Real-time Intersection Optimization (RIO) for Signal Phase and Timing and Automated Vehicles Trajectory

Mahmoud Pourmehrab, Lily Elefteriadou, Sanjay Ranka
University of Florida Transportation Institute (UFTI)

Introduction

One upon a time ...

1915-1923, Washington, D.C.

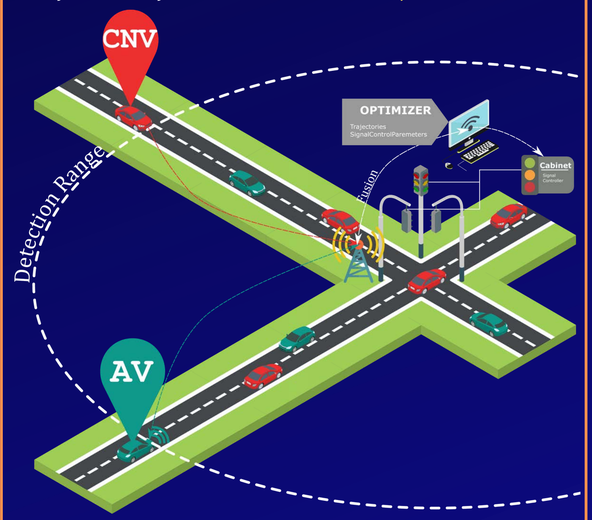
1922, Philadelphia

Automation has been impacting intersection control as well as vehicles.

How to enhance intersections operation under traffic of Automated Vehicles (AVs)?

Proposed Control Algorithm

Consider the following intersection with a central computer to optimize SPaT and AV trajectories:



Optimization Framework

Mathematical programming can be used to model intersection performance based on SPaT and AV trajectories decisions. For instance, the following model minimizes the travel time delay of a lead AV subject to signal parameters, acceleration capabilities, and speed limit:

$$\text{LAVO: } del^*_{n_l} = \min_{v_{n_l}(t^1_{n_l}), v_{n_l}(t^3_{n_l}), a^1_{n_l}, a^3_{n_l}} \sum_{i=1}^{3} (t^i_{n_l} - t^{i-1}_{n_l}) - \frac{d_{n_l}(t^0_{n_l})}{V^{des}_{n_l}} \quad (1)$$

subject to

$$t^s_\phi(t) \le \eta_{\phi l} \times (t^3_{n_l} - t^0_{n_l}) \le t^s_\phi(t) + G_\phi(t) + Y_\phi(t) \quad \forall\ \phi \in \Phi \quad (2)$$

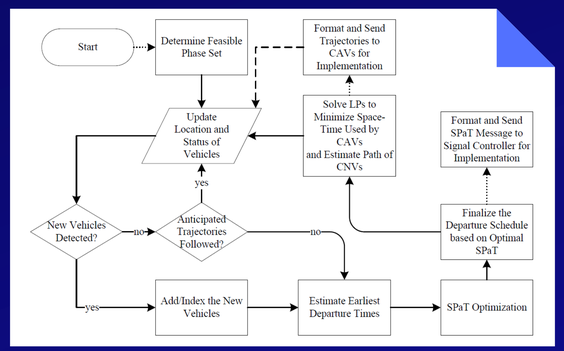
$$0 \le v_{n_l}(t^1_{n_l}) \le V^{max} \quad (3)$$

$$0 \le v_{n_l}(t^3_{n_l}) \le V^{cross}_{m(n_l)} \quad (4)$$

$$a^{dec}_{n_l} \le a^1_{n_l} \le a^{acc}_{n_l} \quad (5)$$

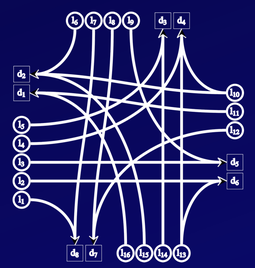
$$a^{dec}_{n_l} \le a^3_{n_l} \le a^{acc}_{n_l} \quad (6)$$

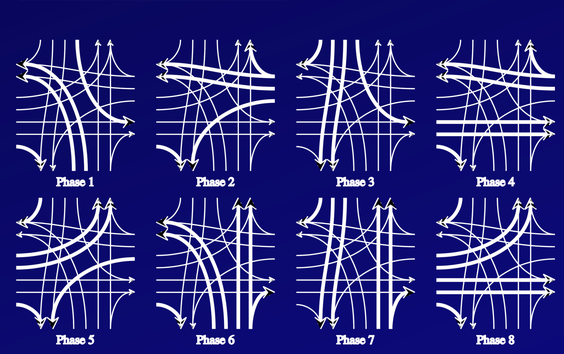
The proposed control algorithm functions under mixed traffic of AVs and conventional vehicles (CNVs) in real-time. It aims to achieve coordination among incoming vehicles and SPaT through joint optimization. The input to the algorithm includes vehicles arrival data, and the output is consist of optimized trajectories and SPaT commands to AVs and the signal controller, respectively, to be implemented.



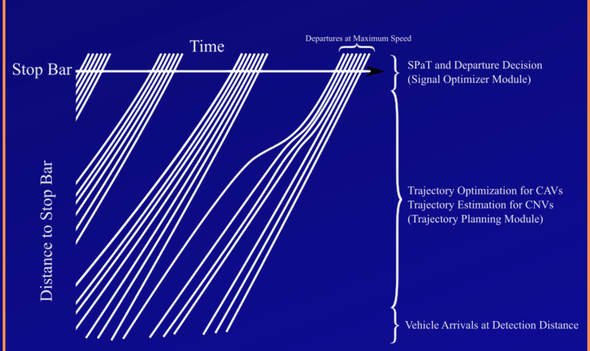
Simulation Experiments

Feasible phase set determination for the test intersection:

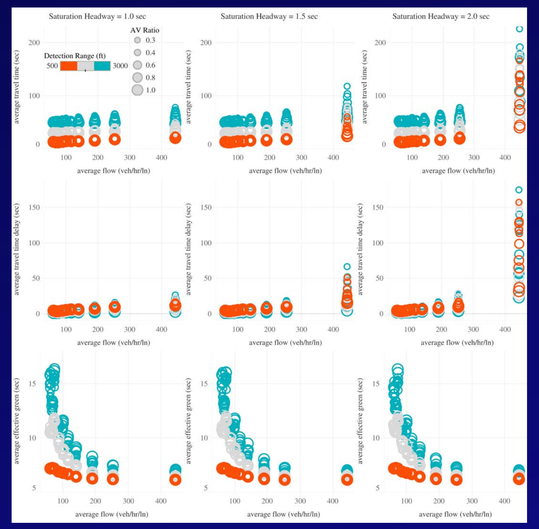




Using the proposed algorithm vehicles cross the intersection at maximum discharge speed and at lowest discharge headway.



Results and Conclusions



- Capacity also increase with increase in AV ratio. (optimized trajectories are more coordinated with SPaT which increases green utilization.)
- Capacity increases as the saturation headway decreases.
- The average delay slightly decreases as the detection range increases.
- Comparison of the algorithm to operations with a fully actuated signal control shows 38 to 52% reduction in average travel time.

Acknowledgement

- NSF Grant No. 1446813
- Florida Department of Transportation (BDV31-977-45)

(For more information visit avian.essie.ufl.edu)

Reference:
Pourmehrab, Mahmoud, et al. "Optimizing Signalized Intersections Performance under Conventional and Automated Vehicles Traffic." arXiv preprint arXiv:1707.01748 (2017).