April 7, 2020

- **Autonomous Driving Research: Overview, progress and potential**
  - What is essential for vehicle driving?
  - Autonomous Vehicles as Robots 1980-2010, exemplary accomplishments
  - Autonomous "Robotic" Driving on Real Roads 2014 --
  - Human-Centered Autonomous Driving

  - Object detection, classification, segmentation, Preliminaries: Nachiket Deo

- "Looking at" vehicles, lanes, pedestrians, signs on the road
- Object Detection and Localization
- Semantic, Instance & Panoptic Segmentation
- Multi-object Tracking and Multisensory Systems
- Trajectory/Behavior/Intent Prediction
- Looking in the vehicle cabin: eyes, gaze, hands, activity analysis
- Driver State, Attention, Behavior Analysis
- Prediction of Surround criticalities
- End-to-end Driving, Domain Adaptation, Adversarial Attacks
- Safe Control Transitions between humans and autonomous vehicles
2014 Birth of a new age?

Autonomous Driving: Commercial Possibilities
Autonomous Driving: Commercial Possibilities

Maximizing the Benefits of Self-Driving Vehicles

Principles for Public Policy

Autonomous, or self-driving, vehicle technology may be the most significant innovation in transportation since the mass introduction of automobiles in the early 20th century. Whether the widespread adoption of self-driving vehicles results in positive outcomes in the years ahead will depend largely on how public policy guides the introduction of this emerging technology today. The potential benefits include safer roads, more affordable transportation, improved access to jobs, and a cleaner, healthier environment. Without well-crafted policy, though, self-driving vehicles could increase vehicle miles traveled and global warming emissions, worsen congestion, exacerbate air pollution, and put millions of Americans out of work (Litman 2016).

UCS has outlined a set of principles that policymakers, businesses, and other stakeholders can follow to shape the introduction of self-driving vehicles in ways that reduce oil consumption and global warming emissions, protect public health, and enhance mobility for all.

1. Make Transportation Safer for Everyone, Not Just Motorists

While self-driving vehicles have the potential to reduce vehicle-related fatalities, this is not a guaranteed outcome (Kockelman et al. 2016). Vehicle computer systems must be secure from hacking, and rigorous testing and regulatory oversight of vehicle programming are essential to ensure that self-driving vehicles protect both their occupants and those outside the vehicle. Therefore, public policy related to self-driving vehicles must improve safety for all Americans, whether they are driving, walking, or biking.
Safe Autonomous Driving?

**UBER ATG**

- Top mounted lidar units provide a 360° 3-dimensional scan of the environment.
- Side and rear facing cameras work in collaboration to construct a continuous view of the vehicle's surroundings.
- Roof mounted antenna provide GPS positioning and wireless data capabilities.

**Self Driving Uber sensor suite**

- 7 Cameras
- 1 Laser
- Inertial Measurement Units
- Custom compute and data storage
- 360° radar coverage

**Seeking Autonomy 2017: Real Roads, Real-lives**

- Seeking Autonomy 2016: Real Roads, Real-lives
The accident illustrated in Figure 2.1 occurred on March 24, 2017. Vehicle V₁ (Honda CRV) northbound in the left turn lane of S. McClintock Dr entered the intersection during green with 5s left in the crosswalk timer, stopped, made a left turn onto E. Don Carlos Ave, and collided with vehicle V₂ (Uber automated Volvo), southbound in lane 3 of S. McClintock Dr, which had entered the intersection on yellow at 38 mph (56 fps). After being hit, the Volvo continued across the intersection, struck a traffic signal pole, flipped on its side and collided with Vehicles V₃ (Hyundai I35) and V₄ (Ford Edge), which were stopped in traffic southbound in lane 2 of S. McClintock Dr. The self-driving Uber had the right of way and was programmed to enter the busy intersection at the speed limit while the light was yellow, but a human driver likely would have slowed down [15].

Four possible errors contributed to the accident. The Uber automated Volvo (V₂)
1. may not have known that traffic in the opposing direction was permitted to turn left;
2. did not predict that the light would turn yellow before it entered the intersection;
3. did not consider that the vehicles stopped in the adjacent lanes 1 and 2 prevented it from seeing a left-turning vehicle until the Uber was within 10 feet of the stop bar and at a speed of 56 fps it could not come to a stop within 10 feet. (At a deceleration of 32 ft/s², the Uber would stop in 49 ft.)
4. was obstructed by vehicles stopped in lanes 1 and 2 and she could only see 10 feet into lane 3, and seeing no vehicle there, concluded that none was going to cross the intersection; she did not realize that the obstruction by stopped vehicles was hiding a vehicle more than 50 feet away approaching at 40 mph.

The Honda (V₁) driver’s view

Figure 2.2 shows a snapshot of a PreScan [10] simulation of the described collision: 2 seconds before the impact V₁ and V₂ do not see each other.
Need for Safe Autonomous Driving

Tesla crash: how it happened

A preliminary investigation into 25,205 Tesla Model S cars has been opened after a driver of one of the vehicles was killed while operating in Autopilot mode in a crash in Williston, Florida. Here is how the fatal accident occurred according to authorities.

1. Tesla travels eastbound at US 27
2. A tractor-trailer on the westbound lane prepares to turn left
3. Tesla’s windshield strikes the underside of the trailer as the car passes underneath it
4. The car keeps going, veers off the road and hits a wire fence
5. After traveling across a field, the car strikes another wire fence
6. It passes through the fence and hits a utility power pole
7. It rotates and comes to a final rest

Diagram not to scale.
Sources: Florida Highway Patrol Troop; U.S. National Highway Traffic Safety Administration
E. Chan, 30/06/2018
Need for Safe Autonomous Driving

Tempe Police Vehicular Crimes Unit is actively investigating the details of this incident that occurred on March 18th. We will provide updated information regarding the investigation once it is available.

3:23 PM - 21 Mar 2018

Need for Safe Autonomous Driving

DEADLY CRASH WITH SELF-DRIVING UBER
The death of Elaine Herzberg (August 2, 1968 – March 18, 2018) was the first recorded case of a pedestrian fatality involving a self-driving (autonomous) car, after a collision that occurred late in the evening of March 18, 2018. Herzberg was pushing a bicycle across a four-lane road in Tempe, Arizona, United States, when she was struck by an Uber test vehicle, which was operating in self-drive mode with a human safety backup driver sitting in the driving seat. Herzberg was taken to the local hospital where she died of her injuries.\(^2\)\(^3\)\(^4\)

Following the fatal incident, Uber suspended testing of self-driving vehicles in Arizona.\(^5\) where such testing had been sanctioned since August 2016.\(^6\) Uber chose not to renew its permit for testing self-driving vehicles in California when it expired at the end of March 2018.\(^7\)

Herzberg was specifically the first pedestrian death involving a self-driving car\(^{citation needed}\); a previous fatality, in which the driver of a semi-autonomous car was killed, had occurred almost two years prior.\(^8\)

A Washington Post reporter compared Herzberg’s fate with that of Bridget Driscoll who, in the 1896, was the first pedestrian to be killed by an automobile.\(^9\)

"The driver said it was like a flash, the person walked out in front of them. His [sic] first alert to the collision was the sound of the collision. [...] it’s very clear it would have been difficult to avoid this collision in any kind of mode (autonomous or human-driven) based on how she came from the shadows right into the roadway."

— Chief Sylvia Moir, Tempe Police, San Francisco Chronicle interview, March 19, 2018\(^{35}\)

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*Note: The diagram illustrates the Uber self-driving system data playback from the fatal crash of an Uber test vehicle in Tempe, Arizona, 18 Mar 2018.*

- At 1.3 seconds before impact, the system determined emergency braking was needed to mitigate a collision.
- The yellow bands depict meters ahead of the vehicle.
- The orange lines show the center of mapped travel lanes.
- The purple area shows the path of the vehicle and the green line depicts the center of that path.
### A Quest for Human Robot Cohabitation: Towards Human-Centered Autonomous Driving

**What happens if the robot makes a mistake?**

**What happens if the robot doesn't know it made a mistake?**

**What happens if the robot refuses to let go?**

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**A Quest for Human Robot Cohabitation: Towards Human-Centered Autonomous Driving**

Does the robot understand state, preferences, intentions, abilities of humans in the vehicle?

Does the robot understand state, intentions, abilities of humans around the vehicle?

Does the robot understand state, intentions, abilities of humans driving surrounding vehicles?
**LISA Research: Four Points**

**Big Picture:**
**Safe, Stress-free, Efficient, Enjoyable Driving/Riding**

**Long-Term Goals:**
**Human cohabitation** with intelligent robots

**Holistic Distributed Cognitive Systems Perspective:**
Learning from Naturalistic Driving Studies, Predictive, Attentive, Holistic Systems

**Open Issues:**
Fail-safe, Control transitions, Trustworthy, Performance Metrics, standards, evaluations, multi-agents, cooperation, Reliable communication links, security, etc. etc.

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**Towards Human-Centered Autonomous Driving**

*Research Motivation, Scope and Framework*

*Autonomous Driving (AD) = Humans + Self-Driving Automobiles*

*AD = Distributed Cognitive Systems: Human-Vehicle Teams*

*Research Explorations and Samplings:*
Multimodal 360° Sensing, Multiple Intelligent Agents,
Holistic Situation Perception, Selective Semantic Understanding, Understanding Intentions, Predicting Behaviors, Awareness,
Shared "Mental" Models, Continuous Risk Assessment, Smooth/ Safe Control Transitions, Security, …
Predictions by Inferring Intent!

Questions:

*Can autonomous vehicles predict "Driver"s Intentions?*

*Can autonomous vehicles predict surround vehicle intentions?*

*Can autonomous vehicles predict "pedestrian"s intentions?*

If yes, then

*How? How well? How fast?*

*Robust? Generalizable?*

*What are the metrics? What are the limits?*

Ng, Milic, Prati, McCall, Wipf, Gandhi, Huang, Cheng, Park, Wu, Murphy-Chutorian, Krotosky, Morris, Doshi, Tran, Johnson, Ly, Sivaraman, Tawari, Mogelmose, Satzoda, Ohn-Bar, Martin, Jensen, Phillipsen, Kristofersen, Duhalm, Rajaram, Vora, Li, Lu, Khoreshahi, Eduardo, Frankie, Sean, Akshay, Nachiket, Kevan, Ishan, Siddharth, Kirill, Daniella, Bowen, Ross, Kaouther

Human-Centered Autonomous Driving: LISA Research Agenda


Humans in vehicle cabin

Humans around vehicle

Humans in surround vehicles

LISA Publications [http://cvrr.ucsd.edu/publications/](http://cvrr.ucsd.edu/publications/)
Vision for Intelligent Safe Vehicles: LISA 2001 --

https://www.youtube.com/watch?v=wZg5I7l_MkQ&feature=youtu.be

Sivaraman, Trivedi IEEE Intelligent Vehicles Symposium, 2013
Tawari, Martin, Trivedi, IEEE Trans Intelligent Trans Systems 2014

UCSD LISA: Vision for Safe Autonomous Driving, 2001 --

LISA Publications http://cvrr.ucsd.edu/publications/index.html
Introducing LISA-T, 2018

LISA
Laboratory for Intelligent and Safe Autonomous Vehicles

Introducing LISA-T, 2018