Intersection Management with Constraint-Based Reservation System

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April 16, 2014

Transportation Infrastructure: Present and Future

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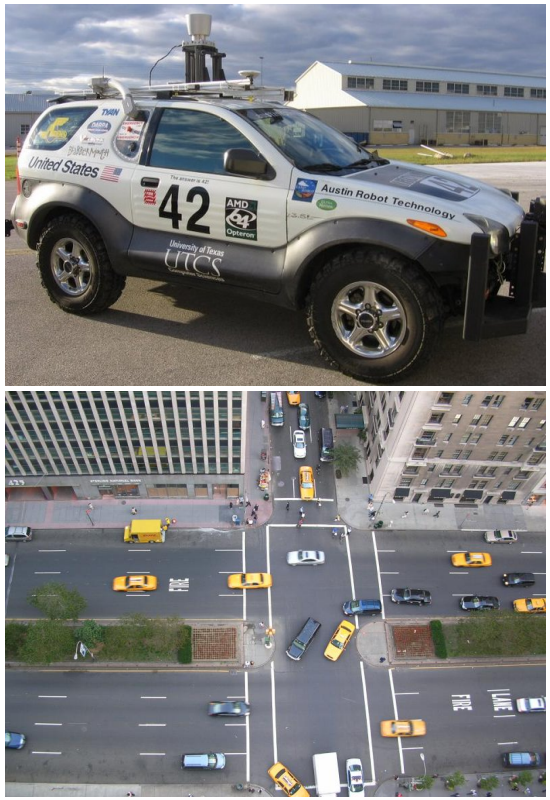
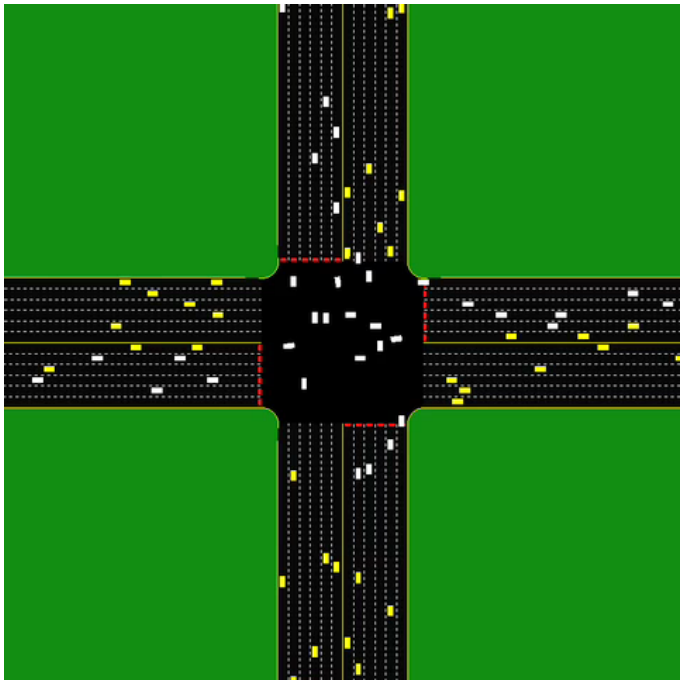
- In the future: **Autonomous Intersection Management**
  Utilize the capacity of autonomous vehicles to improve traffic in transportation systems.

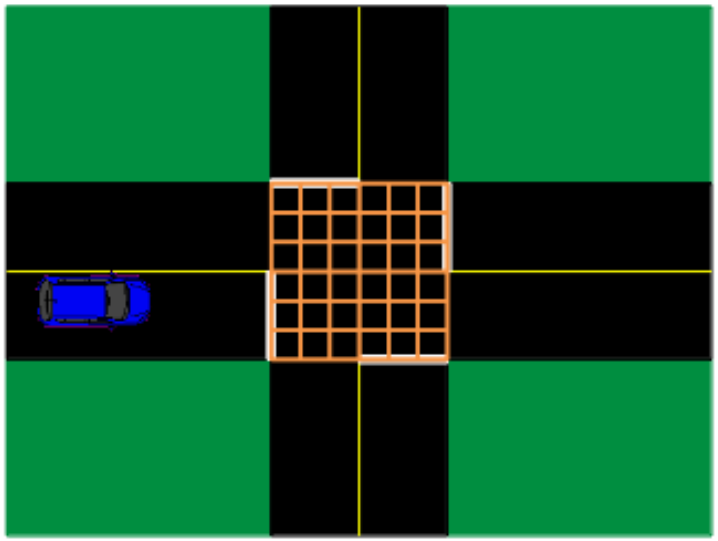


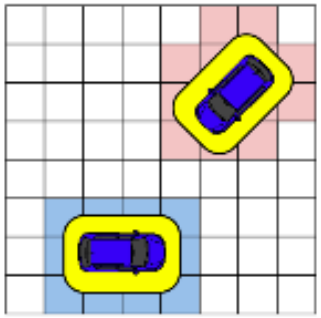
Autonomous Intersection Management



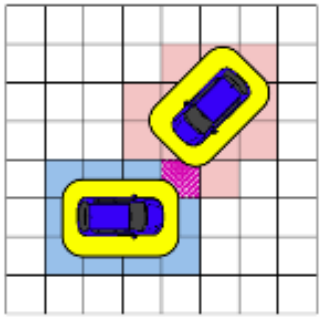
- Dramatically reduce the traffic delay.
- Reduce the overhead of fuel consumption by approximately two thirds. [Dresner and Stone, 2008]

Grid-Based Collision Detection





Accept



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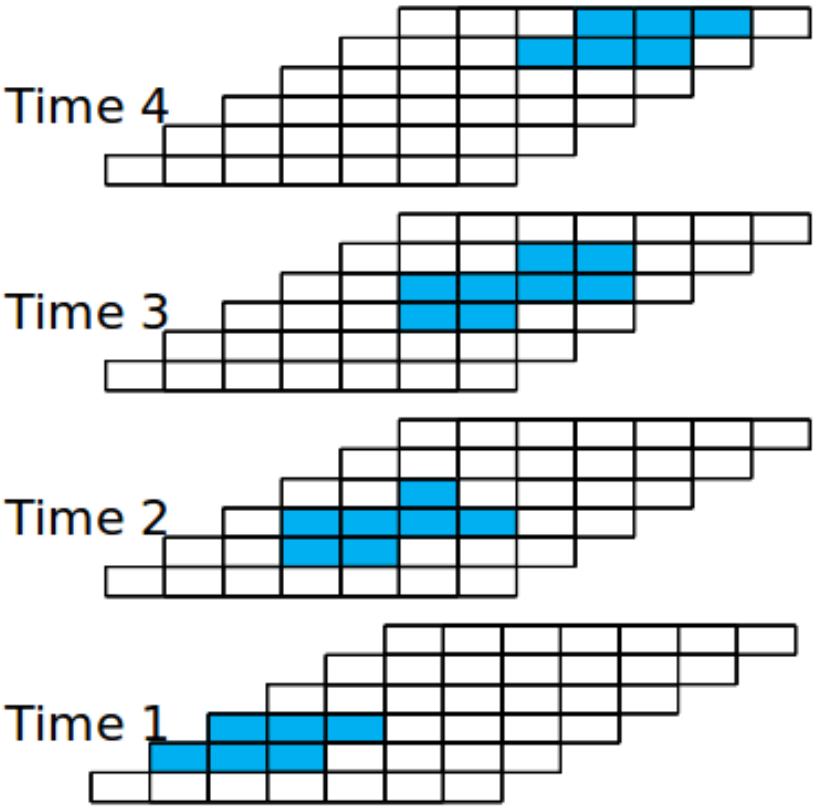

Sharing the Road with Human Drivers

- AIM is designed for the time when vehicles are autonomous.
- Autonomous vehicles won't displace manual-controlled vehicles in one day. Some people enjoy driving.

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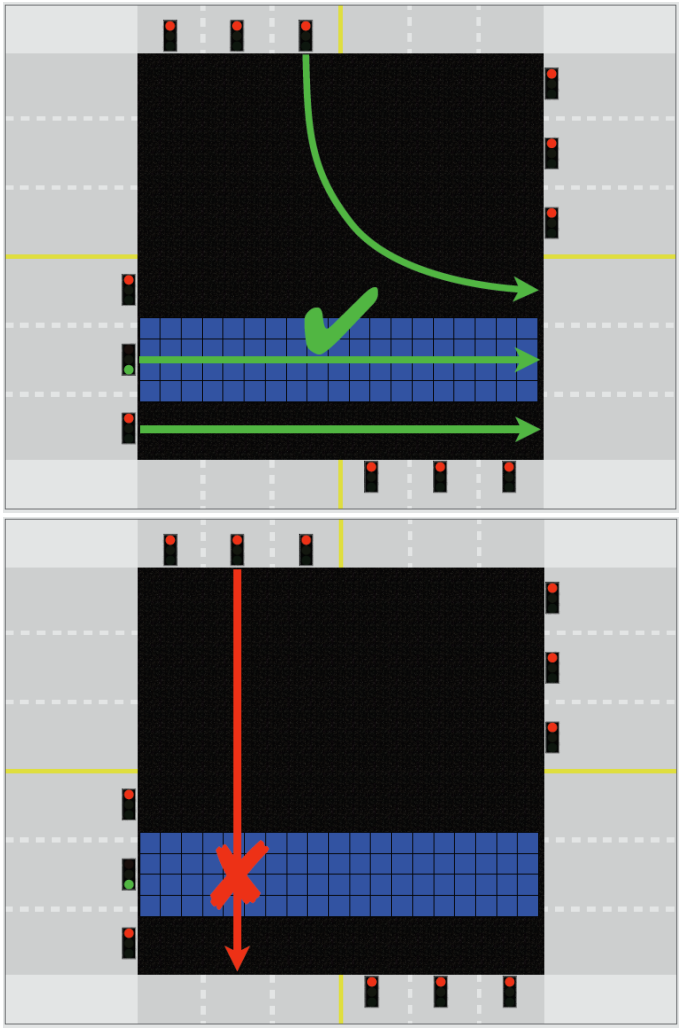
- Autonomous vehicles won't displace manual-controlled vehicles in one day. Some people enjoy driving.
- One solution: FCFS-light = First-Come First-Served Policy + Traffic Signals



Observation

- This ignores the possible equipments of human-driven vehicles (e.g. cruise control).
- **Goal**: find a way to make all types of vehicles to achieve the benefits (better than traffic signal, may not be as good as fully autonomous vehicles).

Definition

Semi-autonomous vehicles: vehicles with limited autonomous driving and wireless communication capabilities.

They are able to follow a *limited number* of predictable trajectories at intersections more precisely than human drivers.

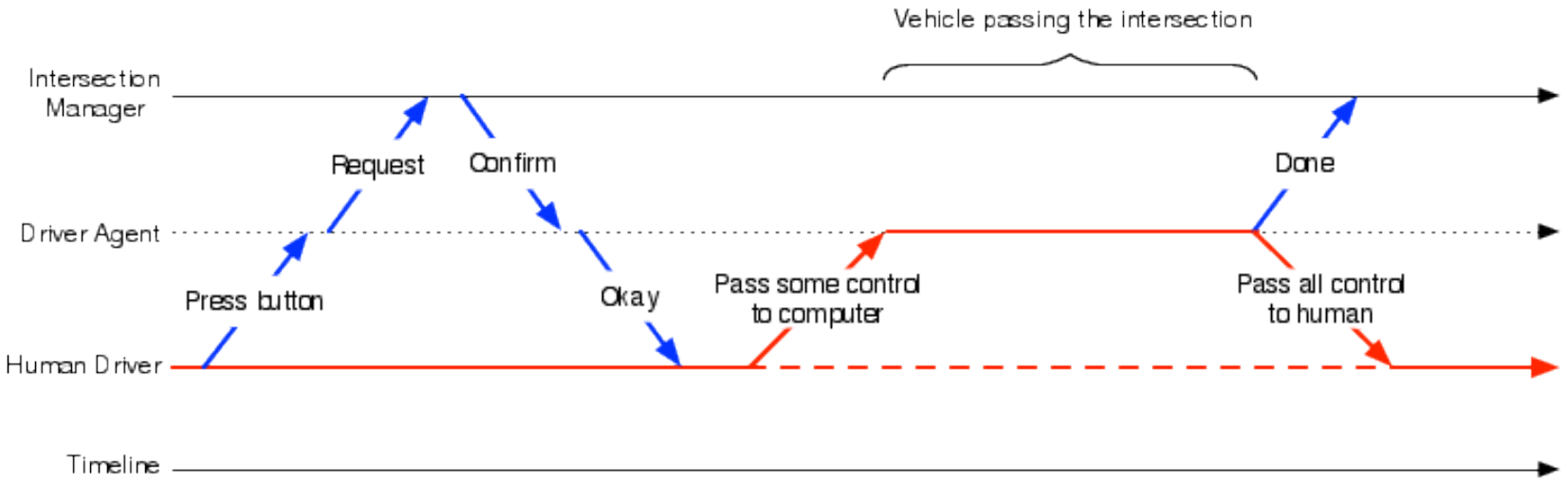
Set of Equipments

- **Communication Device (Com)**: a component in a vehicle's on-board electronic system that enables the vehicle to wirelessly communicate with the transportation infrastructure including the IM.
- **Simple Cruise Control (CC)**: An optional speed control subsystem in vehicles' drivetrain that automatically controls the vehicle speed by taking over the throttle of the vehicles.
- **Adaptive Cruise Control (ACC)**: an advanced cruise control system that automatically adjusts the speed of a vehicle in order to maintain a certain distance from vehicles ahead.

Type of Semi-Autonomous Vehicles

Vehicle Type	Communication Device	Cruise Control	Adaptive Cruise Control
SA-ACC	X	X	X
SA-CC	X	X	
SA-Com	X		

Interaction Model



Constraint-Based Reservation

We turn AIM into a *constraint-based reservation system*, which allows vehicles to make reservations in terms of constraints over

- their driving profiles such as their arrival time and arrival velocity
- the relationships with other vehicles.

Basic Elements

- **Intention**: The direction in which the vehicle intends to move.
- **Vehicle Type**: The type of vehicle.
- **Entry Condition**: The condition under which the vehicle will enter the intersection.
- **Acceleration Profile List**: The list of possible acceleration schedules from among which the vehicle will choose one to follow during the traversal of the intersection.

Constant-Velocity Request

- Intent $= (l_1 \vee l_2 \vee \ldots \vee l_n)$ in which l_i is a possible lane from which the vehicle exits the intersection;
- Type is the vehicle type;
- Entry $= ((l'_1 \vee l'_2 \vee \ldots \vee l'_n), [t_1,\ t_2], [v_1,\ v_2])$ is the entry statement; and
- AP $= (\langle (t_1, 0) \rangle)$

This is particularly used by Simple Cruise Control.

Whole-Row Request

- Intent $= (l_1 \vee l_2 \vee \ldots \vee l_n)$ l_i is a possible lane from which the vehicle exits the intersection;
- Type is the vehicle type;
- Entry $= ((l'_1 \vee l'_2 \vee \ldots \vee l'_n), [t_1,\ t_2], [v_1,\ v_2])$ is the entry statement; and
- AP is the acceleration profile list.

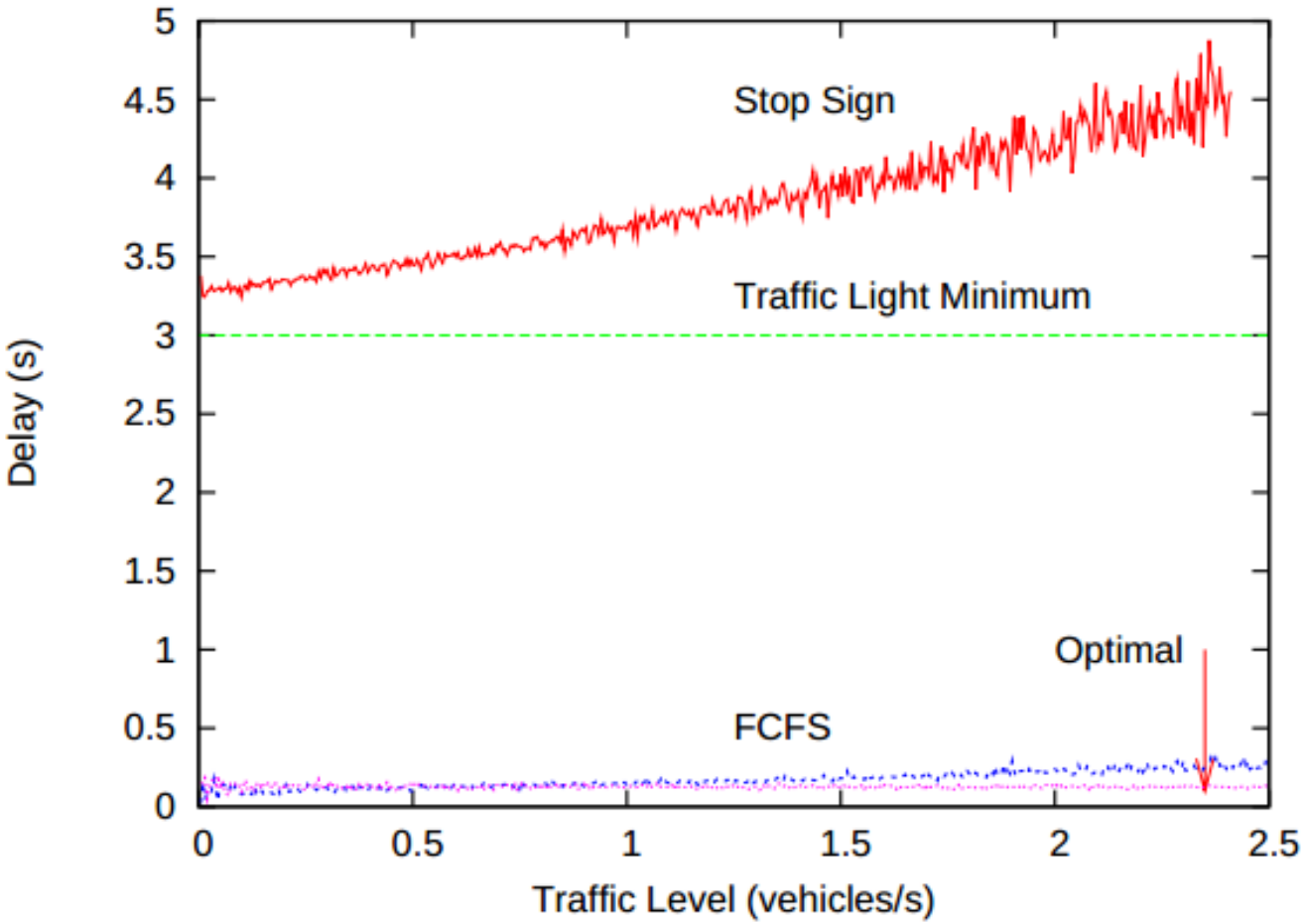
This is particularly used by Communication Device.

An General Request

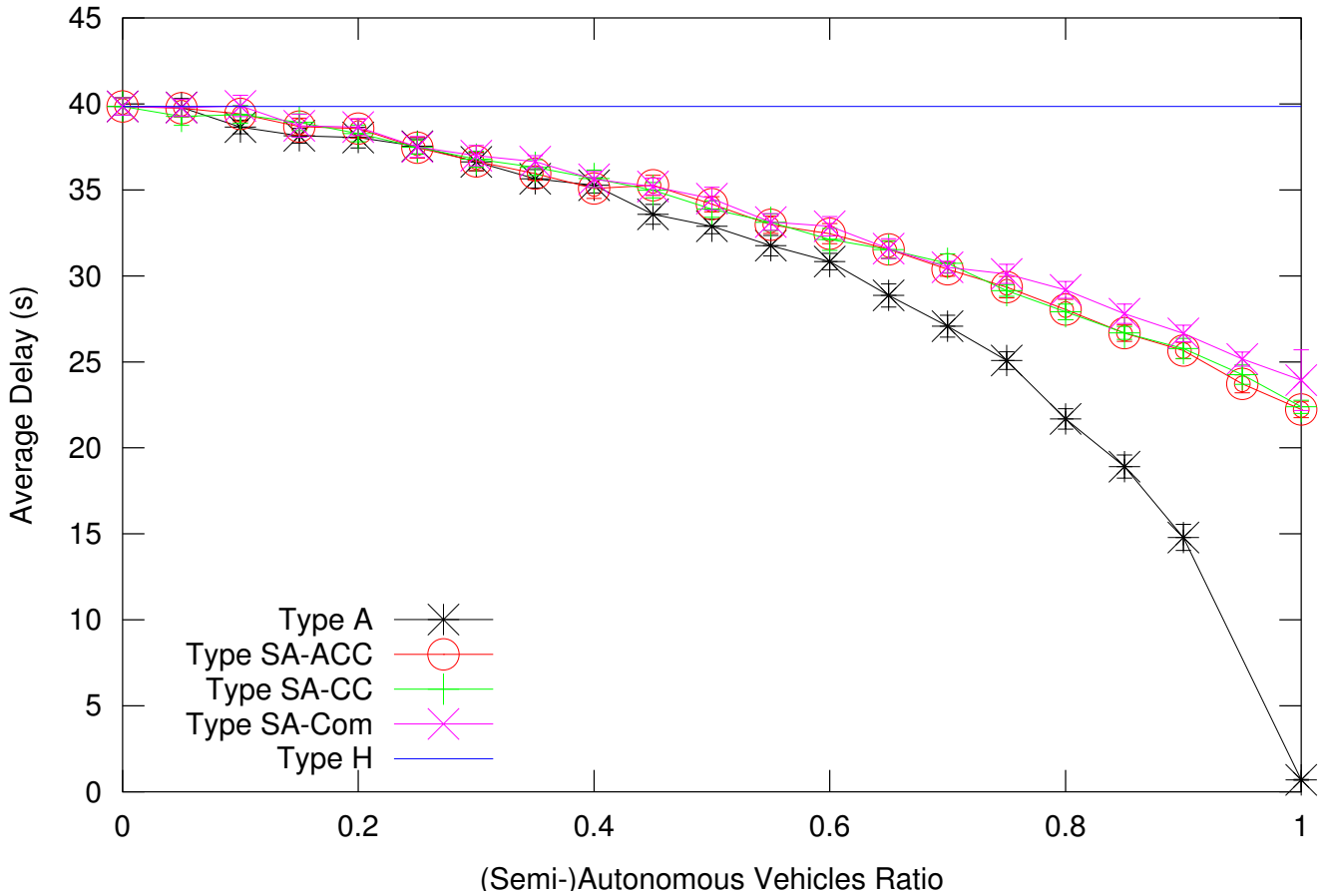
In Lisp syntax,

```
(cc-profile (v verror angle)
  (is-auto-speed-control)
  (not is-auto-steering)
  (< velocity (+ v verror))
  (> velocity (- v verror))
  (< steer-angle angle) (> steer-angle -angle))
```

Evaluation on AIM

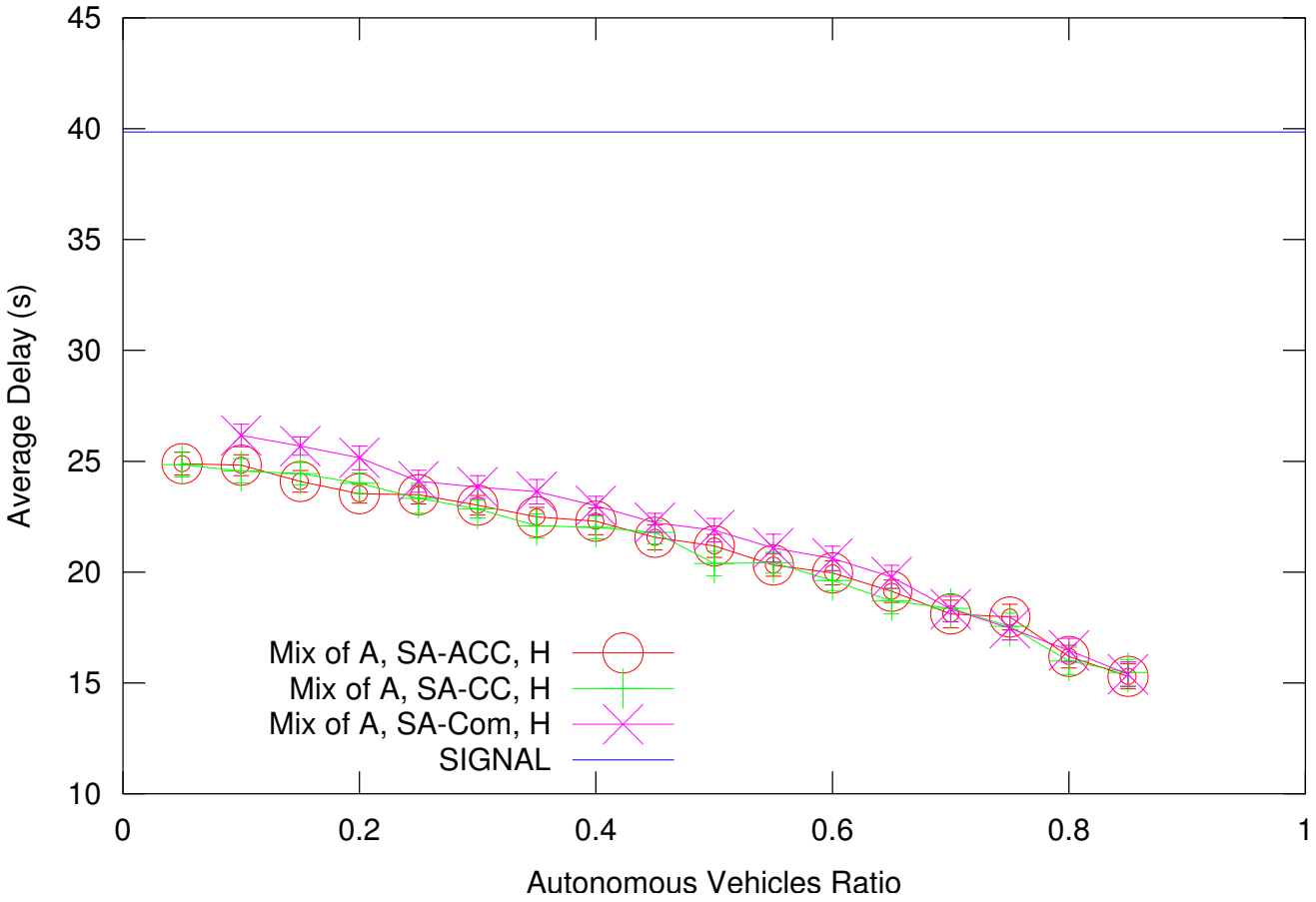


Evaluation on SemiAIM



(Semi-)Autonomous vehicles vs. Human-Driven vehicles. Traffic level = 360 vehicles/lane/hour.

Evaluation on SemiAIM



The average delay according to a deployment schedule. Traffic level = 360 vehicles/lane/hour.

Related Works

- The main context of our work is an extension to the FCFS policy proposed by Dresner and Stone [Dresner and Stone, 2008].
- Similar to the analysis of adaptive cruise control performance by Jerath and Brennan [Jerath and Brennan, 2010].
- Part of a series of robotic car competitions such as the *DARPA Grand Challenges* [DAR,].
- Autonomous vehicles can even outperform many human drivers in carrying out intricate maneuvers [Squatriglia, 2010].
- etc.

Conclusion

- SemiAIM is the first multiagent protocol to enable smooth interactions between human-driven, fully autonomous, and semiautonomous vehicles.
- Our initial experiment showed that our system can greatly decrease trafc delay when most vehicles are semiautonomous, even when few (if any) are fully autonomous.

Bibliography


DARPA grand challenge.
http://en.wikipedia.org/wiki/DARPA_Grand_Challenge.


Dresner, K. and Stone, P. (2008).
A multiagent approach to autonomous intersection management.
Journal of Artificial Intelligence Research (JAIR).


Jerath, K. and Brennan, S. N. (2010).
Adaptive cruise control: Towards higher traffic flows, at the cost of increased susceptibility to congestion.
In *AVEC'10*.


Squatriglia, C. (2010).
Audi's robotic car drives better than you do.
http://www.wired.com/autopia/2010/03/audi-autonomous-tts-pikes-peak.