Vehicle-to-Vehicle Communication for Autonomous Vehicles: Safety and Maneuver Planning

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V2V can help autonomous driving!
Extended sensing horizon

Ego Vehicle

Out-of-range vehicle
Intention sharing

Ego Vehicle
Outline

Safety

Accidents involving AVs

Accidents potentially avoided

Using V2V

Maneuver planning

Lane change and turns

NLOS sensing and intention sharing

Quantifying the benefits of V2V
Safety
Autonomous vs Conventional (State of the art)

Autonomous vehicles not necessarily safer

**Conventional (2015) [1]**
Miles driven: 3,095,373 million
Accidents: 6,296,000
Accidents per 100 million miles driven

**Waymo (aka Google) (2016/17)**
Miles driven: 988,412 [2][3]
Accidents: 10 [3]
Accidents per 100 million miles driven

More than 4x higher accident rate for autonomous cars

Example rear end collision

Waymo AV 09/07/2016

Safe distance

[1] https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/autonomousveh_ol316
Waymo AV 09/07/2016

At stop sign, Waymo advances forward at 5 km/h to gain view

[1] https://www.dmv.ca.gov/portaldmv/detail/vr/autonomous/autonomousveh_ol316
Passenger van moves forward at 11km/h and causes accident
Example rear end collision

Forward Collision Warning deactivated for speeds below 32 km/h [2]

Intention sharing using V2V can help

Waymo AV 09/07/2016

Passenger van moves forward at 11km/h and causes accident

Red light running accidents

771 deaths and 137,000 injuries in 2015

Waymo vehicle got hit after it’s light was green for more than 6s

At 35 km/h, an AV will has a stopping distance of 18.3 m with LOS sensing

The road design permits on 6.6 m view [1]

With V2V range of 107 m [2], an AV can make safe stop for up-to 90 km/h

### Accident Classification

Accidents reported to DMV in 2016/2017

<table>
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<th>Accident Type</th>
<th>Lane Change</th>
<th>Rear-end</th>
<th>Intersection</th>
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<td>V2V can help</td>
<td>6</td>
<td>8</td>
<td>1</td>
<td>1</td>
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</tr>
</tbody>
</table>

V2V possibly helpful for 100% of the relevant accidents

V2V possibly helpful for 80% of the total accidents involving autonomous cars
Maneuver planning
LOS sensing based maneuver planning not necessarily optimal
Maneuver planning

Better path planning with V2V: NLOS sensing and trajectory sharing

Ego Vehicle
Objective: Reach left-most lane
Subsequent travel at maximum allowable speed

Maneuver planning

Three maneuvers
- Stay in lane
- Change to right
- Change to left

Maintain speed, accelerate, or decelerate
Lane change will take ~5 seconds [1]
Search for the shortest path using A* [2]
Forward simulation to check feasibility

Sensing and communication assumptions

Vehicle awareness

Trajectory awareness

LOS only

Vehicle awareness

Trajectory awareness

LOS + V2V

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Example Run

Red: LOS only Ego Vehicle
Blue: V2V enabled Ego Vehicle
Black: Currently detected vehicles
Magenta: Current undetected vehicles
Line segments: vehicles detected via LOS sensing

Results

Averaged time

Trajectory information helps more than NLOS sensing
Turn Maneuver

Objective: Make right or left turn
Saves time in urban driving

Right turn takes 6.5 sec [1]
Left turn takes 7.5 sec [1]
LOS sensing based on sight triangles
Vehicles arrive at the intersection with exponential rate

Example Run

Red: LOS only Ego Vehicle
Blue: V2V enabled Ego Vehicle
Black: Currently detected vehicles
Magenta: Current undetected vehicles
Line segments: vehicles detected via LOS sensing

Results

Averaged time

Percent savings higher in left-turn maneuver
Conclusion
Conclusions

V2V can help in reducing the accidents involving AVs

V2V can reduce the time to left-most lane by up to 42%

V2V can help reduce the time of left and right turn by 47% and 36% respectively

Sharing current speed/velocity is not sufficient – trajectory sharing is needed
Thank you!
Backup slides
Sensors provide noisy measurements

V2V enabled

Upto 60% savings in lane change maneuver with V2V