Cooperative Application of Vehicular Traffic Rerouting Method and Adaptive Traffic Signal Control Method

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Adaptive traffic signal control method

As a method of adaptive control of traffic signals, it is proposed to use the method of maximum weighted flow MaxPWFlow. The detailed description of the adaptive traffic light control method MaxPWFlow is presented below in pseudocode form (Algorithm 1), where τ_{min} is minimum phase switching interval; t_p is the duration of the current active phase $p \in P$ of the traffic signal; P is the set of traffic signal phases, $phase$ is the next phase, selected by MaxPWFlow method.

Algorithm 1: Maximum weighted flow method

Input data: τ_{min}, t_p, p, P

Output data: $phase$

if $t_p < \tau_{min}$ **then**

$t_p = t_p + 1$

$phase = p$

else

$t_p = 0$

$phase = \operatorname{argmax}\left(\{PWFlow(p) \text{ for } p \text{ in } P\}\right)$

end if

The predicted "weighted" flow of vehicles is calculated using the following formula:

$$PWFlow(p) = \sum_{l \in L_p^{income}} \sum_{c \in C_l} \eta(c,l) I\left(t(c) < \tau_{min}\right),$$

where L_{phase}^{income} is the set of incoming lanes to the considered intersection; C_l is the set of vehicles located on the lane l; $t(c)$ is predicted time based on a deterministic predictive model [6] required by the vehicle c to reach the intersection; I is the indicator function; $\eta(c,l)$ is the vehicle waiting time coefficient.

Vehicular traffic rerouting method

The vehicular traffic rerouting method consist of four stages that are performed periodically. At the first stage, information about the current state of the road network is collected and preprocessed. At the second stage, road segments with high congestion levels are selected. Next, search for nearby vehicles to reroute is performed when there are signs of congestion on a certain road segment. Finally, the rerouting is performed by A* with repulsion algorithm.

This paper presents a modified version of known vehicular traffic rerouting method. There are two main modifications of the base method:

1) In contrast to the original method, the proposed modification of this method presented in this paper takes into account the state of the traffic light-controlled intersections closest to the corresponding vehicle by lane level graph weights adjustment. Let the rerouting time period $\tau_{reroute}$ be equal to the minimum phase switching interval of traffic lights τ_{min}; τ_{yellow} be a yellow traffic signal time; p_{in}^{out} be the current active traffic signal for connection between incoming lane in and outcoming lane out, $\tilde{p}_{in}^{out}$ be the next traffic signal for connection between incoming lane in and outcoming lane out. Then the internal connection weight of the controlled intersection w_{in}^{out} is calculated as follows:

$$w_{in}^{out} = \begin{cases} 0, & p_{in}^{out} = green \wedge \tilde{p}_{in}^{out} = green \\ \tau_{min}, & p_{in}^{out} = green \wedge \tilde{p}_{in}^{out} = red \\ \tau_{min} + \tau_{yellow}, & p_{in}^{out} = red \wedge \tilde{p}_{in}^{out} = red \\ \tau_{yellow}, & p_{in}^{out} = red \wedge \tilde{p}_{in}^{out} = green \end{cases}$$

2) The calculation of footprint of road lane, that estimates the future impact of each vehicle in the road network on its congestion level, is also changed. The farther the route segment is located from the initial position of the vehicle, the less it should have an impact on the rerouting process, since rerouting can be repeated while the vehicle is moving to its destination. Therefore, we propose to use the following definition of footprint n_i:

$$n_i = \sum_{c \in C} \sum_{j=0}^{len_{r_c}-1} \alpha^j I(r_{c_j} = i),$$

where C is the set of all vehicles in the transport network; len_{r_c} is the length (in a number of edges) of route r_c of vehicle c; r_{c_j} is the j-*th* road lane of route r_c; α is the coefficient of impact.

Experiments

Experimental studies of the effectiveness of the proposed method were carried out using the SUMO (Simulation of Urban Mobility) modeling system. The experiments compared the proposed modified method of traffic rerouting and the original method. At the same time, traffic lights at intersections were controlled by an adaptive traffic signal control method MaxPWFlow.

During the experiments, the simulation was performed 10 times for each of the considered scenarios, the results were averaged. The starting positions and departure times of the vehicles were different in different episodes of the same scenario. Experimental studies were carried out with a simulation step of 1 second and a total simulation time of 3600 seconds. The results of comparing the methods are presented below. The conducted experiments confirm the effectiveness of the proposed vehicular traffic rerouting method in cooperation with the adaptive traffic signals control method according to all the considered criteria.

	Average fuel consumption, ml			Average travel time, s			Average waiting time, s		
Scenario	**Proposed method**	**Original method**	**Without rerouting**	**Proposed method**	**Original method**	**Without rerouting**	**Proposed method**	**Original method**	**Without rerouting**
«grid4x4»	**200516.06**	210352.41	356808.55	**188.73**	202.07	397.90	**38.59**	42.97	192.40
«cologne8»	**70391.32**	74023.71	74050.43	**84.31**	89.21	89.28	**3.49**	3.89	3.92

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