Safety Impacts of Automated Vehicles in Mixed Traffic

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Objectives

- Analyzing the real AV involved crashes
- Developing a behavioral framework for simulating different levels of automation
- Investigating the safety impact of interaction of AVs with human-driven vehicles regarding the crash rate

Introduction

- The economic impacts of traffic crashes in the US amounted to $836 billion of losses in 2010
- Humans are contributing to 94% of the crashes
- AVs can potentially improve the current state of the transportation by removing human-errors from the system
- The question is: what is the impact of AVs on the safety performance of the system?

Background in AV Crashes

- Since September of 2016, the Google AVs have driven more than 2 million miles in autonomous mode on public roads
- In California State, every company testing their AVs on public roads have to report their car crashes to the Department of Motor Vehicles
- The database for this section is 31 AV involved crashes from October 2014 to May 2017

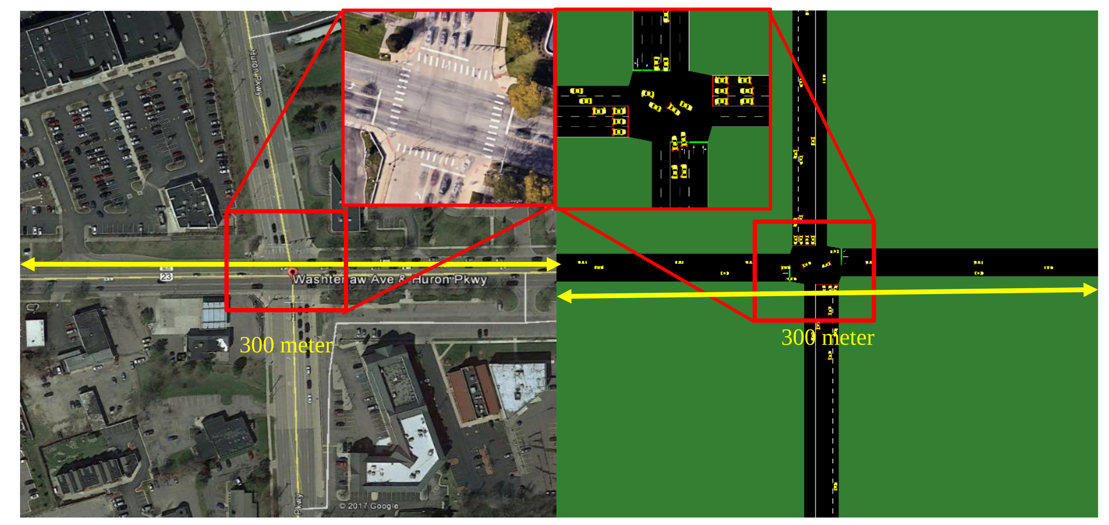
Crash location	
intersection	25 (80.6%)
other	6 (19.4%)
Operation mode	
autonomous	22 (71%)
manual	9 (29%)
Crash type	
rear-end	19 (61.3%)
angle	5 (16.1%)
side-swipe	7 (22.6%)
Number of vehicles involved	
1	2 (6.5%)
2	28 (90.3%)
3	1 (3.2%)
Pedestrian or bike involved	
Yes	1 (3.2%)
No	30 (96.8%)
Severity	
property-damage-only	26 (80.6%)
minor injuries	5 (19.4%)
AV at fault	
Yes	5 (19.4%)
No	26 (80.6%)

- **Results:**

1. In almost all of the crashes, the human-driven vehicle was at fault, however, there is one crash that AV failed to yield the right of way to other car and led to the collision → at this stage, we cannot assume that AVs are errorless
2. Similar to conventional vehicles, AVs are more probable to have a crash at an intersection in comparison with other locations
3. Rear-end crashes are the most frequent type of the crashes

Simulation

Software: SUMO (Simulation of Urban MObility)
Location: intersection of Hurson Pkwy and Washtenaw Ave (150 meters from the center)
Duration: 3 months
Intersection Characteristics:
➢AADT of the real intersection
➢Speed limit of 40 and 45 mph
Vehicle Characteristics:
➢Maximum acceleration : 3 m/s2
➢Maximum deceleration : -5 m/s2
➢Vehicle length: 4.5 meters



Wiedemann Car-Following model

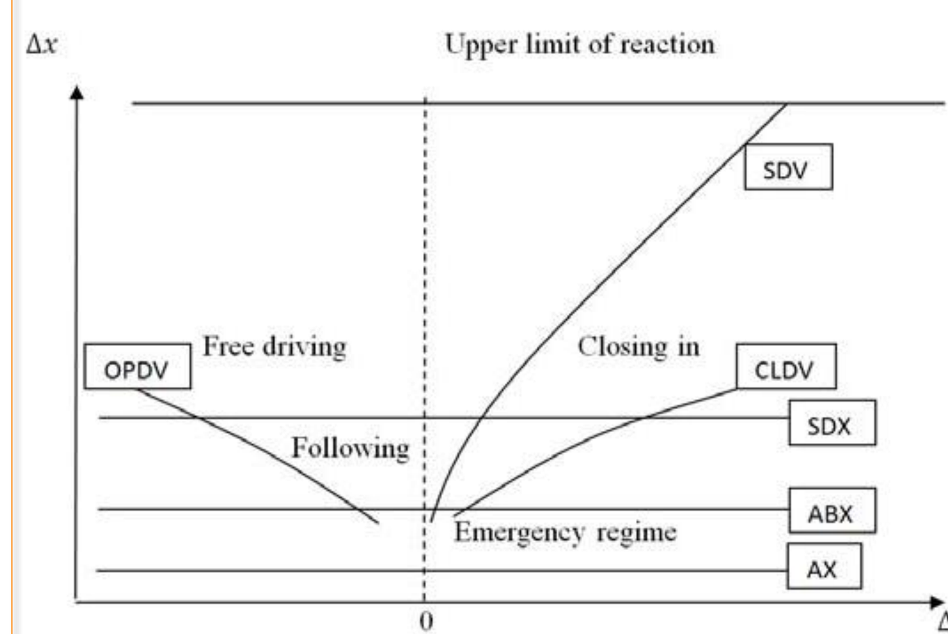
- To model behavior of vehicles, a modified version of Wiedemann car following model was used. The key reasons are:

1- The model represents perception and cautiousness of drivers that allowed us to represent different levels of automation.
2- The model allows for collision occurrence in the simulation

→ making it possible to study the impact of different levels of automation on the safety performance of an intersection

Wiedemann Formulation

- This model considers four regimes of movement for the following vehicle: 1- Free-driving regime; 2- Closing in regime; 3- Following regime; and 4- Emergency regime.

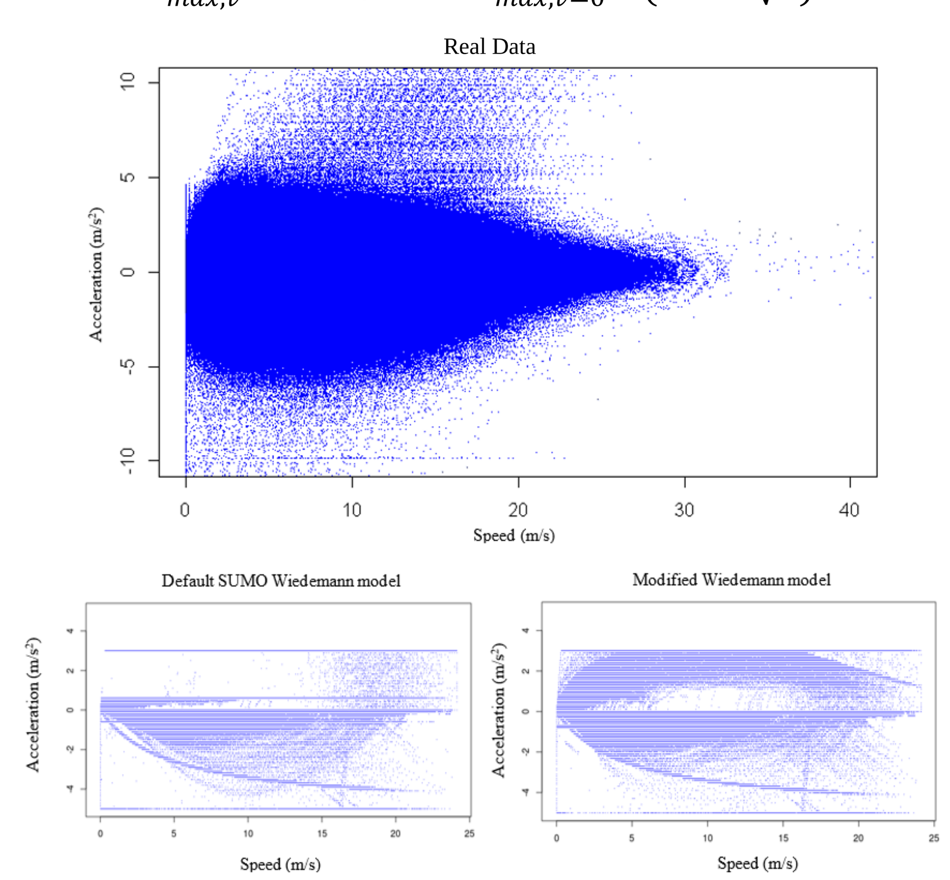


AX: desired space gap between two stationary cars (minimum gap)
ABX: desired minimum following distance
SDX: maximum following distance
SDV: threshold indicating where driver perceive approaching slower vehicle (long distances)
CLDV: defines the threshold driver starts to react and decelerate (short distances)
OPDV: defines the threshold that driver perceives his/her speed is lower than in front vehicle
L: vehicle length
ZF1: level of cautiousness (called "security" in SUMO) (0 to 1)
ZF2: level of situation awareness (called "estimation" in SUMO) (0 to 1)
Rand: random number with mean 0.5 and standard deviation 0.15

Modified Wiedemann Model

- Comparing the real data with the simulation is showing that default Wiedemann model in the SUMO does not generate the acceleration behavior of the vehicles. Thus, the acceleration regime of the model is modified.

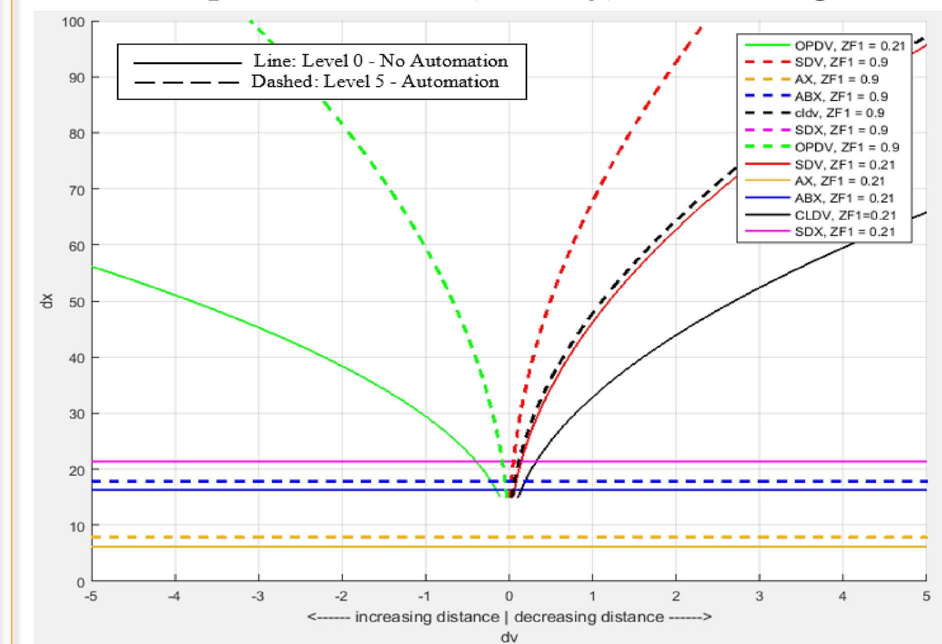
$$a_{max,v} = 0.2 + 0.8 * a_{max,v=0} * (4.6 - \sqrt{v})$$



Speed vs. acceleration diagram from real-world observations (top, n = 216,430,346), default Wiedemann, and modified Wiedemann (bottom)

Capturing Automation

- Assumption: AVs have better security, perception, and awareness in comparison with human-driven vehicles
- Used parameter ZF1 (security) to model higher security & awareness of AVs



- Level 0: ZF1=0.21 (No Automation-should get nearly 38 crashes at the intersection)
- Level 3: ZF1=0.36 (less crashes, but still we have some crashes)
- Level 5: ZF1=0.9 (Full automation-no crashes)

Scenario Definition

Scenario Set 1

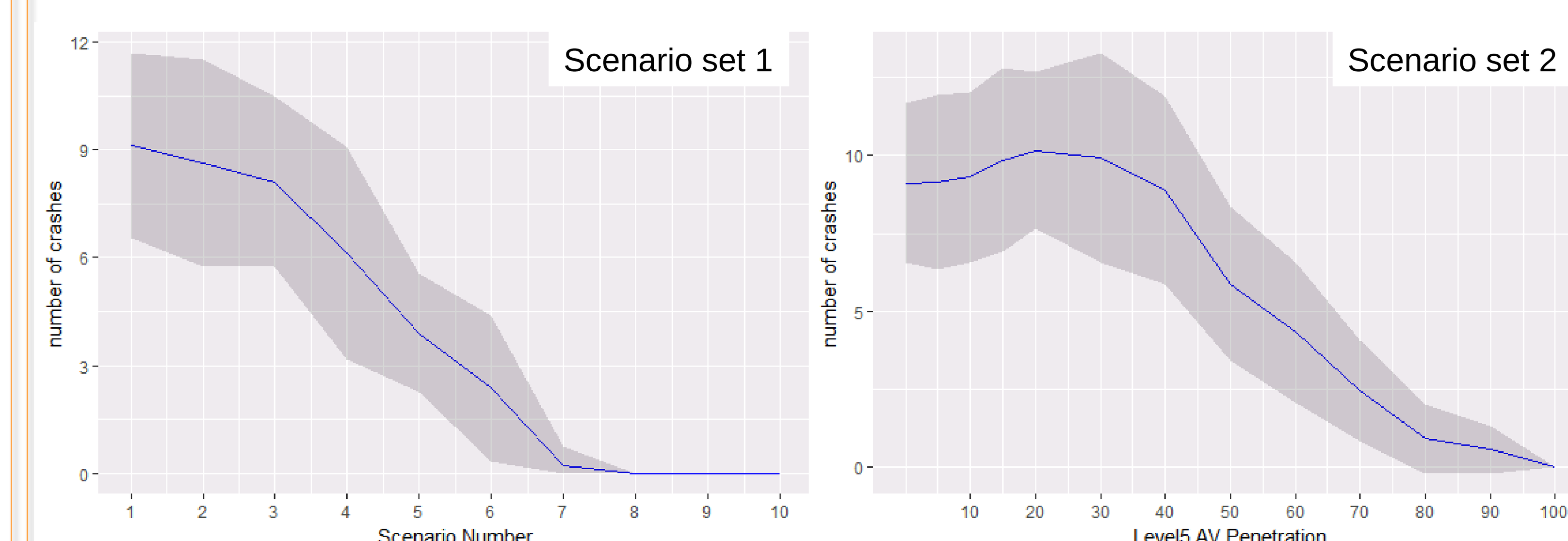
The interaction of Human-driven, level 3 and level 5 AVs

	Sc1 (base)	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Level 0	100%	93%	85%	60%	40%	20%	0%	0%	0%	0%
Level 3	0%	5%	10%	25%	40%	50%	50%	30%	10%	0%
Level 5	0%	2%	5%	15%	20%	30%	50%	70%	90%	100%

Scenario Set 2

The interaction of Human-driven, and level 5 AVs to study the extreme condition

	Sc1 (base)	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Sc11	Sc12	Sc13
Level 0	100%	95%	90%	85%	80%	70%	60%	50%	40%	30%	20%	10%	0%
Level 5	0%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	100%



Conclusion

- Predicting the safety impact of AVs in the mixed traffic
- Decrease in Human-driven vehicles and increase in level 3 and 5 → less crashes
- More level 5 only → first increase (up to 20%) and then decline
- Simulation and real-life data shows that AVs are rear-ended by human-driven cars
- This can be attributed to higher security and awareness of Level 5 AVs leading to a faster response to the front vehicle behaviors which in some cases might not be expected by human drivers following the AV vehicles, leading to rear-end crashes

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