2012 15th International IEEE Conference on Intelligent Transportation Systems
Anchorage, Alaska, USA, September 16-19, 2012

Network Zoning based on Community Detection for Urban Traffic Control

Cheng Chen, Yunfeng Ai, Fenghua Zhu

Abstract— **Network Zoning is a key problem for the coordination in hierarchical control system. In traffic control area, considering the characteristics of road network, like directed and spatial property, we give one appropriate method for network zoning. Inheriting the advantages of several community detection methods, this method takes the distance between intersections and the scale of intersection into account simultaneously. And we also applied it to the parallel transportation management systems (PtMS) in Tianhe area of Guangzhou for network zoning. The results of experiments illustrate its effectiveness.**

I. Introduction

For the dynamic and complexity of system, the optimal control in single-point mode is often unable to obtain a global satisfactory solution. Hence, the hierarchical control is one main option for the management of systems [1][2]. In one hierarchical control system, the intelligence is continuously increasing from bottom to top. However, the precision and real-time property of control is continuously increasing in opposite direction. This property of system meets the control requirement of dynamic systems. As one important part of hierarchical control, coordinated control is one hot topic, which includes the study about the scope [3] and mechanism [4] of coordination. The former one is to choose appropriate objects for coordination, which is also called as network zoning or sub-area decomposition in traffic control system. The "appropriate" word means that the individuals within the scope of the coordination are more closely related than the other parts of the whole system. This closer relationship can refers to the degree of proximity in distance, the degree of similarity between the two objects and so on. It makes sense to cooperate. Based on the determined scope, researchers can develop appropriate mechanism of coordination for them to pursuit the common control aims. Hence, the decision-making about the scope of coordination is the first and meaningful step for the whole process of coordination.

In transportation field, making road network being hierarchical is widely used in various fields, like routing and control system. However, there are differences among the hierarchical processes in different applications. For example, in the application of routing, the aim is to find out the quickest or shortest path for users. Hence, designers pay more attention to the links on the road network. The whole road network is divided by hierarchical algorithm into two layers: top layer and bottom layer [5]. The top layer is sparse and consisted of major arcs in the network. Hence, the whole network is divided by top level into several sub-networks. These sub-networks build up the bottom layer. The arcs in the top layers are indispensable to connect the sub-networks in the bottom layer. The Louvain's method [6], as one community detection method for undirected graph, is used to find out these sub-networks. Community detection methods take closer nodes into the same community. Hence, the travel time of each link is used to determine the weight of arcs. The average travel time of the links in communities is much lower than the links between communities.

In the coordination of hierarchical control systems, its aim is to make different controlled objects work together for a goal, which comes from the organization. To achieve these control goals, we need to clarify these controlled objects and the relationship among them. Then, the scope and mechanism of coordination can be determined. Previous work in network zoning depends on a set of principles, like the principle of road level [7], the principle of regional function and so on. According to these principles, people need to pick out the arterial roads and different functional areas from the city map, and then determine the scope of coordination. However, these principles are only one specific form of expression about the characteristics of the intersection. For example, several large-scale intersections are connected by one road, which generally has more lanes than average. This road is more likely to be one arterial road in this area. On the contrary, in one living area or business district, central region is mainly composed by small-scale intersections and local streets. Hence, the characteristics of intersection reveal the information of these principles. The controlled objects of traffic control system mainly are intersections. Hence, we focus on intersections and pay more attention to the relationship between them. System designers need to find out closely relative intersections and put them under the same coordinator. In this paper, according to the characteristics of urban traffic network, we imply community detection to the realization of network zoning for traffic hierarchical control. The community detection method is inspired by the Louvain's method and two improved forms of modularity: one is used for directed networks [8] and the other is used for spatial networks [9]. Hence, the rest of paper is organized

This work was supported in part by NSFC 60921061, 70890084, 90920305, 90924302, 60904057, 60974095; CAS 2F09N05, 2F09N06, 2F10E08, 2F10E10; 2F11D01.

Cheng Chen, Fenghua Zhu are with the State Key Laboratory of Management and Control for Complex Systems, Chinese Academy of Sciences, Beijing, 100190, China. They are also with Dongguan Research Institute of CASIA, Cloud Computing Industrial Technology Innovation and Incubation Center, Chinese Academy of Sciences, Songshan Lake, Dongguan 523808, China. (e-mail: chengchen.cas@gmail.com, fenghua.zhu@ia.ac.cn).

Yunfeng Ai is with the College of Computing and Communication Engineering, Graduate University of the Chinese Academy of Sciences, Beijing 100049, China (e-mail: aiyunfeng@gmail.com).

as follows: we firstly discuss the influential elements of urban traffic network for the scope of coordination in the next section. Then, from Louvain's method to our method for network zoning in this paper will be detailed in turn. After that, the experiments in Guangzhou and related analysis will be given. At last, we make further discussion and concludes this paper.

II. Influential elements for the scope of coordination

In this section, we need to find out the influential elements for the scope of coordination in urban traffic networks. The intersections, which are closely related, need to be under the same coordinator. Hence, we need to propose the mathematical presentation about the relevance between two directly related intersections to evaluate their closeness. We define the parameters of these two intersections as follows:

R_{ij}: The relevance of intersection i and j;

$F_{i\to j}$: The influence from intersection i to j;

d_{ij}: The length of the road between intersections, as shown in the (a) of Figure 1;

$N(i)$: The intersections in the neighborhood of intersection i, which are directly connected with intersection i;

$L_{i\to j}$: The number of lanes about the link which depart from intersection i to j, as shown in the (a) of Figure 1;

O_i^{in}: The ability of intersection i to accept vehicles, called as carrying capacity;

O_i^{out}: The ability of intersection i to release vehicles, called as radiation capacity;

S_i: The scale of intersection, which is equal to the number of involved lanes in the network;

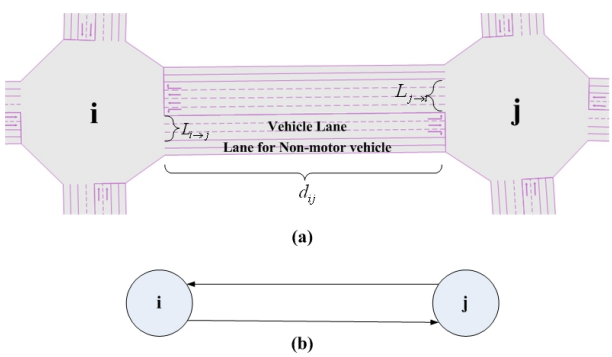

Fig. 1. Actual road map (a) and its schematic representation (b) of two directly related intersections.

For the existence of one-way road and two-way road, the interaction between two intersections is directed. Hence, $F_{i\to j}$ and $L_{i\to j}$ are directed parameters. However, the parameter d_{ij} is undirected. In most case, the directed links of two-way road in urban rely together as shown in the (a) of Figure 1. Hence, d_{ij} is the same for both directions. Of course, the situation that the lengths of roads in both directions are different exists. If there is one separation zone between the roads, this situation appears. According to the different distances in two directions, the influence between two intersections show different degrees of attenuation. In Figure 1, from (a) to (b), we can see how to schematic represent one actual road map into one directed graph. O_i^{in} and O_i^{out} are the sum of export or import lanes of intersection i respectively. Hence, they can be expressed as follows:

$$O_i^{out} = \sum_{j\in N(i)} L_{i\to j} \quad and \quad O_i^{in} = \sum_{j\in N(i)} L_{j\to i} \tag{1}$$

$L_{i\to j}$ reveals the capacity of intersection i to free traffic flow when traffic light in the direction $i \to j$ is green. This capacity is determined by the narrowest section of road. $L_{j\to i}$ is reverse. O_i^{in} reveals the total capacity of free traffic flow about intersection i, and O_i^{out} is reverse. And the scale of one intersection S_i is determined by the throughput capacity of the intersection, including O_i^{in} and O_i^{out}. This parameter directly shows the importance of the intersection in the road map. Considering the radiation capacity of intersection i and carrying capacity of intersection j, the item $\frac{L_{i\to j}}{O_i^{out}O_j^{in}}$ illustrates the influence in the direction from i to j. However, this influence is also weakened with the growth of distance. Hence, the impact factor d_{ij} should be considered. The $F_{i\to j}$ can be given as follows:

$$F_{i\to j} = f(\frac{L_{i\to j}}{O_i^{out}O_j^{in}}, d_{ij}) \tag{2}$$

For R_{ij} is the relevance of intersection i and j, it should include the influence from both direction. Taking two intersections as one group, when they are important in the road map, the number of lanes between them needs to be more to certify that they are closely related. Also this relevance can be weakened by increasing of distance. Hence, R_{ij} take the following form:

$$R_{ij} = g(\frac{L_{i\to j}}{O_i^{out}O_j^{in}} + \frac{L_{j\to i}}{O_i^{in}O_j^{out}}, d_{ij}) \tag{3}$$

And it can be further expressed as:

$$R_{ij} = (\frac{L_{i\to j}}{O_i^{out}O_j^{in}} + \frac{L_{j\to i}}{O_i^{in}O_j^{out}}) * \frac{1}{w * d_{ij}} \tag{4}$$

where w is the ability of the distance to weaken the relevance. If w is known, the directed road map can be convert to a weighted and undirected graph. And R_{ij} is the weight between two intersections. The method of Louvain can be used to community detection. However, in practice, w is hardly to acquire. Hence, the exploration about how to combine these influential elements for network zoning is meaningful. According to the influential elements for the scope of coordination, we construct one weighted and directed spatial network for actual road map. The weight between node i and j in this network is $L_{i\to j}$. Considering the topological information of the graph, one spatial matrix is used to record the spatial information (i.e. distance of road, d_{ij}) for this graph. The network will be illustrated in the section of experiment and analysis. Then, we should find out how to make use of these influential elements to community detection.

III. Community Detection Methods

In this section, one community detection method and two improved modularity are involved. Our method is inspired by them. Community detection methods are widely used to find out the most reasonable partition of a network into communities to maximize the one quality function for the network. One high score of the quality function indicates the nodes in the communities have closer relationship than the average level in the graph. The quality function used in this section is called as modularity [10]. From the view of modularity, we will find out one inheritance relationship among the content in this section. The basic form of modularity [11] is shown as follows:

Q=(fraction of edges within communities under original graph) - (expected fraction of edges within communities under chosen null model).

Null model can be defined as a graph which matches the original in some of its structural features, but which is otherwise a random graph. Based on the basic form, in the following part of this section, we detail the different forms of modularity, which are used to handle different kinds of graph.

A. Louvain's method

The Louvain's method [6] is one community detection method for undirected graph, which take a greedily optimization method called as fast unfolding to maximize the modularity. Fast unfolding is an iterative algorithm that each round of iteration will produce one graph partition at different granularity to form hierarchical community detection. During each iteration, every node will try to place with its neighboring nodes in the same community to see whether can improve the modularity of whole graph. To reduce the computational load, only neighboring nodes in different community will be considered. The procedure of fast unfolding method is given in Figure 2.

```
Step 1: There are n nodes in the network. Assign one community to each node in the network .
Step 2:
    While there is improvement for modularity or the improvement is more than one certain threshold
      For i=1:n
        The number of neighbors of each node i  is m.
        For j=1:m
              Remove node i from its community to the community of its neighbor;
              Calculate the  variance of modularity and record it.
        end
        Place node i into the community which will bring the max positive increment of modularity;
        If  no positive increment, node i stays in original community.
      end
    end
Step 3: If the modularity of graph is not change after step 2
              The algorithm is over.
      else
          Reconstruct the  network:
          1.Each community is represented by one node in the new network.
          2.The weight of arc between two nodes in the new network is equal
            to the sum of weights of arcs between related communities in original network.
          Go to Step 2;
      end
```

Fig. 2. Fast unfolding method in Louvain's method.

For its fast processing speed and high-quality partition ability, Louvain's method has drawn lots of attention in hierarchical community detection of large networks. The modularity used in this method is shown as follows:

$$Q = \frac{1}{2m}\sum_{ij}(A_{ij} - P_{ij})\delta(C_i, C_j), P_{ij} = \frac{k_i k_j}{2m} \quad (5)$$

where A is the adjacency matrix, which record the weight of the edge between every pairs of nodes in the graph. The m is the total weight of all the edges in the graph, it can be expressed as $m = \frac{1}{2}\Sigma_{ij}A_{ij}$, A_{ij} and P_{ij} represents the actual and expected fraction of edges within communities. P_{ij} also can be understood as the probability of two points associated with each other. The output of δ-function is one if vertices i and j in the same community, zero otherwise. k_i is the sum of weights about the edges attached to node i. This form of modularity is suitable for undirected graph.

B. Improved modularity for directed graph

In [8], to handle directed graph, the form of modularity has taken some appropriate adjustment. The basic idea behind this adjustment is given as following. Assuming two nodes in the graph, which are node A and B. The node A has a high out-degree but low in-degree. The situation of node B is reverse. Hence, the possibility about the existence of one arc from node A to node B will be more than the opposite direction in this graph. The happen of low-probability event means the importance of this arc and a higher modularity to cluster two related node in the same community. The form of modularity for directed graph is given as follows:

$$Q = \frac{1}{m}\sum_{ij}(A_{ij} - P_{ij})\delta(C_i, C_j), P_{ij} = \frac{k_i^{out} k_j^{in}}{m} \quad (6)$$

where A_{ij} is defined as the weight of the arc from i to j, it is directional. The k_i^{out} and k_j^{in} are out-degree of node i and in-degree of node j respectively.

C. Improved modularity for spatial graph

Spatial networks widely exist in complex networks, like internet, transportation and so on. In these spatial networks, the topographies have been affected by the geographic spaces in varying degree [9]. Different distance between nodes will have directly impact on the connection density in the graph. For modeling this character of spatial networks, gravity models are widely used to model flows in spatial network. Many researchers use the following equation to estimate the average connection density for different distances.

$$T_{ij} = N_i N_j f(d_{ij}) \quad (7)$$

where T_{ij} is the value about the connection between two nodes, which can be used as the weight of the arc. N_i represent the importance of node i in the network and f-function describe the influence of space on the average connection density of graph, which is called as deterrence function. Here, the average connection density plays the same role as the probability of two points associated with each other in null model. Hence, the modularity for spatial graph can be given as follows:

$$Q = \frac{1}{2m}\sum_{ij}(A_{ij} - P_{ij})\delta(C_i, C_j), P_{ij} = N_i N_j f(d_{ij}) \quad (8)$$

The acquirement of f-function is available from empirical data based on the following function:

$$f(d) = \frac{\sum\limits_{ij|d_{ij}=d} A_{ij}}{\sum\limits_{ij|d_{ij}=d} N_i N_j} \quad (9)$$

where in applications, the accurate value of f-function for all distances is unnecessary and a huge computational burden. The whole distance range can be divided into several subintervals based on one bin at a certain size. The average value in each bin is enough to fit to f-function. We only need to make a decision about the appropriate size of bin.

D. Our method for network zoning

As shown in Figure 3, our method for community detection has two parts: the definition of the modularity about the graph and community detection method. The community detection method of our method is fast unfolding method, and the definition of the modularity is based on the improved modularity for directed and spatial graphs.

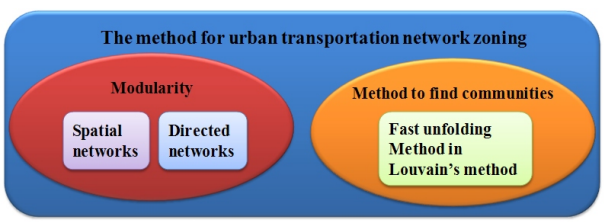

Fig. 3. Structure of the method for network zoning.

The idea of spatial graph gives us one reasonable approach to take distance and lanes of link into considering for network zoning. And the directional characteristic of urban transportation network is also considered in the method for network zoning. The modularity of the method for network zoning can be represented as follows:

$$Q = \frac{1}{m}\sum_{ij}(A_{ij} - P_{ij})\delta(C_i, C_j), P_{ij} = O_i^{out} O_j^{in} f(d_{ij}) \quad (10)$$

where A_{ij} is defined as the one in directed graph, which is equal to $L_{i\to j}$. O_i^{out} and O_j^{in} are the carrying capacity of intersection i and the radiation capacity of intersection j respectively. d_{ij} is the distance between two intersections i and j. $f(d_{ij})$ is the average lane density, which can be acquired based on the following equation:

$$f(d) = \frac{\sum\limits_{ij|d_{ij}=d} A_{ij}}{\sum\limits_{ij|d_{ij}=d} O_i^{out} O_j^{in}} \quad (11)$$

However, the repeated calculation about the modularity of the whole graph is a heavy burden after each adjustment of the zoning of the network. Hence, the variance of modularity after moving node i into zone c can be computed by:

$$\Delta Q = \frac{1}{m}[k_{i\_c}^{in} + k_{i\_c}^{out} - O_i^{out}\sum_{j\in c} O_j^{in} f(d_{ij}) - O_i^{in}\sum_{j\in c} O_j^{out} f(d_{ij})] \quad (12)$$

$k_{i\_c}^{in}$ is the sum of the weights of arcs between node i and community c, which take node i as the destination. And $k_{i\_c}^{out}$ is inverse.

IV. Experiment and Analysis

In this section, in order to illustrate the effectiveness of our method, we implement it in the agent-based distributed and adaptive platform for transportation systems (aDAPTS) of parallel transportation management systems (PtMS) [12] in Tianhe area of Guangzhou, which has twenty-two controlled intersections. We represent the city map and one detailed actual road network of this area in Figure 4.

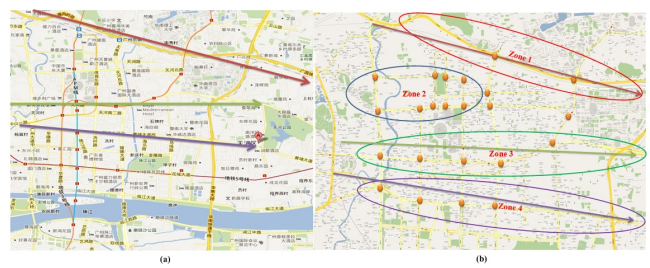

Fig. 4. Actual road network of Tianhe area from Google, (a) the city map of Tianhe area; (b) the detailed road network of our controlled area.

Guangzhou is one typical southern Chinese city, built along with the Pearl River. Generally speaking, the arterial roads in this kind of cities are also built along the rivers. Hence, as shown in the (a) of Figure 4, we can find out three arterial roads in the Tianhe area easily, which controlled by PtMS. Considering the actual relationship between these intersections and experience of engineering, we can find four zones in this area as shown in the (b) of Figure 4. The characteristic of zone 1, 3 and 4 is the arterial road consisting of several large-scale (important) intersections. And the characteristic of zone 2 is one area which has many small-scale (unimportant) intersections. Hence, these characteristics of network can be used as the basic rule to evaluate the quality of zoning.

Fig. 5. Schematic representation of actual road network in undirected graph (a), directed graph (b) and directed graph with gravity model (c).

To compared with Louvain's method and its version for directed graph, we give the corresponding schematic representations of actual road network in Figure 5. In the undirected graph, if two intersections are connected directly, there will be one arc to connect two nodes, and its weight is set to 1; Otherwise, the weight of arc between two nodes is 0, and no arc between them in the graph. The result of Louvain's method about undirected graph is shown in the (a) of Figure 6. In the directed graph, according to actual road for the connection of intersections, like one-way or two-way road, the nodes of graph are connected by directed arcs. We design three experiments for the improved method for directed graph. The difference of these experiments is the weight of arcs in the graph. Setting the weights of connected arc to 1, we get the result as shown in the (b) of Figure 6. As the weights are determined by the number of lanes in the road, the result as shown in the (c) of Figure 6. And the result shown in the (d) of Figure 6 gives the outcome of the situation that weights are determined by the distance between intersections.

Fig. 6. Result of zoning for undirected and directed graph. (a) undirected graph with 0-1 weights; (b) directed graph with 0-1 weights; (c) directed graph with weights based on the number of lanes of road; (d) directed graph with weights based on distance of road.

We find the common shortcoming in these results is the split of zone 3 in Figure 4. However, considering the limitations of the algorithms, the characteristics of graphs are fully utilized. For example, in the (d) of Figure 6, indeed the intersections which are closer than others are divided into the same zone. However, the zone 1 and zone 3 in Figure 4 are both split by the algorithm for directed graph based on distance.

After that, we use our method to test on the directed graph with gravity model. The weights of arcs in the graph are determined by the number of lanes in the road. And the size of node represents the importance of intersection in the network. When O_i^{in} and O_i^{out} is equal, we only use one circle to represent it. Otherwise, the node will be represented in two concentric circles. The blue inner represents O_i^{in}, and the red one is O_i^{out}. The minimum and maximum about the distance of roads in this area are 88m and 1184m respectively. Hence, the range of actual distance is set from 0 to 1200m. According to this range, we use three different sizes of bins for testing, which are 100m, 200m and 300m. The average lane density for different sizes of bins are shown in the Figure 8. In the (a) of Figure 8, the value is segmented that the average lane density in each bin has no effect on each other. In the (b) of Figure 8, the value is accumulated that the average lane density in each bin is the average of all previous values. In transportation, evaluation of the relationship among long-distance intersections should consider the situation of short-distance intersections. Hence, accumulated form is chosen as the average lane density for our experiment.

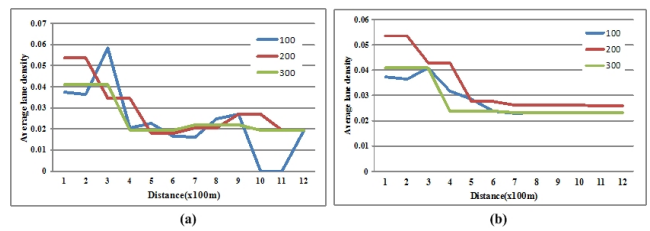

Fig. 8. Average lane density for each bin in segmented form (a) and accumulated form (b).

The results of our method are shown in Figure 7. The zoning of our method conserve the characteristics of actual road network. No phenomenon of split in zone1, 3 and 4 in Figure 4. And large-scale intersections have attraction to the small-scale intersections, hence, the zone 2 which consist of many small-scale intersections is ripped by other zones. This is one reasonable phenomenon.

With the variety about the size of bin, we also can find the change in network zoning. With the finer granularity of bin, the zoning is more reasonable in the global view of the map. In the (a) of Figure 7, the intersection 12, 17 and 21 is out of the control of zone 3 in the Figure 4. The intersection 12 merges into the zone 2 in the Figure 4, whose small-scale intersections are integrated better. The closest intersection of intersection 17 is intersection 16. However, it is dawn out by the force of intersection 12, 18 and 21 together in the coarse-grained bin. The force of intersection 20 and 22 to intersection 21 form one balance. Hence, intersection 17 and 21 merge into the zone 1 in the Figure 4 together.

V. Discussion and Conclusion

A. Discussion

1) Granularity of zoning : Using the fast unfolding method, our method can give the dendrogram [10] of zoning. In the (a) of Figure 9, we show the dendrogram of our method with the bin at size of 100m. According to the actual demand of coordination, designer can adjust the scope of coordination easily. In the (b) of Figure 9, we give the evolutionary process of network zoning.

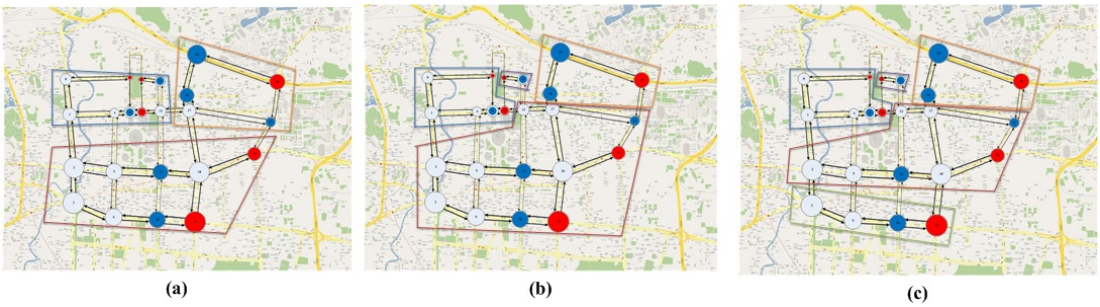

Fig. 7. Result of our method for network zoning with different sizes of bins, which are (a)100m, (b)200m and (c)300m.

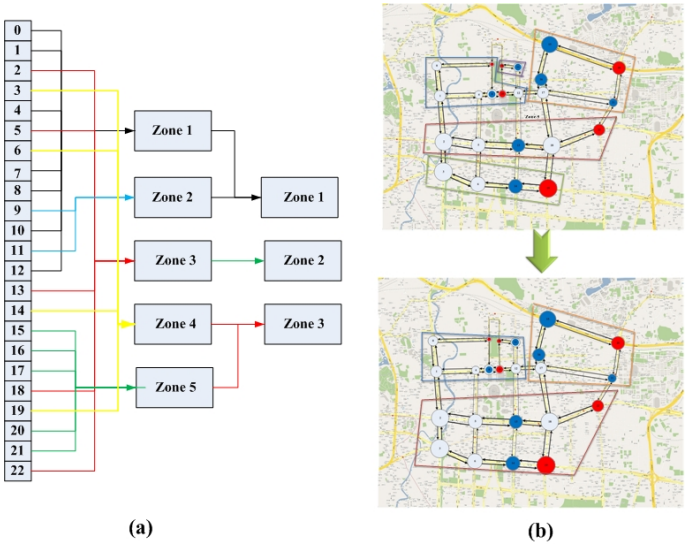

Fig. 9. Dendrogram (a) and zoning process (b) of our method with bin at size of 100m.

2) Static zoning and dynamic zoning: Transportation system is one dynamic system. The traffic volume on the road indeed impacts the relationship of intersections. We can easily add a factor to multiple with the weight of graph to handle the dynamic characteristic of network. The factor can be the ratio about existing traffic volume and saturated traffic volume on the road. Considering the evolving network as a series of snapshots, when the coming of new data about traffic volume on the network, the whole network zoning approach based on community detection need to run again to generate a new network zoning. With one large traffic network of city, the recalculation is a waste of computing resource. Hence, considering the community detection about evolving traffic network, the research about how to use a minimum of computational resource to complete the reclassification about intersections is meaningful.

B. Conclusion

In this paper, we give one method based on community detection with gravity model for the problem of network zoning. This method makes effectively use of two influential elements for the scope of coordination: the distance between intersections and the scale of intersection. And the experiments in Tianhe area of Guangzhou show the zoning method can catch the characteristics of actual road network. However, it is a static network zoning, which is the prelude of dynamic zoning. Considering the influence of traffic volume of the road on the relevance between intersections, the future work of us will focus on develop this method to dynamic network zoning. It will involve the methods of community detection for dynamic graph to save computing resource and reduce time of process.

VI. Acknowledgments

The author would like to thank Professor Feiyue Wang for his support to this work. I also thanks other people contributed to this work in the State Key Laboratory of Management and Control for Complex Systems, Chinese Academy of Sciences.

References

[1] G. Saridis, "On the revised theory of intelligent machines," in *Intelligent Robots and Systems '89. The Autonomous Mobile Robots and Its Applications. IROS '89. Proceedings., IEEE/RSJ International Workshop on*, sep 1989, pp. 24 –30.

[2] F.-Y. Wang, "Agent-based control for networked traffic management systems," *Intelligent Systems, IEEE*, vol. 20, no. 5, pp. 92 – 96, sept.-oct. 2005.

[3] T. Oda, "Meta-heuristic optimization of sub-area decomposition in urban road networks," *Transactions of the Institute of Systems, Control and Information Engineers*, vol. 11, no. 8, pp. 466–476, August 1998.

[4] A. Farinelli, A. Rogers, and N. Jennings, "Bounded approximate decentralised coordination using the max-sum algorithm," in *IJCAI-09 Workshop on Distributed Constraint Reasoning (DCR)*, July 2009, pp. 46–59.

[5] Q. Song and X. Wang, "Efficient routing on large road networks using hierarchical communities," *Intelligent Transportation Systems, IEEE Transactions on*, vol. 12, no. 1, pp. 132 –140, march 2011.

[6] V. D. Blondel, J.-L. Guillaume, R. Lambiotte, and E. Lefebvre, "Fast unfolding of communities in large networks," *Journal of Statistical Mechanics: Theory and Experiment*, vol. 10, p. 8, Oct. 2008.

[7] R. P. Roess, E. S. Prassas, and W. R. McShane, *Traffic engineering*. Pearson/Prentice Hall,, 2004.

[8] E. A. Leicht and M. E. J. Newman, "Community Structure in Directed Networks," *Physical Review Letters*, vol. 100, no. 11, p. 118703, Mar. 2008.

[9] P. Expert, T. Evans, V. D. Blondel, and R. Lambiotte, "Beyond Space For Spatial Networks," *ArXiv e-prints*, Dec. 2010.

[10] Santo and Fortunato, "Community detection in graphs," *Physics Reports*, vol. 486, no. 3-5, pp. 75 – 174, 2010.

[11] M. E. J. Newman and M. Girvan, "Finding and evaluating community structure in networks," *Phys. Rev. E*, vol. 69, p. 026113, Feb 2004.

[12] F.-Y. Wang, "Parallel control and management for intelligent transportation systems: Concepts, architectures, and applications," *Intelligent Transportation Systems, IEEE Transactions on*, vol. 11, no. 3, pp. 630 –638, sept. 2010.