer. To control the overlaps between labels, priority labelling option is used, during the rendering of the layer. The proposed hierarchy is specified as a priority value in the SLD to calculate relative spatial importance for each feature in GeoServer. Figure 6 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.

Figure 6 displays sample labelled areas using the proposed hierarchy as a priority value at scale, a)1:8K and b)1:16K

(a)



(b)



4 Conclusion

Generalization and labelling processes using the proposed hierarchy is implemented to best represent important streets at intermediate level of details. Centrality measures help in 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. These issues are not referenced to the implemented hierarchy.

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