Poster Abstract: Real-Time Adaptive Signaling for Isolated Intersections

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1. INTRODUCTION

Efficient design is required for a cyber-physical system, as we need to trade off the complexity and performance benefits. We consider the CPS of a traffic-light controller at an isolated intersection that is used by autonomous, semi-autonomous, and human-driven automobiles. Existing traffic systems are vulnerable to accidents (more than 1 million people die in automotive accidents globally) and undesired traffic delays (the average U.S. driver spends a week stuck in traffic every year). The next generation of traffic-light control systems should protect against these disruptions while maintaining enhanced control of the system to optimize features of interest. The potential benefits of such a system include increased safety in the presence of higher density traffic, increased fuel and time efficiency (as less time is wasted in queuing), and decreased demands on drivers to make driving decisions. Here, we demonstrate a novel approach to adjusting the cycle length, yellow time, and red-to-green ratios of a traffic signal by minimizing the average loss per vehicle due the presence of the signal.

2. MATHEMATICAL MODEL

The following model is developed for simulating the real-time traffic scenario. When the light is green, vehicles seek to travel at some cruising speed. When the light turns yellow/red, approaching vehicles decelerate and brake if needed. Some first vehicle that can possibly do so stops at the red light while others behind it maintain a minimum safe distance (as would be determined by adaptive cruise control). After a switch back to green, vehicles that have stopped or slowed accelerate until they reach their cruise velocity, all while maintaining an assured clear distance.

Required Input Parameters: Distance of the car from intersection, velocity of the car, braking power, and maximum acceleration.

Safety Constraints: The stopping distance of a car is defined as the distance in which it can stop after applying its brakes. Assuming uniform vehicle parameters simplifies the calculation of the safe following distance,, which then depends only on the initial velocities and braking deceleration of the two cars and the reaction time of the follower. Of course, the reaction time may vary significantly between human-driven and autonomous vehicles, but as long as vehicle properties are similar the above calculation of assured clear distance is sound [1].

Arrival of Cars: In our current simulations (though this is easily changed), vehicles arriving at the intersection are modified Poisson arrivals. If cars were points, then Poisson arrivals would be a reasonable model. But the imposed safety constraint means a safety time (safe distance converted to time) is added to the inter-arrival time that would otherwise be observed, giving a slightly reduced arrival rate. This correction is important when comparing results to approximations, such as Webster's equation, that arise from analytical models.

3. OPTIMIZATION

3.1 Performance metrics

Distance Lost: Average per-vehicle distance a car would have been ahead of the actual car location if there had been no traffic signal

Time Lost: Same as distance lost, except it is time

Fuel Lost: Same as distance lost, except it is fuel

3.2 Optimal signal timings

Various loss scores that combine the performance metrics can be devised. The goal is to adjust the green, yellow, and red phase timings to minimize the total loss score—in real time. It appears this is feasible.

4. REFERENCES

[1] Loos, S.M., Platzer, A., and Nistor, L., "Adaptive Cruise Control: Hybrid, Distributed, and Now Formally Verified", Proc 17th Intl Symp Formal Methods, LNCS 6664, Springer, 2011, 42-56.

[2] Pavlic, T., *et al.*, "Comments on Adaptive Cruise Control: Hybrid, Distributed, and Now Formally Verified", OSU CSE Dept TR22, July 2011.

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