Self-driving Vehicles, Can They Be Safe in Mixed Traffic?

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See webpages for publications by us. Some illustrations taken from the web, acknowledged

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Göteborg / Gothenburg

- Chalmers university
- Volvo Trucks
- Volvo Cars
- AutoLiv
- Zenseact (Zenuity)
- Veoneer
- + more suppliers

Research in cooperation with, mainly, the local automotive industry eco-system
Is the problem solved? You are welcome to join this Open House event

Zenseact Open House: Explore why cars drive better than humans

Join our Open House event on the 10th of May and discover the secrets of self-driving technology
Human decisions requires slow speed
Outline of the talk and for algorithms for self-driving vehicles

• One vehicle: Traffic situation is known – just calculate the optimal trajectory.
• If several autonomous vehicles are involved – communicate and solve as above.
• Traffic situation change, “surprises” due to other road users’ decisions: repeat optimization frequently, MPC.
• Possible surprises known, described them with probabilities and include in the optimization.
• So far, decision problem described as based on traffic situation. This means no interaction. More realistic: Other road users react on your decision. This is feedback with delay – dangerous.
Objectives

- Shorter travel time
- Energy efficiency

- Higher throughput
- Less infrastructure

- Verified safety
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Formulate decision: steering and velocity as an optimization problem

\[
\max_{Vehicle \ commands} \quad Vehicle \ Performance
\]

Subject to

- Vehicle dynamics
- Control authority
- Performance requirements
- Collision avoidance

Challenges:

- Knowledge of traffic situation now and future
- Real-time solving the optimization
Predicting other vehicles, human driven or self-driving

Three approaches:

1. Vehicle model, s(t), v(t), a(t), steering
2. Based on logged data
3. Or combination of both

• Green vehicle can be predicted using the logged data.
• Easy to predict, as long as no surprise decision taken.

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Several collaborative self-driving vehicles

\[
\max_{\text{number of vehicles}} \sum_{i=1}^{\text{number of vehicles}} \text{Performance Vehicle } \#i
\]

Subject to:

- Vehicle dynamics
- Network delays and information losses
- Control authority
- Performance requirements
- Collision avoidance

- The optimization problem becomes more complex
- Solution dependent of reliable communication
Experiments with Wifi (802.11p)

View from Vehicle 2

Velocity
Distance to intersection
Acceleration

Solving SQP
Timeslot Control Active
Mixed traffic – reduce uncertainty of human driven vehicles by placing them in platoons with collaborative autonomous vehicles.

In this way, the platoons can be scheduled in a similar way as if there were individual cooperative autonomous vehicles.

Muhammad Faris, Paolo Falcone, Jonas Sjöberg, ”Optimization-based Coordination of Mixed-Traffic at Unsignalized Intersections Based on Platooning Strategy”, accepted in 33rd IEEE Intelligent Vehicles Symposium (IV), 2022.
Experiments with 5G PoC at AstaZero

The use of the communication system is part of the optimization problem.
Pedestrians are hard to predict

- The road seems clear – cross the road
- One vehicle arrives and stops
- Second vehicle....
- ... and now they change their mind and turn around and go back.
Pedestrian prediction based on data

- Also possible, stochastic model
- Rational pedestrian has a goal
- Pedestrain follow Newton’s laws…
- But not the traffic laws!

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Experimental results

Time dependent pedestrian pattern

- Pedestrian movement change over the day.
- Autonomous vehicle receives statistics while approaching the crossing and can optimize its decision taking with respect to that.

Collective Decision Making using Attractive and Repulsive Forces in Markovian Opinion Dynamics, Carl-Johan Heiker, Paolo Falcone, Pre-print
Some insights

• Predicting pedestrians decision making can never reach 100%.
• A safe algorithm should limit speed so that emergency stops are possible.
• Hence, speed should be low if pedestrian are present.
• Good stochastic prediction models can however lower the risk of (unpleasant) emergency braking. And in that way permitting a higher speed than without the models.
Pedestrian prediction with low uncertainty

- Solutions like this are necessary to allow speed and safety.
- Pedestrians must be kept away!
- It is similar, with human driven vehicles if safety is prioritised.
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Interaction at zebra-crossing

• So far, decision taking depending on the traffic situation

• Interaction, ie two controllers in the loop

• This is, in general, not good, especially not with a human 1 second delay

• Possible oscillation between two possibilities
Two decision makers: Cascade control

• If inner loop is much faster than outer loop stability is easy to analys.

• In traffic this means that the one making fast adaptations, should adapt to the slow one.
Who makes the fast decision?

- This depends on the traffic situation
- A fast vehicle is approaching the pedestrian crossing
  - Pedestrian is faster and “should” adapt to the vehicle. If not, the vehicle must reduce speed to become a fast decision maker
- A T-crossing
  - Slower vehicle can change its speed faster
Reflections

- This makes sense
- but means
- and we don’t want the pedestrian to be in command.
- Just “Safe mixed traffic” is not the traffic system we want. Something must be changed.

- Maybe automatic penalty or fee for rule breaking.
- Rewards for “well-behaving” road users. Necessary also between autonomous vehicles for smooth traffic
Is the problem solved?

- Not in mixed traffic if we want speed and 100% safety
- Separation is one possible solution