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Traffic Signal Green-Wave Control Strategy Based on Divers' Behaviors

The behaviour of vehicles runing in urban areas depends on the driver behaviour and also, their are influenced by traffic control and environmental factors. On the basis of this context and the increase, year by year, of the number of vehicles in urban areas, the authors are focused on finding solutions to use the current road infrastructure in an intensive manner. The paper presents a new model for a bidirectional green wave traffic signal control which is improved by the results of analyzing the relation between vehicles/drivers behavior and the movement of the vehicles and groups of vehicles. The authors will model this dependency using MATLAB software and the paper is concluded with the results of testing of several measures on this functional model.

Keywords: *urban arterial road, green-wave, drivers' behaviors, offset*

1. Introduction

Traffic congestion is a crucial problem in the urban road network, normally caused by an inadequate usage of road capacity. Therefore a lot of work in network transport and traffic research is currently under development and the authors are focused on finding solutions to use the current road infrastructure in an intensive manner.

Till now there are various approaches for the concept of a "green-wave", and it aims to reduce the number of stops and each delayed travel time of car in the rout [2]. The idea is to share the resources, in this case the road, between different users and the main scope is to assume a minimum travel time for each users. The basic research on this issue demonstrated a dependency among the different classes of vehicles (in terms of behavior), constrains imposed by road infrastructure and traffic congestions. The behavior of vehicles, running in urban areas, depends on the driver behavior and also, there is influenced by traffic measures generated by traffic control centers and operators, and various environmental factors.

This article aims to analyze an intelligent traffic green-wave control system, taking into account drivers' behavior [3], [4]. Vehicular Ad-Hoc Network (VANET) is also a highly promising technology for providing solutions to current road congestion problems [5], [6]. Thus, we assume that data collection, data processing and data analyzing are performed by VANET system agents (sub-network monitoring systems, base stations, vehicles, etc), and we propose an adjusted green wave algorithm for drivers' behavior.

Note that the "green-wave" strategy can be developed in conditions of relaxed traffic flow, if the configuration of urban arterial road is favorable – that consists in a route of great interest and less crowded secondary routes. In this case, it is the major importance the way we establish the traffic light cycle and red-green split depending of cars' number in the queue, and the green phase offset [1] between two intersections. If all traffic lights in a network have the same cycle time, one can also look at the "offset" of the intersections with respect to a global system time [7].

The urban vehicle traffic and drivers behavior are some of the most hazardous features. Therefore we chose to use for our project the fuzzy technology, which has the ability of mimicking human intelligence for taking decisions. The software based on MATLAB has been developed to calculate the "green offset" on a road section, with containing information from the neighbors being used through the simulation [8].

The paper is organized as follows: Section 2 contents an explanation of the traffic model. The third section deals with our experimentation methods and results. Section 4 concludes the paper. And section 5 contents some references which we have used in the paper.

2. Proposed model

Overview

First of all, we shall state our problem and some assumptions we made about it. According with our problem, we assume that all the roads under consideration are two-way roads, each side of them has 3 lanes; the required information level and data acquisition are provided by Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) wireless/wired communications technologies [5], [6]. We also assume that V2X system connected with a network of sensors will provide us an accurate information about the number and the vehicles type in queue, the divers' behavior on sections between two intersections (speed, the number of vehicles on lane), while the system has an knowledge database for information infrastructure (road section length, lines' number and speeding).

The proposed model for traffic signal green-wave control strategy is shown in Figure 1. In this figure the urban intersections are shown by letters by i, i+1, …, i+n. The ad hoc domain (VANET) is composed of vehicles equipped with OBUs (on-board units) and stationary units along the road RSUs (road-side units). Components of our proposed model and their functions are briefly summarized below [9].

On-board Units (OBUs)

On-Board Units are responsible for car to car and car to infrastructure communications. An OBU is equipped with at least a single short range wireless communications network device. The network device is used to send, receive and forward data in ad hoc domain [9].

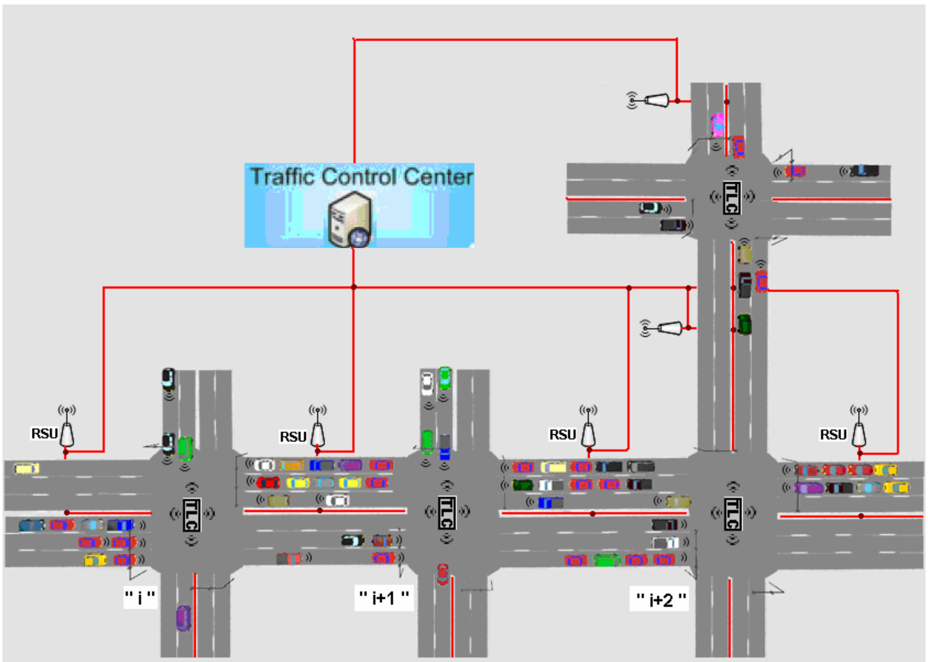

Figure 1. The proposed model for traffic signal green-wave control strategy.

Road-side Units (RSUs)

A Road-Side Unit is a physical device located at fixed positions along roads (and highways), or at dedicated locations (gas station, parking places, restaurants etc). An RSU is equipped with at least a network device for short range wireless communications radio technology. The main function of RSU are extending the communication range of an ad-hoc network, possibly running safety applications, possibly providing Internet connection to OBUs, possibly cooperating with other RSUs in forwarding or in distributing safety information etc [9].

Traffic Light Controller (TLC)

The traffic Light Controller has the function to adaptive calculate the cycle length and effective green time corresponding to each phase traffic light. We suppose that TLC can wireless/wired communicate with OBUs, RSUs, and other adjacent TLC, and takes in to account the physical presence of vehicles, and queue length of vehicles for deciding signal timing. It also takes in account the predictive travel time and driver's behavior to calculate the order of the phases and the offset between traffic signals at adjacent intersections [5], [6].

Traffic Control Center (TCC)

Traffic Control Center serves as the focal point for the management of the transportation system in urban area. It integrates data from a variety of different sensor sources and provides a means for operators to manage traffic and inform the public from a centralized point. TCC directly communicate with RSUs and TLCs, and examine data traffic information to identify potential traffic problems, and then develop strategies to address the problems. TCC often serve as the central media contact point for any urban road related problems [5], [6].

3. Experimentation methods and

In this chapter, we will concentrate on optimizing the offset between consecutive traffic signals and we will explain you the way we adjust the offset time depending on driver behavior. Additionally, we assume a common cycle time at each traffic signal, while all others parameters are fixed. Thus, we are going to choose the maximum length of the correlated intersections cycle time. Long Cycle times minimize stops while short cycle times lead to less delay.

The performance of traffic signal green-wave strategy can be measured by average delay travel and the number of stops. Other measures of performance, like preferences for public transport and pedestrians, aren't takes in consideration in this paper. Thus, we are looking for a preferment green-wave strategy for the main route, without affecting traffic on the secondary routes. In this case is very important the way we establish the cycle length and the offset between the phases of two adjacent intersections.

Cycle Lenght

One approach to determining cycle lengths for isolated pre-timed location is based on Webster's equation for minimum delay cycle lengths. Assume that the adjusted saturation flow rate is equal to 1800 vph, which it is corresponding to an headway equal to 1.00 [8].

$$C = \frac{(1.5 \cdot LT) + 5}{1 - \sum x_i}, \tag{1}$$

Where:
C – traffic light cycle length;
LT – Lost Time per cycle in seconds;
$\sum x_i$ - degree of saturation for Phase I;
x_i = Observed Flow/Adjusted Saturation Flow Rate;

Since traffic flow is composed of various vehicles, the volume is expressed as the number of average passenger cars per time unit. For each vehicle type there can be determined an equivalent number of passenger cars. This number is determined on the basis of the fact that various vehicles need different time to pass through the intersection [10]. Table 1. presents the equivalent passenger car units for vehicles [11] , adjusted for our arterial urban roads, when going straight or turning.

Table 1. Equivalent number of passenger cars

Vehicle Type	Straight (pcu/s)	Turning(pcu/s)
Passenger car	1	1
Bus	1.7	2
Heavy truck	1.7	2

Green Time Distribution

The distribution of the green time for a pre-timed signal should be proportional to the critical lane volumes on each phase:

$$G = C - \sum_{i=1}^{M} (Y_i + LT_i), \tag{2}$$

Where:
G – net green time;
Y_i - Yellow time per the phase *i* in seconds;
LT_i - Lost time per phase *i* in seconds;
M – number of phases;

For an arterial road of "n" intersections, we choose the maximum cycle length;

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$$C = \max\{C_1, C_2, ..., C_n\}, \tag{3}$$

Offset optimization is the essentially analysis in our chosen model. In the literature we can found different approaches of the signal coordination problem, but all of them have in common the offset optimization problem. Generally, in literature is suggested that the offset time to be calculated with:

$$\tau_{i,i+1} = \frac{l_s}{v_m}, \tag{4}$$

Where:

l_s - length of road segment;

v_m - average speed of vehicles (on the road segment);

Offset Adjustment

For our approach we propose the below algorithm for the offset calculation:

$$\tau_{adjust} = t_{i,i+1} - t_d, \tag{5}$$

$t_{i,i+1}$ – travel time of vehicles between intersection *i* and intersection *i+1;*

t_d – the time of queue vehicles discharge of intersection *i+1;*

$$t_{i,i+1} = \frac{l_s}{v_m} \cdot k_i, \tag{6}$$

k_i - offset adjustment constant. . According to the degree of each parameter influence, the adjusted offset is calculated as below.

$$k_i = \sum x_i, \tag{7}$$

The offset parameters are: weather (x_1), age/experience (x_2), and events (x_3). Traffic measurements have shown that weather (such as rain, fog, snow) can influence the traffic flow up to 20 km/h; age/experience (old man driver, inexperienced driver) corresponds to 15 km/h; and minor events (minor accident witch occupy a single line, emergency car warning etc) up to 10 km/h. Table 2 aims to show you the dependence between average speed and the different type of parameters.

Table 2.

No. Crt.	Weather (x_1)	Age/experience (x_2)	Events (x_3)	Speed ($v_{i,i+1}$)
1	Good weather conditions	20-40 years old	No events	50 km/h
2	Adverse weather conditions	18-20 and 40-65 years old	Minor events	40 km/h
3	Severe weather conditions	65-80 years old		30 km/h
4	-	-	Major events	>30km/h

$$t_d = SLT + h \cdot N + t_{vm}, \tag{8}$$

$$\tau_{adjust} = \frac{l_s}{v_m} \cdot k_i - (SLT + h \cdot N + t_{vm}), \tag{9}$$

Where:
SLT – Start Up Lost Time [s];
t_{vm} – time unit to reaches the average speed [s];
N – vehicles number [veh/lane];
h – headway factor [s];
$v_{i,i+1}$ - speeding of the road section;

Evaluation of offset algorithm

In the final of our study, we have developed an fuzzy logic program [12 – 15], to automatically calculate the offset coefficient (k_i), depending on the hazardous features (weather, age/experience, minor events). We perform three experiments of offset evaluation, based on 50 km/h, 40 km/h and 30 km/h corresponding features. In each experiment, we have varied the inputs and we have analyzed the offset value, as is shown in the below Figure 3.

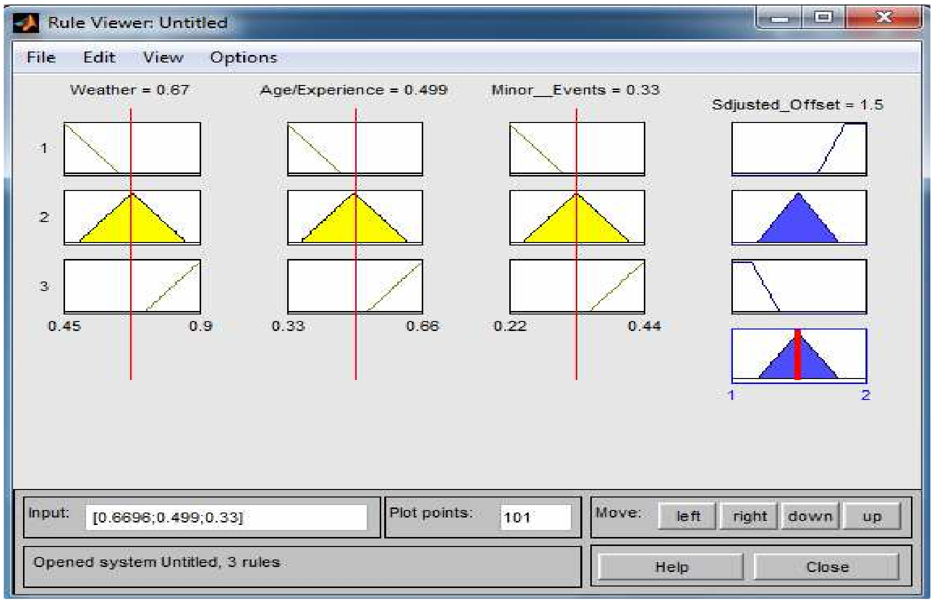

Figure 2. Input and output values of the fuzzy logic model.

In Table 3 there are the initial traffic data conditions that we take in account for our analyses. As you can see, we have used only three adjacent intersections for simulation, enough to highlight our approach. Although the Cycle Length, Brut Green Time and initial offset were calculated according formulas presented above, we considered them as part of initial conditions.

Table 3.

Inters number	Distance [m]	Speeding [km/h]	W-E Volume [vph]	N-S Volume [vph]	SLT [s]	Cycle Length [s]	W-E Green Time [s]	$\tau_{i,i+1}$ [s]
i	-	-	800	500	5	72	39	-
i+1	380	50	450	300	5	35	15	7.4
i+2	290	50	900	500	5	80	45	9.2

Simulations showed that for an inadequate offset calculation, more than 50% of vehicle will receive red light before pass through the artery road, and this automatically increases the travel delay. Of course that is difficult to reach the limit case of our approach (30 km/h), but this cannot be omitted. In our approach we didn't consider the major events (accident that takes more lanes, average speed < 30 km/h), because this case the control light cannot improve the traffic flow. As you can see below, Table 4 presents results obtained during the testing.

Table 4.

x_1	x_2	x_3	Common Cycle [s]	k_i	Average Speed [km/h]	τ_{adjust} i,i+1 [s]	τ_{adjust} i+1,i+2 [s]	Stop Number ($\tau_{i,i+1}$)	Stop Number (τ_{adjust})
1	1	1	80	1	50	7.4	9.2	1	1
0.67	0.5	0.33	80	1.5	40	5.5	7.75	up to 2	1
0.9	0.66	0.44	80	2	30	4.3	5.3	up to 2	1
-	-	<0.44	80	<2	>30	-	-	-	-

4. Conclusions

In this paper we have proposed a new "two directional green wave" control algorithm that takes in account the driver's behavior. According with our approach, it is clearly that in this case traffic flow will be improved by reducing stop number and each car's delay travel. To calculate the offset adjustment constant we have used a fuzzy logic simulator, while the remaining results are simply mathematical calculations. The main advantages of using a fuzzy logic model are the simplicity of the approach. This is because the fuzzy logic can capture human expertise better through manual adjustment of membership functions. Simulations have shown that using fuzzy systems, we can have satisfactory results even if with a small number of information.

The next steps especially focus on the improvement our algorithm by taking in account others parameters like driver fatigue, or time of day (in terms of behavior), for adjusted offset constant. An improvement of the algorithm will lead to better performance of the green wave control sistem, and the existing resources of the road and traffic light can be full used.

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