EINDHOVEN UNIVERSITY OF TECHNOLOGY

Platoon Forming Algorithms For Intelligent Street Intersections

Rik Timmerman, 02-07-2019
Joint work with Marko Boon

Applied^2 Probability Workshop

Outline

- Introduction
- Model description
  - Platoon forming algorithms
  - Speed regulation of vehicles
- Performance analysis
  - Mean delay
  - Fairness
  - Case study
- Conclusions

Self-driving vehicles introduction

Waymo is gearing up to put a lot more self-driving cars on the road

Kirsten Korosec @kirstenkorosec / 3 months ago

Comment

Self-driving vehicles introduction

Model assumptions

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- There is a central controller at the intersection.
- There is a control region around the intersection.
- Speed regulation of vehicles is possible.

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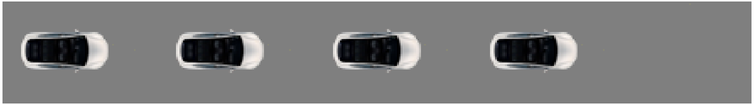

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Speed regulation of arriving vehicles

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$$\texttt{MotionSynthesize}(z_{i,k}(t'_0), t'_0, t'_f, y) :=$$

$$\begin{aligned}
\underset{x:\,[t'_0,t'_f]\to\mathbb{R}}{\arg\min} \quad & \int_{t_0}^{t_f} |u(t)|dt \\
\text{subject to} \quad & \ddot{x}(t) = u(t), \text{ for all } t \in [t'_0, t'_f]; \\
& 0 \le \dot{x}(t) \le v_m, \text{ for all } t \in [t'_0, t'_f]; \\
& |u(t)| \le a_m, \text{ for all } t \in [t'_0, t'_f]; \\
& |x(t) - y(t)| \ge l, \text{ for all } t \in [t'_0, t_f]; \\
& x(t'_0) = x_{i,k}(t'_0); \quad \dot{x}(t'_0) = \dot{x}_{i,k}(t'_0); \\
& x(t'_f) = 0; \quad \dot{x}(t'_f) = v_m,
\end{aligned}$$

(After Miculescu and Karaman, 2016)

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- a vehicle is at the right time at the right place and at the right speed;
- the amount of acceleration is minimized;
- no collisions occur.

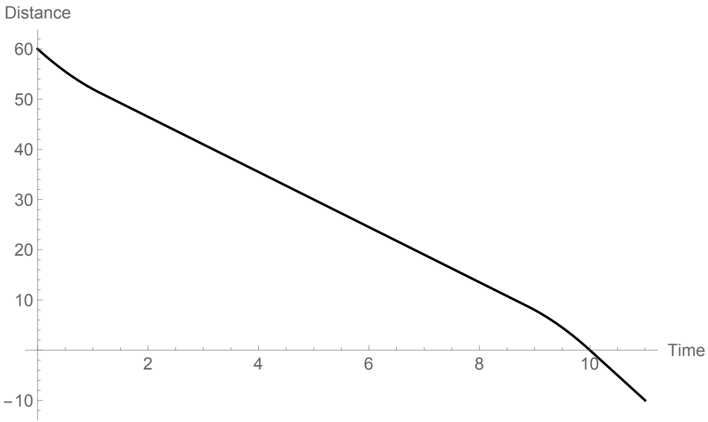
Speed regulation of arriving vehicles

This results in the following control:

$$a(t) = x''(t) = \begin{cases} -a_m & \text{if } t_0 \leq t < t_1, \\ 0 & \text{if } t_1 \leq t < t_2, \\ a_m & \text{if } t_2 \leq t < t_3, \\ 0 & \text{if } t_3 \leq t < t_f, \end{cases}$$

for certain known and computable t_1, t_2 and t_3 and fixed t_f.

Speed regulation and a link to queueing



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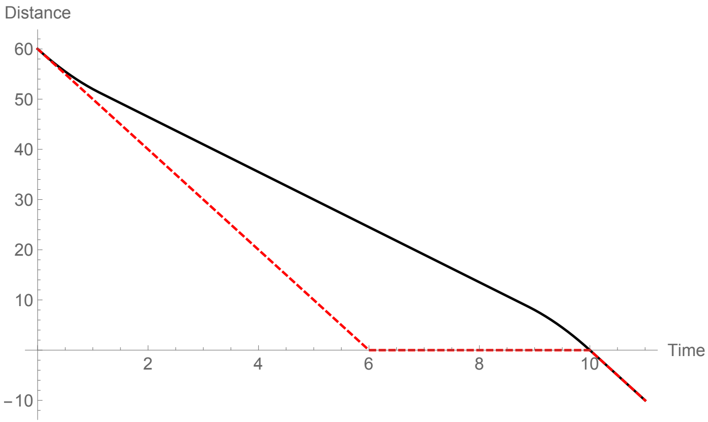
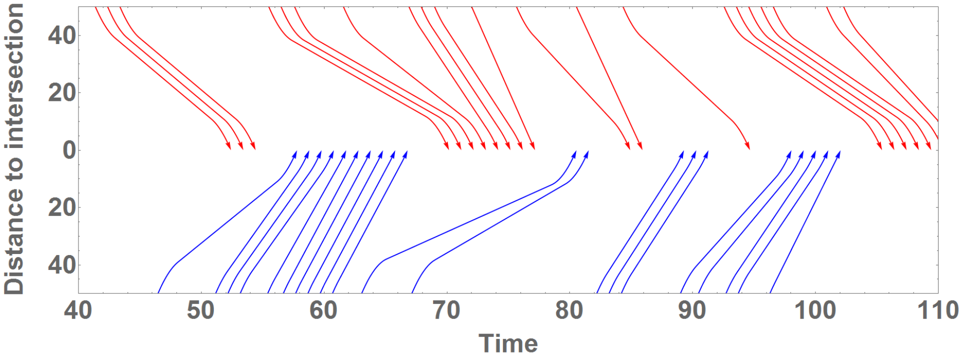


Example with two streams of vehicles



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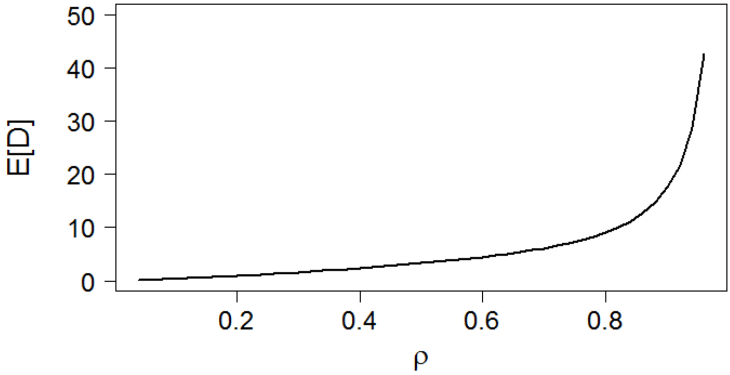
$$\mathbb{E}[D_i] = \frac{K_{0,i} + K_{i,1}\rho_i + K_{2,i}\rho_i^2}{1 - \rho_i},$$

where ρ_i is the load on the intersection and with carefully chosen constants $K_{0,i}$, $K_{1,i}$ and $K_{2,i}$.

Approximations – mean delay



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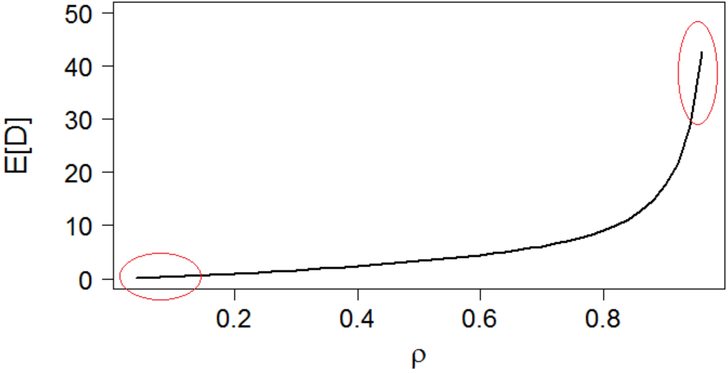

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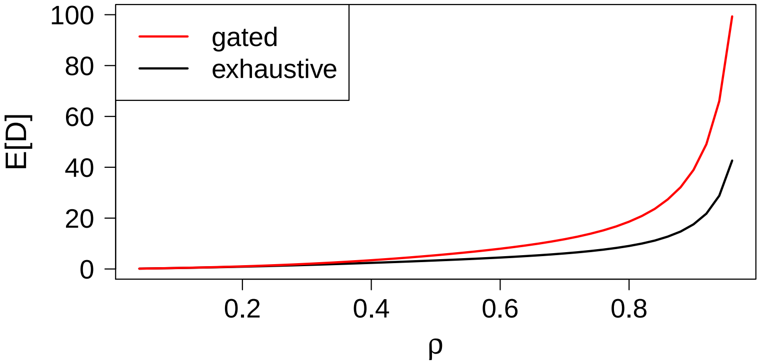

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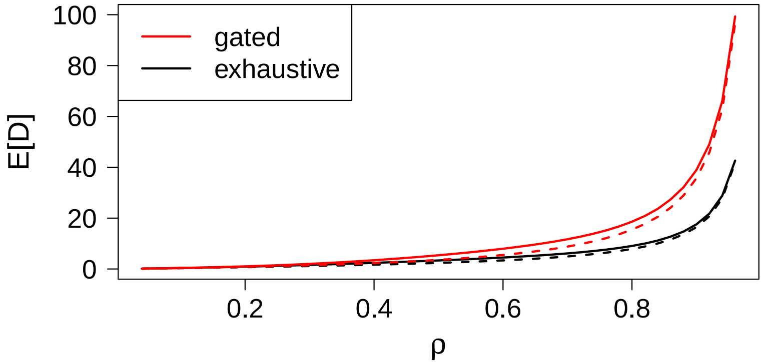

Simulations – fairness

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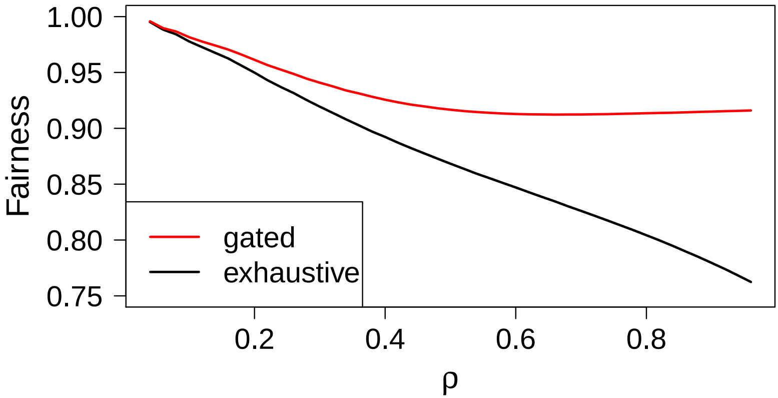
We define fairness as:

$$F = \frac{\mathbb{E}[Y]}{\mathbb{E}[X]},$$

where X is the number of cars seen by an arbitrary arriving vehicle and Y is the number of cars from those X that leave the system before that arbitrary car does (Shapira and Levy, 2016)

Simulations – fairness



Case study – SUMO

To represent the current traffic situation with conventional cars, we perform a simulation in SUMO

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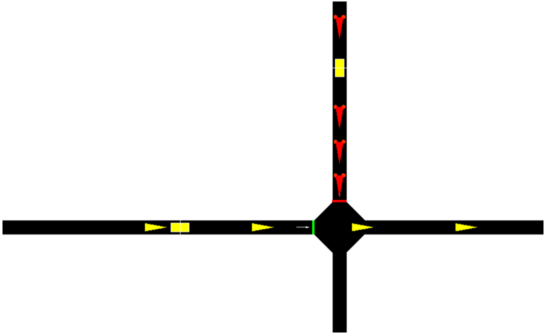

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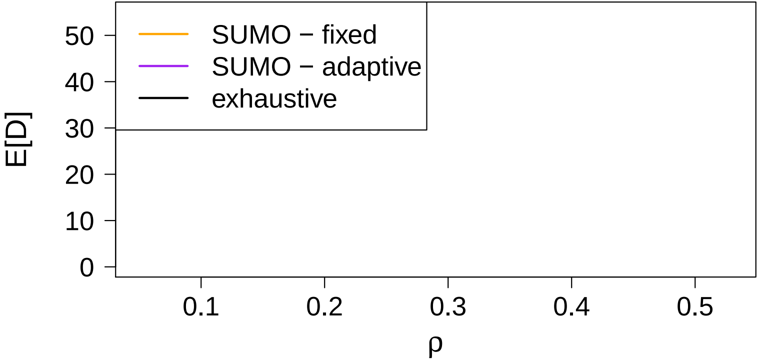

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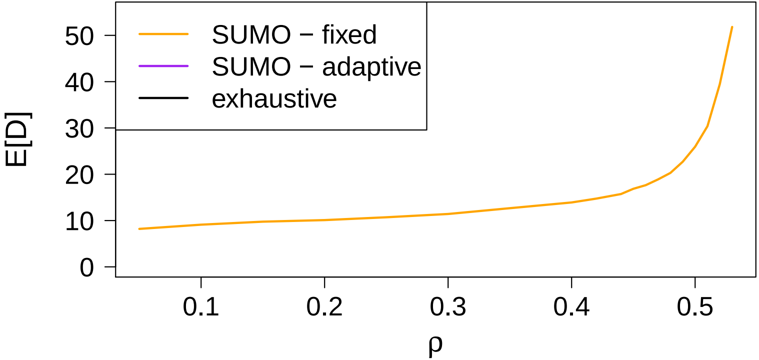

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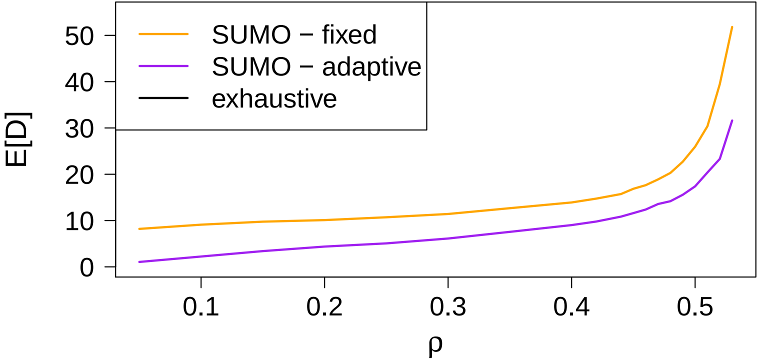

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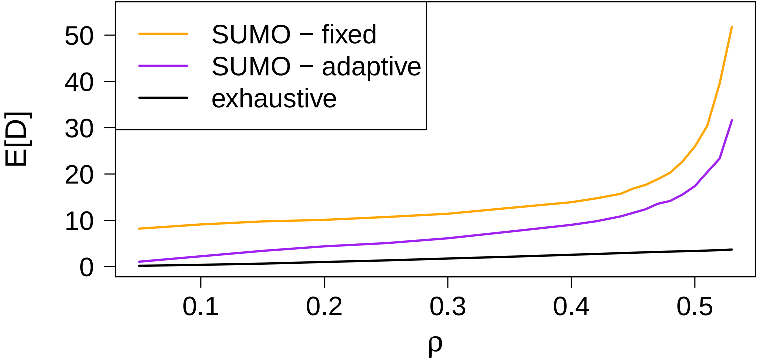

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- The exhaustive PFA is performing very close to optimality with respect to mean delay.
- There is a lot to be gained, using platoon forming and speed regulation.
- We have been looking at an *isolated* intersection. What about networks?

Thank you for your attention!