A Survey of Urban Traffic Coordination Controls in Intelligent Transportation Systems

Shuangshuang Li
State Key Laboratory of Management and Control for Complex Systems, Institute of Automation, Chinese Academy of Sciences, Beijing, China
Dongguan Research Institute of CASIA, Cloud Computing Center, Chinese Academy of Sciences, Songshan Lake, Dongguan 523808, China
shuangshuang.li@ia.ac.cn

Abstract—**The urban traffic coordination controls (UTCCs) can make full use of the mutual advantages of intersections, which makes it can improve the traffic access capacity and decrease the possibility of traffic congestion in intersections. This paper gives an overview of UTCCs. After reviewing the concept of UTCCs, we survey the several main hot topics in UTCCs: the correlation degree analysis of intersections, the division approach of traffic control subareas and the objects of coordination. This paper provides a survey of urban traffic coordination controls with the goal of promoting research in this area and concludes with some comments on future research directions.**

Keywords-Coordination; Urban traffic control; Intelligent transprotation systems

I. INTRODUCTION

Traffic signal control is a very important research area in intelligent transportation systems (ITS) [1][2][3][4]. In recent years of development process, the development of traffic signal control is from manual control to automatic control, from fixed-time control to variable-time control, from non-responsive control to responsive control, from single isolated intersection control to traffic trunk road coordination control, then to regional coordinated signal control[5][6]. The urban traffic coordination control is a hot topic in traffic signal control. For a traffic control area, according to the traffic condition, the function of a control for an intersection is not only to meet the control of its own needs but also to coordinate with other intersections in order to realize the urban traffic coordination controls (UTCCs). Based on this, the UTCCs can play a very important role in dealing with the traffic congestion which is caused by one intersection. According to the change of the traffic information which is referred to traffic flow, mean speed, occupancy and so on in a traffic network, the UTCCs can make full use of the advantages of the intersections and balance the traffic flow of every intersection. The traffic access capacity of the traffic network can be improved by UTCCs.

With the growth of modern urban traffic and increase of the density of the road network, the correlation between the intersections is more and more obvious. For example, in a region or the whole city, an adjustment of the traffic signal in an intersection will often affect the traffic flow of neighboring several intersections. Furthermore, with the passage of time, an intersection congestion may gradually spread to the surrounding several intersections or intersections of the area. The urban traffic coordination control is more and more welcomed by the researchers' attention.

In this paper, UTCCs are divided into three aspects, as shown in Figure 1. The first aspect is the correlation degree analysis of intersections. The second aspect which includes the static and dynamic division is the division approach of the traffic control subareas. The last aspect is the objects of coordination. The objects of coordination are divided into adjacent intersections, agents, bandwidth, route guidance and traffic control and so on.

The paper is organized as follows. In Section II, we provide a survey on UTCCs' recent development. In Section III, we discuss some comments on future research directions about UTCCs, followed by the final conclusion in Section IV.

II. URBAN TRAFFIC COORDINATION CONTROLS

A. *The correlation degree analysis of intersections*

The correlation degree analysis of intersections is the basis of UTCCs, also is the groundwork of the division for traffic control subarea and the selection of the coordinated methods. The main task of the correlation degree analysis is to analyze the coupling degree between intersections which directly determine whether the intersections need to coordinate.

Yagoda *et al.* [7] define the coupling between adjacent intersections as the ratio of the value of road traffic flow to the length of the road, and put forward whether to make coordination control according to the size of coupling degree between the adjacent intersections. Pinnell *et al.* [8] analyze the influence factors about the size of the correlation degree between adjacent intersections. Those factors include intersection spacing, signal phase design, traffic flow and so on. Transportation Research Board (TRB) [9] recommends using the Whitson model to calculate adjacent intersections' correlation degree. In order to obtain a comprehensive reflection of the correlation degree by the relating factors such as road length, the travel speed, traffic flow and vehicle steering ratio, TRB introduced road travel time, the maximum traffic flow and the average traffic flow of upstream intersections into the model. Ma *et al.* [10] make a correlation degree model which took a comprehensive consideration of the signal phase, the non-uniformity of traffic flows, intersection spacing and vehicle queue length. Furthermore, they analyzed

978-1-4673-2401-4/12/$31.00 ©2012 IEEE

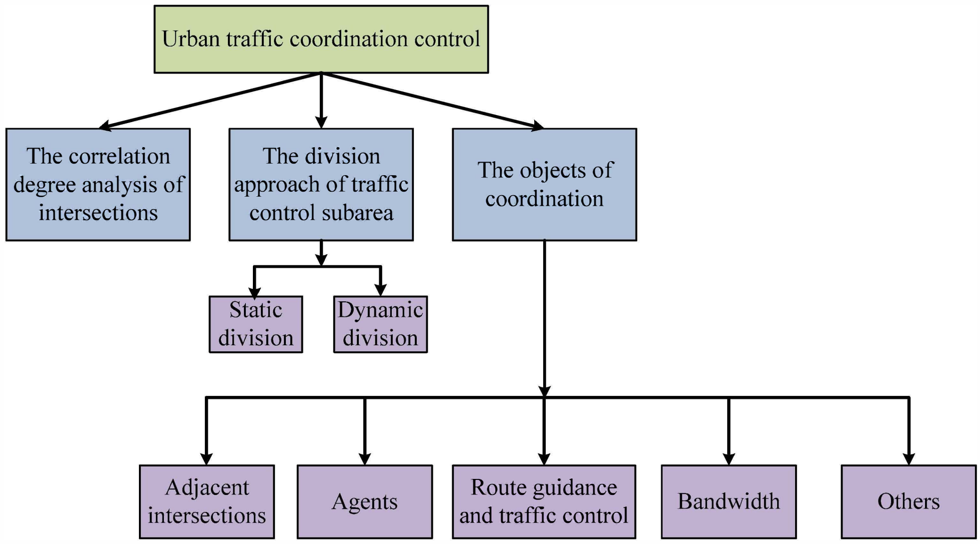

Fig.1 The classification of urban traffic coordination control

the effects of intersection spacing, vehicle queue length and the signal phase on correlation degree of Routes. Lu *et al.* [11] put forward a quantitative traffic description parameter which is called the adjacent intersections correlation degree. What's more, they gave the definition of mix correlation degree between multiple intersections and the calculation formula of this correlation degree.

B. *Division of traffic control subareas*

The division of traffic control subareas is an important topic in urban traffic coordination control. The appropriate division of traffic control subareas plays a crucial role in control plan implementation, operation efficiency, reliability of the urban traffic coordination control system.

Walinchus [12] first proposes the concept of the traffic control subarea. Walinchus thought that the dividing line of the control subareas should be in administrative boundaries or a place where the flow characteristics and road characteristics are greatly changed. The necessity of the division of control subarea is stated in [12]. Some researchers [13][14][15] summarize the influences in the division of control subarea. These influences include the consistency of the traffic condition, the administrative division, the road geometry characteristic, the neighboring intersection spacing, road traffic flow speed, traffic flow, intersection signal timing and so on.

The division methods for control subareas are mainly divided into the static and dynamic division way.

1) *Static division*

Static division is that the intersections and road sections in subarea is fixed in quite a long period after the division.

Both the Traffic Network Study Tool (TRANSYT) [16] and the Split Cycle and Offset optimization Technique (SCOOT) [17][18] use static division control strategy. According to the traffic flow, the properties of roads, relationship of locations and the demand of coordination control in control area, designers should fix the program of the division in advance. However, the Sydney Coordinated Adaptive Traffic System (SCATS) [19] [20] adopt semi-dynamical division control strategy. It should determine the minimum control unit in advance which is the basic unit of the urban control system. And according to the differences between the control signal cycles of the control subareas, the separation and merger of the minimum control units can be achieved by a vote counting method.

2) *Dynamic division*

The traditional method for static division of traffic signal control subarea cannot adapt the rapid change of the traffic flow in urban traffic network. So some researches study on the dynamic division for the urban traffic signal control subarea. Dynamic division is that the intersections and road sections in subarea is variable based on the traffic condition in a traffic control area.

Based on the consideration that the factors which affect the coordination between intersections are not independent except the static factors like the space between intersections, Liu *et al.* [21] analyze the related attributes, which include the intersection space, the difference of intersection cycles, traffic flow and the discrete degree of traffic flow, and propose a new method with grey correlation degree for traffic subarea division. Li *et al.* [22] put forward the application of the fuzzy reasoning theory to divide the control subareas and propose the concept of coordination coefficient which is used to express the size of the demand of coordination control between intersections. The coordination coefficient can be calculated by fuzzy reasoning method and the judgment rule of the division of traffic control subareas with coordination coefficient is presented. Through the classification of urban traffic congestion, an idea, which is based on the static regional control, about using different judgment standards for dynamic zoning control is proposed [23]. Shang *et al.* [24] propose a traffic control subarea division method which based on the traffic saturation, the cycle and the distance between adjacent intersections. The paper [25] put forward a method with Back Propagation (BP) neural network for traffic control subarea division. The input of the neural network is the traffic flow, distances between intersections and circles. The neural network's output is the coordination coefficient of the adjacent intersections. This paper [26] discusses automatic traffic control subarea division process which on the basis of the cycle, the distance or the traffic flow respectively. After analyzing the characteristics of the big city traffic signal control system, Shi *et al.* points out that it is necessary to classify the control area dynamically according to the variation of real-time traffic flow [27]. Zang *et al.* analyze the necessity of dynamic division for urban traffic signal subarea and set up a new optimization control model [28]. Duan *et al.* use the hypergraph to express the road network and achieve the control subarea division through hypergraph partitioning algorithm [29]. Lu *et al.* establish a control subarea division model by using the quantitative analysis method about the correlation degree between the adjacent intersections [30]. Yang *et al.* put forward the concept about the subarea of cycle and the ratio of phase offset to split. Based on this, a dynamic division method of the traffic control zone is presented in detail [31]. After confirming the control zone associated with the oversaturated area computing the correlation degree between the intersections, Yang *et al.* propose an approach for traffic control subarea division under oversaturated condition [32]. Ma *et al.* design a traffic subarea division expert system using fuzzy logic. What's more, some characteristics of traffic subarea division system are analyzed [33]. These characteristics include the topological of roads, statistical traffic flow, some abnormal states and so on. Guo *et al.* [34] consider the following influencing factors of the traffic signal subarea division: distance between intersections, major road traffic flow, major road traffic capacity and signal cycle. Based on this, a new traffic signal control division approach using fuzzy C-means clustering is presented in detail. Li *et al.* [35] point out that the rules of the traffic signal subarea division are the distance, the cycle, the traffic flow, the saturation, split and phase offset. And an automatic method of the division and integration of traffic signal control subarea based on distance and cycle rule is put forward. Considering the travel time and incident workload, Yun *et al.* put forward an optimization model of traffic networks subarea division for incident management systems [36].

III. THE OBJECTS OF COORDINATION

A variety of methods and techniques have been developed to coordinate urban traffic signal control. In general, these methods and techniques can be sorted into the following categories based on the objects of coordination.

A. *Adjacent intersections*

The study of the control in an isolated intersection cannot meet the control demand of the ITS. The coordination model and algorithm of adjacent intersections is a very important research field in ITS. Li *et al.* [37] propose algorithms based on the fuzzy rules and High-order generalized neural networks for two adjacent intersections. Dotoli *et al.* [38] adopt an optimization model to coordinate two adjacent intersections located in an urban area. But they only consider the coordination algorithms of two adjacent intersections. For the coordination of two more intersections, considering that it may cause parking times and operational delays, if each natural intersection is regarded as a minimal control unit for a bi-direction traffic truck line, Zhou *et al.* [39] put forward a conception of new intersection. This new intersection is consists of two or three natural intersections which correlate with each other. And the coordinated controller using Fuzzy control is adopted to control adjacent new intersections. Li *et al.* put forward a new coordinated signal control algorithm based on mobile agent technology to coordinate between intersections, regions, vehicles and video cameras [40].

B. *Agents*

Wang points out "from control algorithms to control agents", because the agent-based control methods provide a cheap, reliable and flexible approach for intelligent, effective control and management of traffic and transportation systems in connected environments [41]. One control agent cannot meet the control demand of ITS, so there are two or more control agents in a urban traffic signal control system. The coordination between control agents is a hot topic in ITS. Bazzan points out that the coordination of traffic signal agents is dependent on the stability of the traffic conditions [42]. If the local traffic condition changes frequently, the coordination is reached slowly. In [42], a coordination concept which makes use of techniques of evolutionary game theory is used. In this coordination concept, intersections in an arterial are modeled as individually-motivated agents or players who should take into account not only their own local goals but also a global one. Katwijk *et al.* use the concepts form domain of agent and multi-agent systems to describe the traffic management instruments which could just as easily be expressed as cooperating agents in a heterogeneous multi-agent environment [43]. Considering the coordination of multi-junction control, Zhao *et al.* put forward a coordination method based on multi-agent technology to coordinate the traffic when traffic jams occur [44]. Liu *et al.* do some study about traffic flow area coordination control. In this paper, there are two types of Agents: intersection agent and segment agent and a coordination algorithm for intersection agent are proposed [45]. Du proposes an urban traffic coordination control system by using multi-agent and game-theory. Each agent in this system chooses the appropriate strategy according to the traffic information which is has and enables their benefit to achieve Nash balance [46]. Some other papers study on coordination of traffic signal control using game theory [47][48][49]. Li *et al.* improve the traffic signal control agent with Q-learning method. Based on this, a new approach which combines game theory and society rules is proposed to coordinate two traffic signal control agents [50]. Wei *et al.* take a traffic signal control agent as a control agent and adopt a approach of distributed reinforcement learning to the coordinated traffic signal control system based on multi-agent [51]. Dai *et al.* propose a multi-agent coordination model to improve the efficiency and relieve traffic congestion [52].

C. *Route guidance and traffic control*

How to coordinate the traffic signal control and route guidance is one important research in ITS. The route guidance usually based on traffic assignment theoretically, so the study on coordination between traffic control and guidance has a close relationship to the study on combining traffic control and assignment. The thought of integrating the control and route guidance was proposed by Allsop[53], Maher and Akcelik[54], and Gartner[55]. From then on, some papers study on model and algorithm about combining traffic signal control and route guidance [56][57][58][59][60]. Some researchers also study on the coordination model and method between the urban traffic control system and route guidance system [61][62][63]. Dai *et al.* try to coordinate the fixed timing control of different time of the day and outdoor guidance system by assuming that the signal timing parameters can be regulated in a week interval according to statistical intersection delays, and the guidance information is explicit traffic condition estimation with fuzzy matching from congestion measurement of intersections [64].

D. Bandwidth

The arterial bandwidth coordination control is an important way for urban traffic signal control systems. Mogan and Little *et al.* put forward the control signal timing design method for arterial bandwidth coordination control and set up the MAXBAND model which is a mixed integer linear programming model[65][66][67]. Based on the MAXBAND model, Gartner and Stamatiadis *et al.* propose the MULTIBAND model whose bandwidth is variable [68][69][70]. Tian *et al.* put forward an arterial bandwidth coordination control method based on the division of traffic signal control subarea [71]. Zang *et al.* propose a control method optimizing phase offset for neighboring intersections on arterial road by using improved genetic algorithm (GA) in order to realize hierarchical cooperative control [72]. Shen *et al.* put forward a novel traffic arterial dynamic bidirectional green wave coordinate control strategy by exchanging messages and cooperating between centre coordination agent and local control agents [73]. Ma *et al.* [74] put forward a phase sequence optimization model for coordinating signalized intersections in arterial systems based on NEMA phase which is design by National Electrical Manufacturers Association for phase configuration in software and hardware devices' TS-2 standards [75]. To maximize the possibility for vehicles in each direction along the arterial road, Kong *et al.* present a new intelligent control strategy whose structure contains two layers: the coordination layer and the control layer [76]. Zhou uses arterial road coordination control method to map out each signal coordination control program and then uses graphic method for each phase of the traffic signal [77].

E. Others

There are also some others objects for urban traffic coordination controls in an urban control system. Porche *et al.* try to maximize the whole control system performance by coordinating local adaptive traffic signal controllers and propose a multi-layer approach for controlling the infrastructure in an urban street network [78]. Papageorigou *et al.* point out that the fixed-time coordinated control and coordinated traffic-responsive strategies cannot meet well the control demand of saturated traffic conditions [79]. In practice, the optimal results which calculate in theory may not be feasible to actually achieve these optimal performances, but the results maybe show that some substantial improvements are possible by simply using the current physical roadway infrastructures more effectively. Considering this, Shah *et al.* develop heuristic algorithms and an optimization model using the space-time network to solve this problem [80]. Qian *et al.* use a fuzzy coordinated control method to solve the congestion problem in Chang'an Street in Beijing. What's more, the use *k*-NN method to forecast the traffic flows in 2-min interval to overcome hysteresis problem in fuzzy method [81]. Yang *et al.* adopt a linear program to solve the problem of optimizing and coordinating city area traffic signal control [82]. Shen *et al.* put forward the road network traffic intelligent coordination control technique with bus priority by regarding the whole road network as a large-scale system and the intersections as subsystems [83]. After analyzing the loop characteristic of partially urban road network in China, Ma *et al.* propose urban loop-road traffic coordination control system based on split-layer parallel cusp catastrophe particle swarm optimization algorithm to reduce delay and the stopping rate in the region [84]. Gündogan *et al.* present a low-cost real-time coordinated traffic signal control system based on a pattern recognition method using feed forward artificial neural networks for megacities [85].

IV. CONCLUSIONS AND FUTURE DIRECTIONS

We have reviewed the urban traffic coordination controls in the current literature. Since much research on urban traffic signal coordination controls is ongoing, this survey is by no means complete. In the current literature, most urban traffic signal problems are studied in algorithms or models about several intersections or control agents. Seldom consider the traffic signal coordination in the whole city or a big region. The reason for this is the real-time problem of the urban traffic control system. It is very time-consuming for processing the traffic data of a whole city or a big region and running the control algorithms based on one or two computers. The real-time demand of control system cannot be guaranteed. In order to ensure the real-time demand of the UTCCs, the following problems need to be solved: the problem of the massive traffic data real-time processing problem, the runtime of the control algorithms or systems and reliability problems.

An urban traffic coordination control system based on cloud computing can solve these problems related with real-time. The future research may be involved in studying how to build such a system which can be called "Intelligent traffic cloud". This system not only can store and process massive traffic data in time but also can coordinate different intersections by parallel computing. There are several following key problems that "Intelligent traffic cloud" needs to been considered.

1) How find the intersections or regions which need to been coordinate with others in a city? It is unnecessary for every intersection or region to coordinate with others. But we should know whether the intersection or region need to coordination with others according to traffic conditions.

2) How to mine the useful information which can be used for the coordination from huge traffic data? The traffic data for a city is massive and find the useful data for the coordinated intersections or regions is a key problem for coordination.

3) How to realize the parallel computing? There may be several intersections or regions need to been coordinated in one

time. The system needs to deal with these coordination problems at the same time.

ACKNOWLEDGMENT

This work is supported in part by NSFC 60921061, 61174172, 60904057, 31170670, 61101220, 70890084, 90920305 and CAS 2F11D03, 2F11N06, 2F11D01, 2F11N07.

REFERENCES

[1] F.-Y. Wang, "Parallel Control and Management for Intelligent Transportation System: Concepts, Architectures, and Applications," *IEEE Transactions on Intelligent Transportation Systems*, September, 2010, vol.11, no.3, pp.630-638.

[2] F. H. Zhu, Z.J. Li, "A Case Study for Traffic Signal Control System Evaluation Based on Artificial Transportation Systems," *IEEE International Conference on Service Operations, Logistics, and Informatics*, July, Beijing, 2011, pp.347-352.

[3] K. Wang, Z. Shen, "Artificial Societies and GPU-Based Cloud Computing for Intelligent Transportation Management," *IEEE Intelligent Systems*, 2011, vol.26, no.4, pp.22-28.

[4] Z. Shen, K. Wang, F. H. Zhu, "Agent-based Traffic Simulation and Traffic Signal Timing Optimization with GPU," *14th International IEEE Conference on Intelligent Transportation Systems (ITSC 11)* Washington D. C., 2011, pp.145-150.

[5] D. C. Gazis, "Traffic Theory," New York: Kluwer Academic Publishers, 2002.

[6] C. K. Wong, S. C. Wong, C. Q. Tong, "Optimization Methods for off-line Traffic Signal Settings: Recent Advances and Prospective Future Research," *Journal of Transportation Systems Engineering and Information Technology*, 2005, vol.5, no.2, pp. 36-54.

[7] H. N. Yagoda, E. H. Principe, C. E. Vick, B. Leonard, "Subdivision of Signal System into Control Areas," *Traffic Engineering*, 1973,vol.43, no.12, pp.42-45.

[8] C. Pinnell, J. J. DeShazo, R. L.Wilshire, "Area wide Traffic Control System," *Traffic Engineering & control*, 1975, vol.45, no.4, pp.16-21.

[9] TRB, Highway Capacity Manual 1987. Washington, D. C., 1987.

[10] W. J. Ma, X. D. Li, X. G. Yang, "Incidence Degree Model of Signalized Intersection Group Based on Routes," *Journal of Tongji University*, 2009, vol.37, no.11, pp.1462-1466.

[11] K. Lu, J. M. Xu, S. J. Zheng, "Correlation Degree Analysis of Neighboring Intersection and Its Application," *Journal of South China University of Technology (Natural Science)*, vol.37, no.11, pp.37-42.

[12] R. J. Walinchus, "Real-Time Network Decomposition and Subnetwork Interfacing," *Highway Research Record*, 1971, no.336, pp.20-28.

[13] C. R. Stockfish, "Guidelines for Computer Signal Systems Selection in Urban Areas," *Traffic Engineering*, 1972, vol.43, no.3, pp.30-63.

[14] J. H. Kell, I. J. Fullerton, "Manual of Traffic Signal Design," 1991, Second Edition, New Jersey: Prentice Hall.

[15] J. L. Pline, "Traffic Engineering Handbook," 1992, Fourth Edition, New Jersey: Prentice Hall.

[16] D. I. Robertson, "TRANSYT-A Traffic Network Study Tool," Berkshire: Transport and Road Research Laboratory, 1969.

[17] P. B. Hunt, D. L. Robertson, R. D. Bretherton, "The SCOOT On-Line Traffic Signal Optimization Technique," *Traffic Engineering and Control*, 1982, vol.23,no.4,pp.190-192.

[18] P. T. Martin, S. L. M. Hockaday, "SCOOT-An Update," *Institute of Transportation Engineers Journal*, 1995, vol.65, no.1, pp.44-48.

[19] J. Y. K. Luk, "Two Traffic-Responsive Area Traffic Control Methods: SCAT AND SCOOT," *Traffic Engineering and Control*, 1984, vol.65, no.1, pp.44-48.

[20] P. R. Lowrie, "The Sydney Coordinated Adaptive Traffic System-Principles, Methodology, Algorithm," *Proceedings of the International Conference on Road Traffic Signaling*, London, 1982, pp.67-70.

[21] X. M. Liu, S. H. Zheng, "Study of Division Approach of Traffic Control Subarea Based on Grey Relation Degree," *International Conference on Electric Technology and Civil Engineering*, 2011, Lushan, China, pp.5486-5489.

[22] R.M. Li, H. P. Lu, Q. X. Shi, "Research on Traffic Signal Control Sub-area Fuzzy Automatic Division Method," *Journal of Wuhan University of Technology*, 2008, vol.32, no.3, pp.381-384.

[23] D. S. Shang, J. J. Shi, L. Y. Sui, G. X. Che, "Dynamic Division in Transportation Region and Its Control Research," *Transportation Science & Technology*, 2007,no.6, pp.82-84.

[24] D. S. Shang, J. J. Shi, "The Transportation Controlled Area Dynamic Division Research," *Road Traffic & Safety*, 2007, vol.7, pp.27-29.

[25] C. G. Li, Y. Xie, H. L. Zhang, X. L. Yan, "Dynamic Division about Traffic Control Sub-Area Based on Back Propagation Neural Network," *2nd International Conference on Intelligent Human-Machine System and Cybernetics*, 2010, vol.2, pp.22-25.

[26] H. K. Mo, G. X. Peng, M. P. Yun, "Automatic division of traffic control sub-area under condition of route guidance," *Journal of Traffic and Transportation Engineering*, 2002, vol.2, no.2, pp.67-72.

[27] J. J. Shi, Q. Yu, P. T. Ren, "Big City Transportation Signal Control System Level and Region Dynamic Division Research," *Road Traffic & Safety*, 2007, vol.4, pp.7-9.

[28] L. L. Zang, X. X. Meng, L. Jia, L. Zhao, "An Optimal Control Framework of Traffic Signal Based on Dynamical Sub-area Partition for Urban Main-roads," *Proceedings of the 8th World Congress on Intelligent Control and Automation*, 2010, pp.4533-4538.

[29] H. L. Duan, Z. H. Li, Y. Zhang, J. M. Hu, "Dynamic subdivision of road network into coordinated control regions," *Journal of Jilin University (Engineering and Technology Edition)*, 2009, vol.39, suppl.2, pp.13-18.

[30] K. Lu, J. M. Xu, Y. S. Li, "Division Method of Coordinated Control Subareas Based on Correlation Degree Analysis," *Journal of South China University of Technology (Natural Science Edition)*, 2009, vol.37, no.7, pp.6-9.

[31] Q. F. Yang, L. Chen, "Division approach of traffic control work zone," *Journal of Jilin University (Engineering and Technology Edition)*, 2006, vol.36, suppl.2,pp.139-142.

[32] X. G. Yang, W. Huang, W. J. Ma, "Method of Delimiting Urban Traffic Signal Coordinate Control Subarea Under Oversaturated Condition," *Journal of Tongji University(Natural Science)*, 2010, vol.38, no.10, pp.1450-1457.

[33] Y. Y. Ma, X. G. Yang, "Traffic Sub-area Division Expert System for Urban Traffic Control," *2008 International Conference on Intelligent Computation Technology and Automation*, 2008, pp.589-593.

[34] J. J. Guo, Q. P. Xiong, S. Chen, "Division Approach of Traffic Signal Control Sub-area," *2009 International Conference on Information Engineering and Computer Science*, 2009, pp.1-4.

[35] H. B. Li, Z. S. Yang, X. G. Yang, "The Research of Division and Integration of Traffic Control Subzones Based on Distance + Cycle Rule," *Proceeding of the 29th Chinese Control Conference*, 2010, China, pp.5358-5361.

[36] M. P. Yun, X. G. Yang, "An Optimization Model of Road Networks Subarea Districting for Incident Management Systems," *IEEE 6th Conference on Intelligent Transportation Systems*, 2003, vol.1, pp.437-441.

[37] L. X. Li, H. J. Gao, R. Liu, F.-Y. Wang, "Control Signal Coordination of Two Adjacent Traffic Intersections," *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics*, 2002, vol.6, pp.255-260.

[38] M. Dotoli, M. P. Franti, C. Meloni, "Coordination and Real Time Optimization of Signal Timing Plans for Urban Traffic Control," *Proceedings of the 2004 IEEE International Conference on Networking, sensing and Control*, Taiwan, 2004, pp.1069-1074.

[39] L. Zhou, W. Li, "A coordination control by sections on the truck line of urban traffic network," *Proceedings of 2008 International Conference on MultiMedia and Information Technology*, 2008, pp.665-668.

[40] X. H. Li, S. H. Ren, L. Shen, "A New Traffic Signal Coordinated Control Method Based on Mobile Agent Technology," *Proceedings of the 27th Chinese Control Conference*, China, 2008, pp.448-453.

[41] F.-Y. Wang, "Agent-Based Control for Networked Traffic Management Systems," *Intelligent Systems*, 2005, vol.20, no.5, pp. 92-96.

[42] A. L. C. Bazzan, "A Distributed Approach for Coordination of Traffic Signal Agents," *Autonomous Agents and Multi-Agent Systems*, 2005, vol.10, no.1. pp. 131-164.

[43] R. V. Katwijk, P. V. Koningsbruggen, "Coordination of Traffic Management Instruments Using Agent Technology," *Transportation Research Part C: Emerging Technologies*, 2002, vol.10, pp.455-471.

[44] J. Y. Zhao, D. K. Tang, "Coordination Traffic Control under the Framework of Multi-Agent Technology," *The Second International Workshop on Computer Science and Engineering*, 2009, pp.219-222.

[45] X. M. Liu, F.-Y. Wang, "Study of City Area Traffic Coordination Control on the Basis of Agent," *The IEEE 5th International Conference on Intelligent Transportation Systems*, Singapore, 2002, pp.758-761.

[46] R. H. Du, "Urban Traffic Coordination Control System Based on Multi-Agent-Game," *2008 International Conference on Intelligent Computation Technology and Automation*, 2008, pp.817-821.

[47] X. H. Xia, L. H. Xu, "Coordination Based on Multi-Agent and Its Application of Urban Intersection Traffic Coordination Control," *Proceedings of the 8th World Congress on Intelligent Control and Automation*, China, 2008, pp.5982-5987.

[48] S. F. Ma, Y. Li, B. Liu, "Agent-Based Traffic Coordination Control Method for two Adjacent Intersections," *Journal of Systems Engineering*, 2003, vol.18, no.3, pp.272-278.

[49] L. Ma, W. Y. Liu, "A Coordination Model of Game Theory for Multi-intersection-agents and the Algorithm for Solving Equilibrium Based on the Reinforcement Learning Method," *Proceedings of the 27th Chinese Control Conference*, China, 2008, pp.477-483.

[50] Y. Li, R. M. Wu, W. Li, "The Coordination between Traffic Signal Control Agents Based on Q-Learning," *Proceedings of the 5th World Congress on Intelligent Control and Automation*, China, 2004, pp. 2690-2693.

[51] W. Wei, S. F. Gong, H. X. Liu, "A Coordinated Urban Traffic Signal Control Approach Based on Multi-Agent," *Proceedings of 2009 International Conference on Intelligent Engineering Systems*, 2009, pp.263-267.

[52] Y. H. Dai, H. L. Duan, Z. H. Li, Z. Zhang, "A Multi-agent Coordinate Model for Urban Traffic Signal Control," *Proceedings of 8th IEEE International Conference on Control and Automation*, China, 2010, pp.1882-1887.

[53] R. E. Allsop, "Some possible using traffic control to influence trip distribution and route choice," *Proceedings of 6th International Symposium on Transportation and Traffic Theory*, 1974, pp. 345-374.

[54] M. J. Maher, R. Akcelik, "The Re-distributional Effect of an Area Traffic Control Policy," *Traffic Engineering and Control*, 1975, vol.16, no.9, pp.383-385.

[55] N. H. Gartner, "Area Traffic Control and Network Equilibrium," *Proceedings of International Symposium on Transportation Equilibrium Method*, 1976, pp.95-110.

[56] H. Yang, S. Yagar, "Traffic Assignment and Signal Control in Saturated Road Networks," *Transportation Research Part A: Policy and Practice*, 1995, vol.29, no.2, pp.125-139.

[57] C. Menguzzer, "Review of Models Combining Traffic Assignment and Signal Control," *Journal of Transportation Engineering*, 1997, vol.123, no. 2, pp. 148-155.

[58] S. F. Lu, X. M. Liu, "Based on Hybrid Genetic Algorithm and Cellular Automata Combined Traffic Signal Control and Route Guidance," *Proceedings of the 26th Chinese Control Conference*, 2007, pp.53-57.

[59] M. Khanjary, K. Faez, M. R. Meybodi, M. Sabaei, "PersianGulf: An Autonomous Combined Traffic Signal Controller and Route Guidance System," *IEEE Vehicular Technology Conference*, 2011, pp.1-6.

[60] H. Dai, Z. S. Yang, X. J. Jiang, "Application of Fuzzy Control in Combined Algorithm between Traffic Guidance and Signal Timing," *Proceedings of the 2006 International Conference on Machine Learning and Cybernetics*,2006, pp.417-421.

[61] S. F. Ma, G. G. He, S. T. Wang, "A Hierarchical Coordination Model for Control Guidance Integrated System in ITS," *The IEEE 5th International Conference on Intelligent Transportation Systems*, Singapore, 2002, pp.522-527.

[62] X. M. Wang, S. F. Ma, Y. J. Li, "The Coordination Modes between Urban Traffic Control and Vehicle Route Guidance," *Proceedings of Conference on Intelligent Transportation Systems*, 2003, vol.2, pp.1633-1638.

[63] Q. Guan, Z. S. Yang, Y. Wang, J. M. Hu, J. Qin, "Research on the Coordination Optimization Method Between Traffic Control and Traffic Guidance Based on Genetic Algorithm," *The Fourth International Conference on Natural Computation*, 2008,pp.320-325.

[64] H. Dai, Z. S. Yang, X. G. Li, "Hierarchical Intelligent Control and Coordination of Urban traffic management Systems," *Proceedings of the 4th International Conference on Machine Learning and Cybernetics*, China, 2005, pp.1170-1174.

[65] J. T. Morgan, J. D. C. Little, "Synchronizing Traffic Signals for Maximal Bandwidth," *Operations Research*, 1964, vol.12, no.6, pp. 896-912.

[66] J. D. C. Little, "The Synchronization of Traffic Signals by Mixed-Integer Linear Programming," *Operations Research*, 1966, vol.14, no.4, pp.568-594.

[67] J. D. C. Little, M. D. Kelson, N. H. Gartner, "MAXBAND: A Versatile Program for Setting Signals on Arteries and Triangular Networks," *Transportation Research Record*, 1981, pp.1-28.

[68] N. H. Gartner, S. F. Assmann, F. Lasaga, et al., "MULTIBAND: A Variable Bandwidth Arterial Progression Scheme," *Transportation Research Record*, 1990, no.1287, pp.212-222.

[69] N. H. Gartner, S. F. Assmann, F. Lasaga, et al., "A Multi-Band Approach to Arterial Traffic Signal Optimization," *Transportation Research Part B*, 1991, vol.25, no.1, pp.55-74.

[70] C. Stamatiadis, N. H. Gartner, "MULTIBAND-96:A Program for Variable Bandwidth Progression Optimization of Multi-Arterial Traffic Network," *Transportation Research Record*, 1996, no.1554, pp.9-17.

[71] Z. Tian, T. Urbanik, C. Messer, et al., "A System Partition Approach to Improve Signal Timing," *Transportation Research Board*, 2003.

[72] L. L. Zang, L. Jia, Y. G. Luo, "Study on Dynamic and Cooperative Control for Neighboring Intersections On Traffic Arterial Roads," *Journal of Highway and Transportation Research and Development*, 2007, vol.24, no.7, pp.103-106.

[73] G. J. Shen, W. M. Xu, "Study on Traffic Truck Dynamic Two-direction Green Wave Control Technique," *Journal of Zhejiang University (Engineering Science)*, 2008, vol.42, no.9, pp.1625-1630.

[74] N. Ma, C. F. Shao, Y. Zhao, "Study of Coordination Control with Bandwidth Optimization for Signalized Intersections in Arterial Systems," *2010 International Conference on Optoelectronics and Image Processing*, 2010, vol.2, pp.425-430.

[75] NEMA, "NEMA Standards Publication TS 2-2003 v02.06," 2003.

[76] X. J. Kong, F. Xia, C. Lin, G. J. Shen, "Urban Arterial Traffic Intelligent Coordination Control Technique and Its Application," *Proceedings of the 8th World Congress on Intelligent Control and Automation*, China, 2010, pp. 5042-5047.

[77] J. Zhou, "Traffic Signal Coordination Control of City Arterial Road that Based on Graphic Method," *2011 International Conference on Electronic & Mechanical Engineer and Information Technology*, 2011, pp. 3562-3566.

[78] I. Porche, S. Lafortune, "Coordination of Local Adaptive Traffic Signal Controllers," *Proceedings of the American Control Conference*, Philadelphia, USA, 1998, pp.1833-1837.

[79] M. Papageorgiou, C. Diakaki, V. Dinopoulou, A. Kotsialos, " Review of Road Traffic Control Strategies," *Proceedings of the IEEE*,2003,vol.91,no.12, pp.2043-2067.

[80] N. Shah, S. Kumar, F. Bastani, I. Yen, "A Space-Time Network Optimization Model for Traffic Coordination and its Evaluation," *IEEE International Conference on Sensor Networks, Ubiquitous and Trustworthy Computing*, 2008, pp.177-184.

[81] H. F. Qian, Y. Z. Chen, Z. L. Li, Y. Z. Yang, "Research of Chang'an Street Coordinated Fuzzy Control Based on Traffic Flow Forecasting," *2009 World Congress on Computer Science and Information Engineering*, 2009, pp.39-42.

[82] X. R. Yang, D. H. Wang, "Study on City Area Traffic Coordination Control Based on Linear Programming," *2009 Chinese Control and Decision Conference*, 2009, pp.6034-6038.

[83] G. J. Shen, X. J. Kong, "Study of Road Network Traffic Coordination control Technique with Bus Priority," *IEEE Transactions on Systems, Man and Cybernetics, Part C: Applications and Reviews*, 2009, vol.39, no.3, pp. 343-351.

[84] C. X. Ma, J. W. Zeng, Y. S. Qian, X. P. Guang, Y. X. Sun, "Study on Urban Loop-road Traffic Coordination Control System Based on Split-layer Parallel Cusp Catastrophe Particle Swarm Optimization Algorithm," *2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics*, 2010, vol.2, pp.529-532.

[85] F. Gündogan, M. Fellendorf, "Pattern Recognition Method for Simplified Coordination Traffic Signal Control," *IEEE Forum on Integrated and Sustainable Transportation Systems*, Austria, 2011, pp.283-288.