PhD thesis subject

Title : **Autonomous Intersection Management (AIM) : Traffic Control and vehicle sequencing problem**

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Urban traffic control of modern cities, especially at intersections, has always been a crucial aspect of human civilization. In fact, the phenomenon of traffic congestion has become predominant due to the rapid increase in the number of vehicles and in the transportation demand. Especially over the last decade, traffic congestions have attracted great attention because of the worldwide energy crisis and environmental concerns.

The conventional method of preventing or reducing congestions in modern cities is based on traffic signals. The right-of-way is assigned to road users by the use of lights in standard colors (red - amber/yellow - green). This makes it possible to “solve” conflicts between traffic flows at intersections. The traffic signal control for intersections generally falls into two basic categories: pre-timed control strategy, which is also called the fixed–time control, and the semi/fully traffic actuated control. Both strategies are based on the estimation of traffic flow rates. Since the flow rate is a continuous variable that needs a period of time to be estimated, there are always big deviations between the last computed flow rate and the actual one. This makes it difficult to exploit the potential of traffic infrastructure to the maximum level.

However, the development in information systems provides us the opportunity to overcome this drawback. The technology of wireless communication like WiFi, WiMax and 3G enabled the Vehicle to Vehicle communication (V2V) and Vehicle Infrastructure Integration (VII), which enforce the link between vehicles, infrastructure and the driving environment. Besides, the advances in the fields of computation and sensor technologies lead to the emergence of fully autonomous vehicles, which take complete control of vehicle operations and eliminate the driver from the control loop. Various applications of autonomous vehicles have been demonstrated in the Europe, Japan and the United States. Under this background, the concept of Autonomous Intersection Management (AIM) has attracted great interests in the last decade.

In the framework of AIM, autonomous vehicles communicate with each other or roadside infrastructures to exchange the information of their states for ensuring the driver safety and increasing the travel efficiency. More specifically, based on VII technology, the roadside infrastructure at intersections, which can be seen as a controller, can communicate with approaching vehicles continuously. Vital vehicle data such as vehicle speed, position and destination are collected by advanced sensors and sent to the controller in real-time. Hence, it is possible to elaborate a traffic control strategy for each vehicle. In other words, the right-of-way is assigned to each vehicle according to its state and the state of the whole intersection. Only vehicles that have received the right-of-way can get through the intersection. The traffic control at intersection aims at determining the vehicle passing sequence, which is a sequence of distributing the right-of-way. This new traffic control strategy has great potential to exploit the capacity of intersection.

However, to implement this new control method, we mainly face two difficulties. First, how to exchange the information among vehicles or between vehicles and roadside infrastructure. Researches about wireless protocols and advanced devices used in autonomous vehicles were well studied. The second one, which is more important for us, how to find an efficient vehicle passing sequence to maximize the traffic throughput at intersections while maintaining driver safety. Most researches determine the vehicle passing sequence based on the simple control policy ``First In First Out" (FIFO). Although this policy requires very low computational cost, it limits the potential of maximizing the capacity of intersection. Recently, some researches pay more attention to optimize the vehicle passing sequences. Some authors enumerated all feasible vehicle passing sequences and used trajectory planning algorithms to find the most efficient one. However, they admitted that the algorithms were not efficient enough because the complexity increases exponentially with the number of vehicles and lanes. Thus, how to resolve the contradiction between vehicle sequence optimization and high computational complexity becomes a big challenge.

This subject is related to the field of traffic control in intersections with consideration of autonomous vehicles. It is the continution of the previous work of Fei YAN. He proposed Branch and Bound and dynamic programming algorithms to find an optimal sequence for an isolated intersection . These algorithms are designed based on carefully analysis of the problem properties. Moreover, and since congestions in modern cities are usually caused by several adjacent intersections located in dense street networks, he extend the proposed control strategy to multi-intersection networks. He proved that an exact algorithm can not be fast enough for multiple intersections and propose then a genetic algorithm to find an optimal or near optimal vehicle passing sequence for each intersection. This algorithm requires less time with ensuring the quality of solution. The final simulations with continuous traffic flow prove the good performance of his algorithms.

The candidate for this subject will continue the work already begun by Fei Yan. The objective is to further research especially in the coordination of several intersections to ensure better traffic and thus reduce congestion. Methods from combinatorial optimization will be considered. Also differences between normal vehicles and special used vehicles such as ambulances, police cars will be considered since special used vehicles should have the privileges to pass through intersection.

<u>Some related References</u>

Fei YAN
Contribution à la modélisation et à la régulation du trafic aux intersections: Intégration des communications Véhicule-Infrastructure
Phd Thesis. 14 Mars 2012. SeT Laboratory.UTBM

Fei Yan, Mahjoub Dridi, and Abdellah El Moudni.
A Scheduling Approach for Intelligent Vehicle Sequencing Problem at Multi-Intersection Networks.
International Journal of Operations Research, Vol 1, pp,57-68

Fei. Yan, Mahjoub. Dridi, and Abdellah .El-Moudni,
New Vehicle Sequencing Algorithms with Vehicular Infrastructure Integration for an Isolated Intersection.
Journal of Telecommunication Systems.Special issue on "Vehicular Communications, Networks, and Applications",

Fei Yan, Mahjoub Dridi and Abdellah EL Moudni,
Autonomous vehicle sequencing problem for a multi-intersection network: a genetic algorithm approach
International Journal of Applied Mathematics & Computer Science (to appear)