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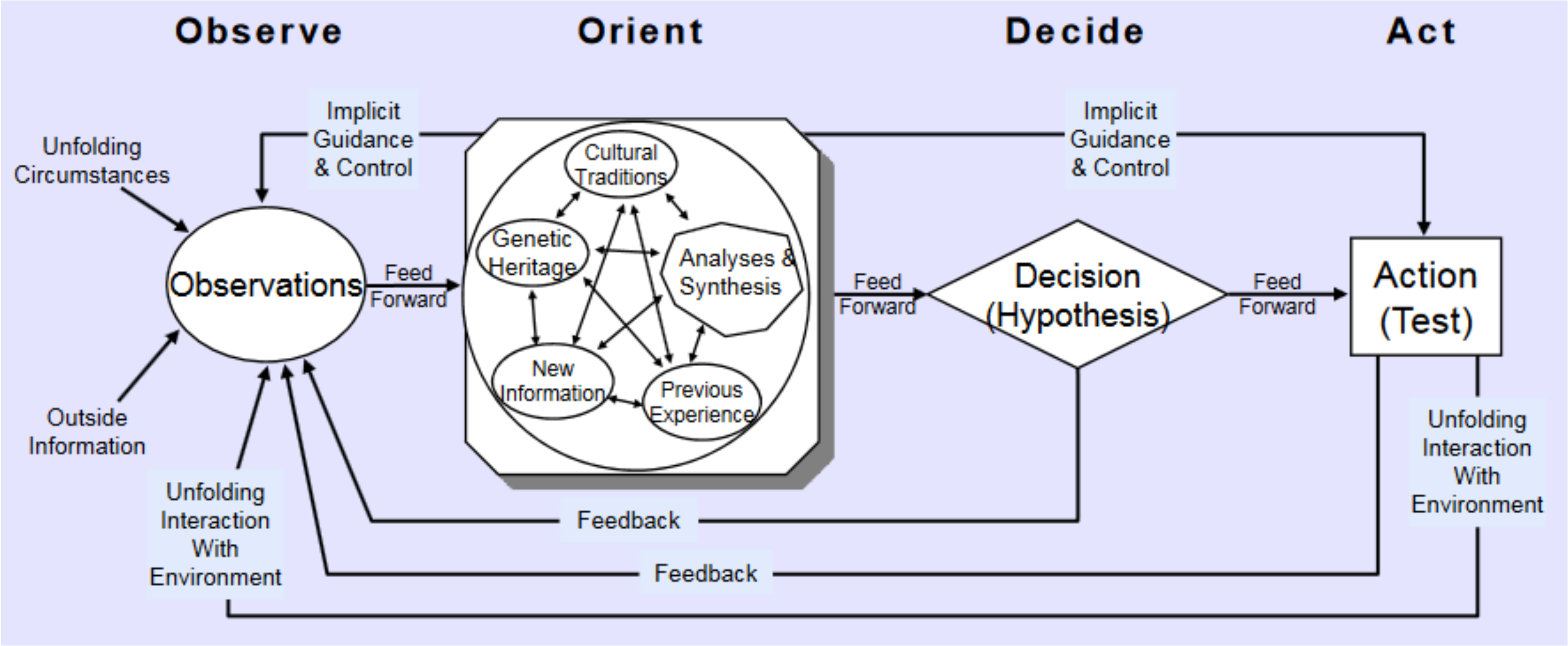
Challenges and Opportunities for Intelligent Transportation Systems

Akshay Rajhans, PhD

Senior Research Scientist
Advanced Research and Technology Office
MathWorks
https://arajhans.github.io

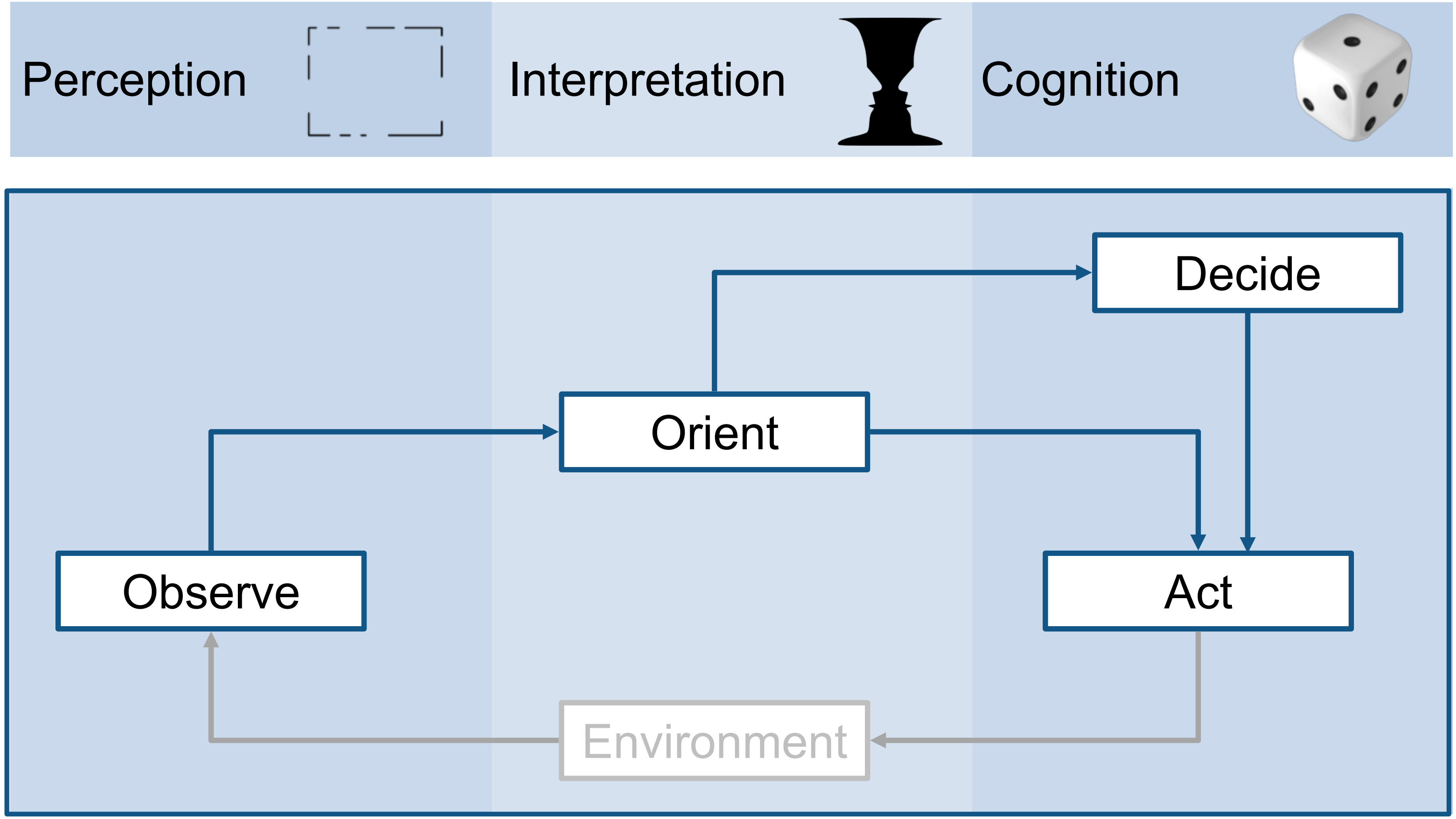
Invited talk in the session on Intelligent Transportation Systems at Robotica 2017
June 15, 2017

The Observe-Orient-Decide-Act (OODA) loop

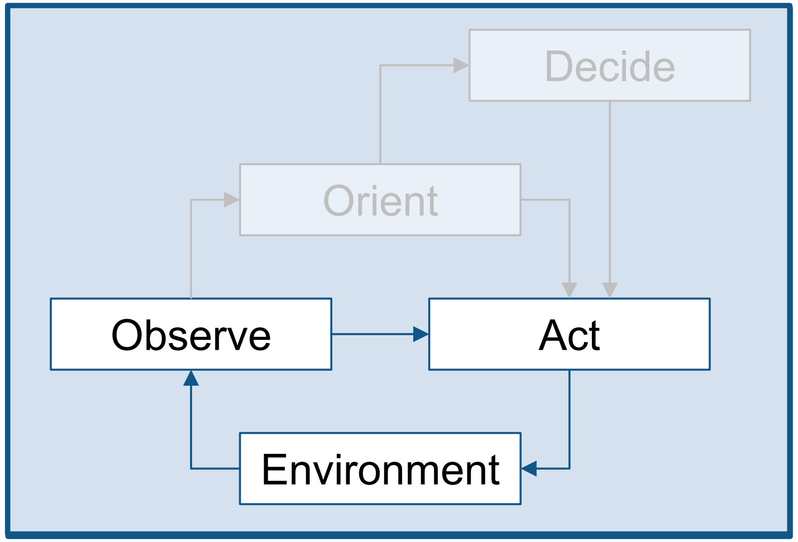


https://en.wikipedia.org/wiki/John_Boyd_(military_strategist)#The_OODA_Loop

OODA and the stages of cognition



Engineered systems and levels of cognition

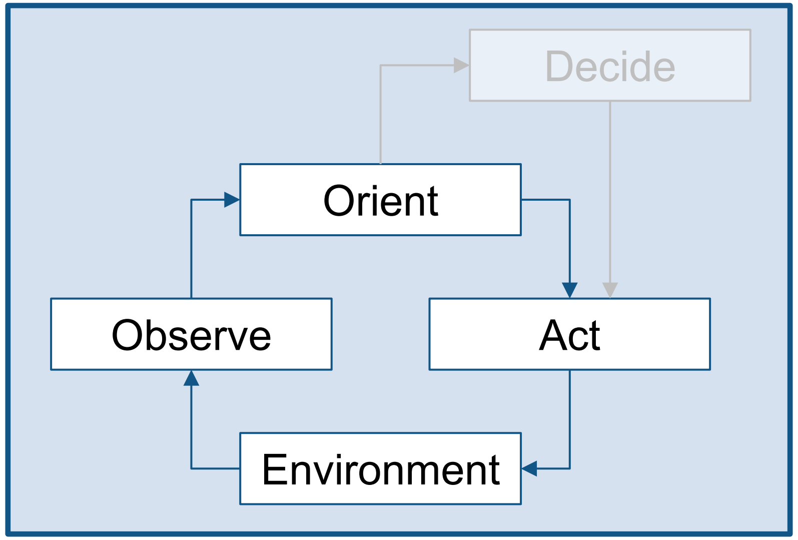


Automatic

Perception

Process (video)
Analyze for validity (filter, reject)

Compute control signals

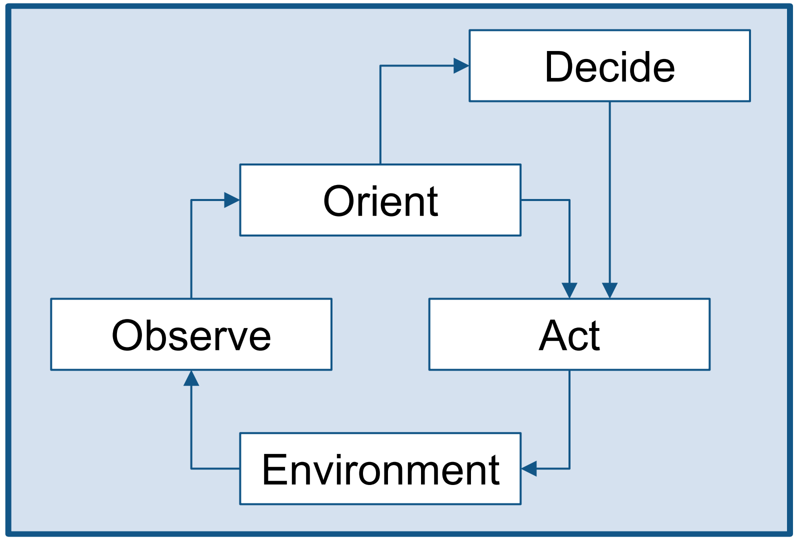


Adaptive

Interpretation

Map to semantic concepts
Fuse sensor data

Adjust control
Reconfigure behavior



Autonomous

Cognition

Reason based on knowledge
Plan for objectives and constraints

Assess alternatives
Determine course of action

A feature classification

Ensemble	**Distributed**	**Connected**	**Collaborative**
Individual	**Automatic**	**Adaptive**	**Autonomous**
	Perceive	Interpret	Reason

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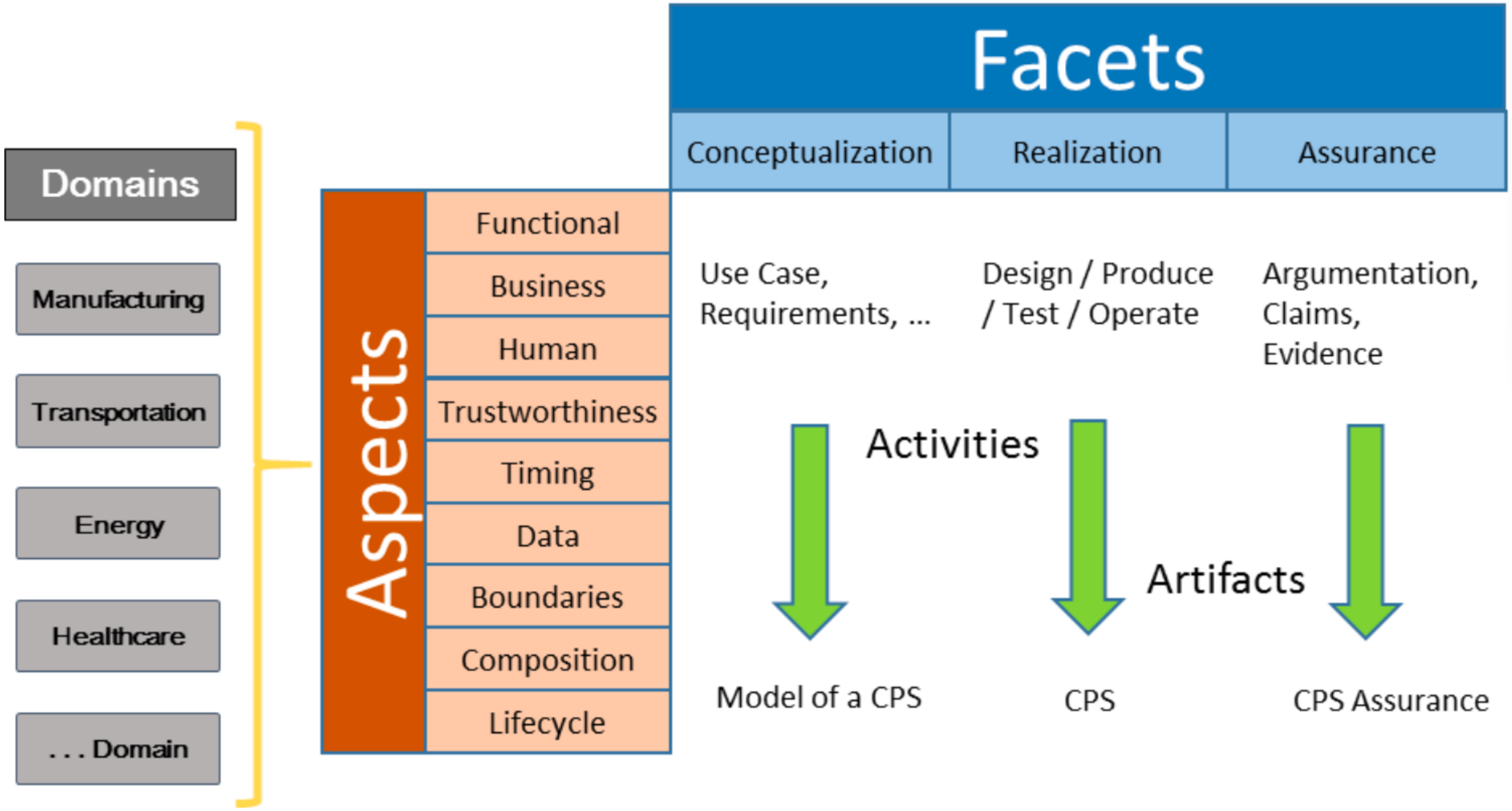
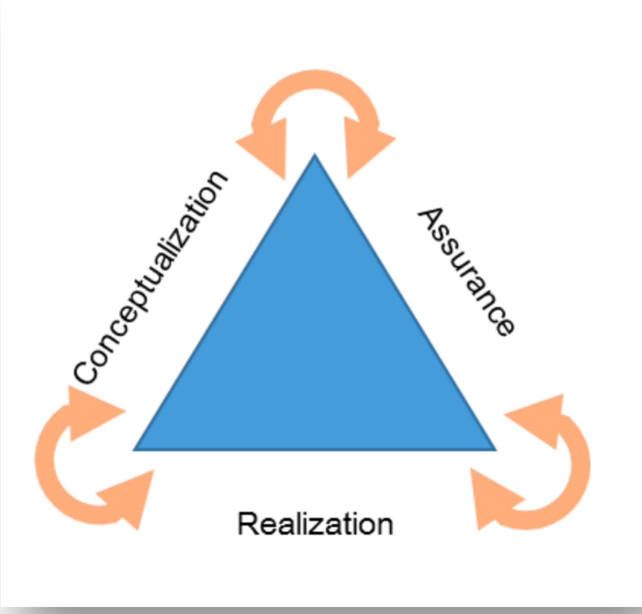
NIST CPS Framework – Facets





https://pages.nist.gov/cpspwg/

Adaptive

Conceptualize
- How to limit learning to safe behavior?

Realize
- What sensory system has sufficient richness?
  - How to prevent over interpretation?
- Robustness against interpretation edge case?
- Correctly fuse sensor data that is misaligned in time and space?

Assure
- How to test a self-changing artifact?
  - If regimes are not pre enumerated?
- Ensure successful and correct online calibration?

https://www.theverge.com/2016/3/24/11297050/tay-microsoft-chatbot-racist

"Unfortunately, in the first 24 hours of coming online, a coordinated attack by a subset of people exploited a vulnerability in Tay. Although we had prepared for many types of abuses of the system, we had made a critical oversight for this specific attack."

http://blogs.microsoft.com/blog/2016/03/25/learning-tays-introduction

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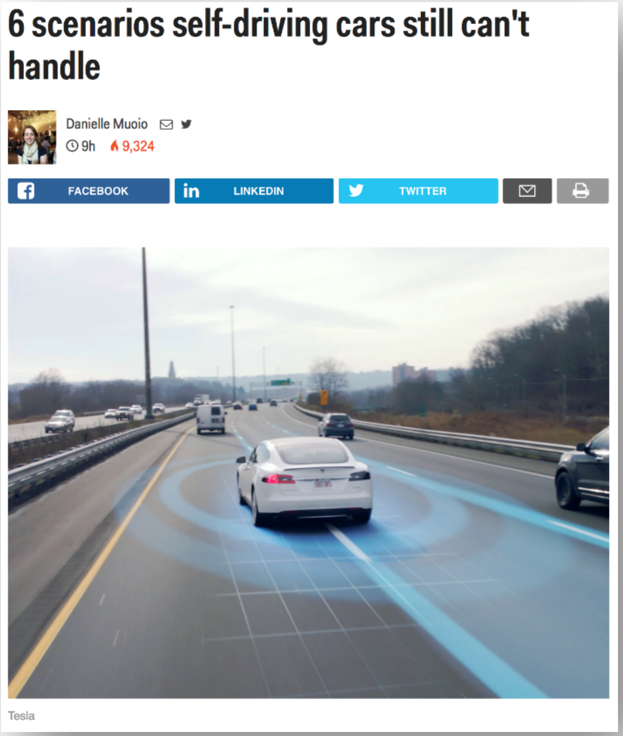

6 scenarios self-driving cars still can't handle

Danielle Muoio
9h 9,324

FACEBOOK LINKEDIN TWITTER

Tesla

1. Driverless cars struggle going over bridges

“Because bridges don't have many environmental cues like surrounding buildings, it's hard for the Uber car to figure out where it is. GPS helps the car position itself, but not to the accuracy Uber wants.”

http://www.businessinsider.com/autonomous-car-limitations-2016-8

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Tesla

2. Cars struggle in inclement weather

"Heavy snow and rain tend to confuse LiDAR sensors and also cameras," John Dolan, principle systems scientist at Carnegie Mellon's Robotics Institute, told Business Insider. "So you end up having some problems."

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http://www.businessinsider.com/autonomous-car-limitations-2016-8

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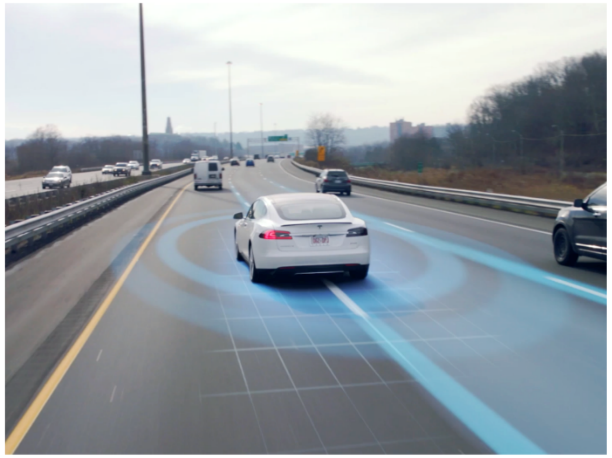

Tesla

3. Cars struggle without clear lane markings

"When driverless cars can't distinguish the lanes, it makes it nearly impossible for them to drive or change lanes safely."

Autonomous

Conceptualize

- Models of environment with sufficient predictive quality?
- Safe but nontrivial interaction with humans?
  - What are safe level of aggressiveness?

Realize

- Robust operation in an exceedingly complex environment?
- Fail safely with loss of minimum information?
- Know a planned action is safe?
- Assess risk online?

Assure

- Turing test for cars?
- Ensure the reasoning is always safe?
- Degraded safety (there is no perfect safety)?


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Tesla

4. City driving is much harder than highway

"Cities are a mess of pedestrians, cars, potholes, traffic cones — you get the point."

"…you get into areas where there are a lot of tall buildings it's hard to receive the GPS signal and you'll have drop outs"

http://www.businessinsider.com/autonomous-car-limitations-2016-8

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Tesla

5. Robot cars can't interact like humans can

"… more times than not, we rely on waving to let someone know it's ok to go. Driverless cars don't have that luxury"

http://www.businessinsider.com/autonomous-car-limitations-2016-8

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Tesla

6. High-speed situations may be trouble

"… when human drivers try to merge onto roads with cars traveling at higher speeds, they tend to inch forward to make sure it's ok."

"But a driverless car probably wouldn't take that risk"

http://www.businessinsider.com/autonomous-car-limitations-2016-8

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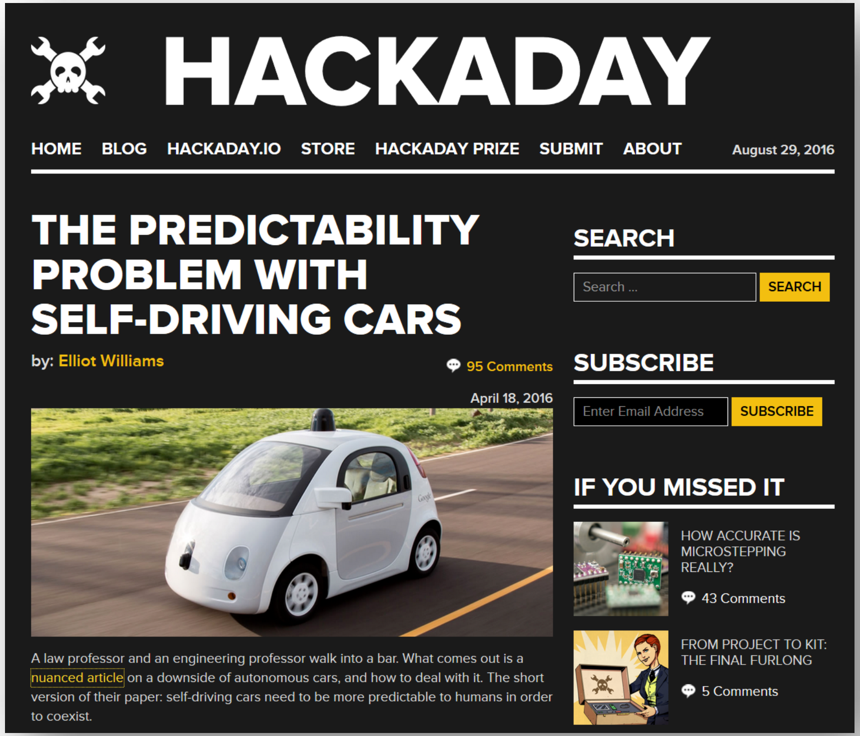

When we want to know what another car is going to do, we think about the driver of the car, [..] We then think about what we'd do in their place,

If people can't read your car's AI's mind, you're gonna get your fender bent.

http://hackaday.com/2016/04/18/the-predictability-problem-with-self-driving-cars/

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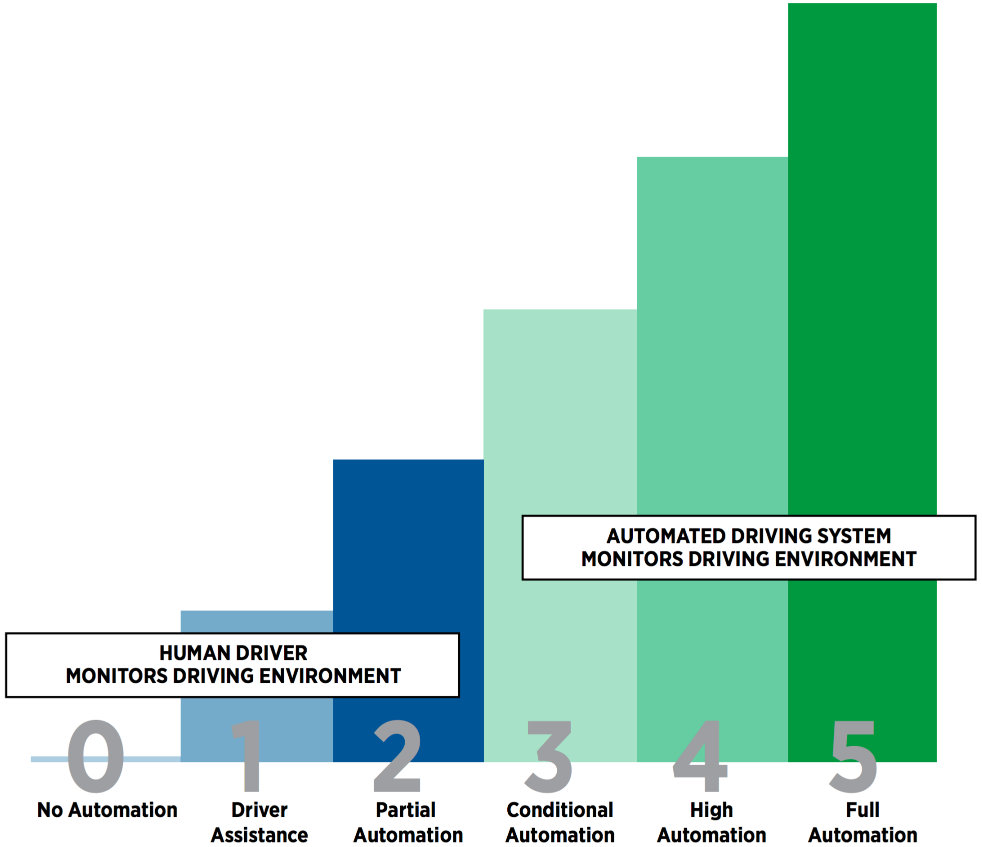

SAE “levels of autonomy”

Learn more about SAE J3016 or purchase the standard document:
www.sae.org/autodrive

https://www.sae.org/misc/pdfs/automated_driving.pdf

We are here

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

https://www.sae.org/misc/pdfs/automated_driving.pdf

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The New York Times

TECHNOLOGY

Robot Cars Can't Count on Us in an Emergency

Bits

By JOHN MARKOFF JUNE 7, 2017

"…most drivers required more than five seconds to regain control of a car when — while playing a game on a smartphone — they were abruptly required to return their attention to driving."

https://www.nytimes.com/2017/06/07/technology/google-self-driving-cars-handoff-problem.html

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"Taking back control of a car is a very different experience at a high speed than at a low one, and adapting to the feel of the steering took a significant amount of time even when the test subjects were prepared for the handoff."

https://www.nytimes.com/2017/06/07/technology/google-self-driving-cars-handoff-problem.html

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"I believe that Level 3 autonomous driving is unsolvable," said John Leonard, a mechanical engineering professor at [MIT].

"The notion that a human can be a reliable backup is a fallacy."

https://www.nytimes.com/2017/06/07/technology/google-self-driving-cars-handoff-problem.html

Connected

Conceptualize

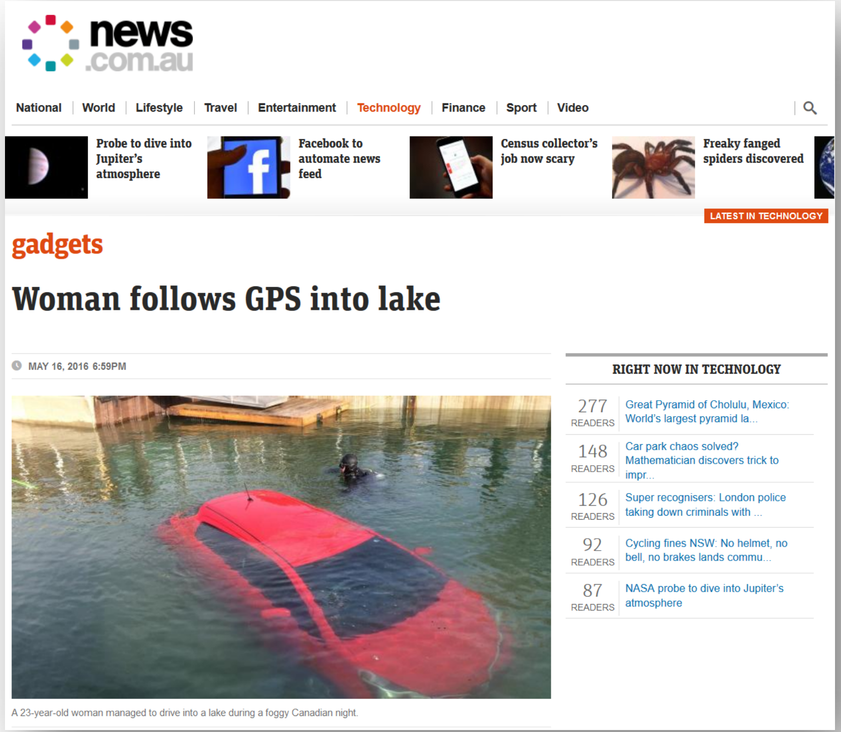
- How to interpret data safely
  - Which data to corroborate information?

Realize

- Safely operate in the face of communication challenges
  - Degradation, loss
  - Corruption
- Timeliness and responsiveness guarantees?
  - Service discovery time out, DoS

Assure

- Is closed loop verification possible?
- How do you obtain failure probabilities?



the woman was following a route on her car's GPS while driving in the dark on a foggy night in Ontario when it directed her to drive onto a boat launch, and she ended up in a lake.

http://www.news.com.au/technology/gadgets/woman-follows-gps-into-lake/news-story/a7d362dfc4634fd094651afc63f853a1

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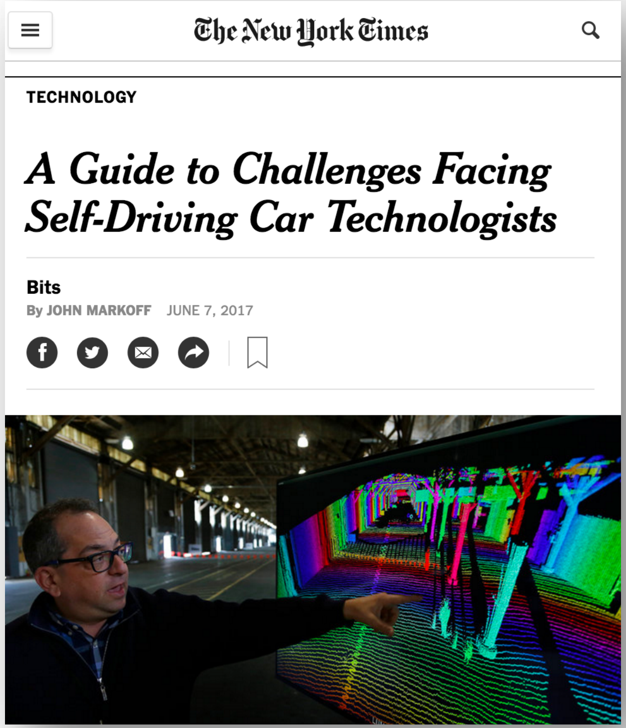
The New York Times

TECHNOLOGY

A Guide to Challenges Facing Self-Driving Car Technologists

Bits

By JOHN MARKOFF JUNE 7, 2017

The ability to respond to spoken commands or hand signals […]

There are subtle signals that humans take for granted: the body language of a traffic control officer, for example, or a bicyclist trying to make eye contact. How do you teach a computer human intuition?

https://www.nytimes.com/2017/06/07/technology/autonomous-car-technology-challenges.html?smid=tw-share&_r=0

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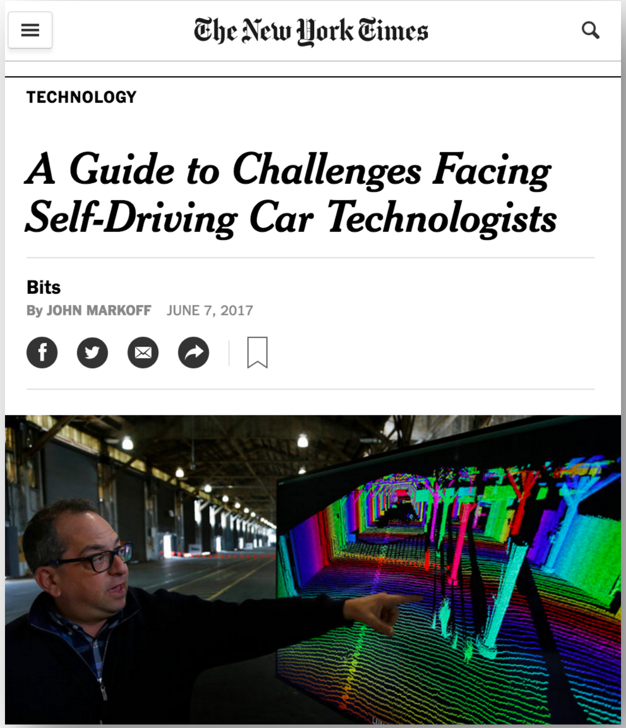

The New York Times

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Making left turns into intersections with fast-moving traffic.

Merging into rapidly flowing lanes of traffic is a delicate task that often requires eye contact […]. How can machines subtly let other machines and humans know what they are trying to do?

https://www.nytimes.com/2017/06/07/technology/autonomous-car-technology-challenges.html?smid=tw-share&_r=0

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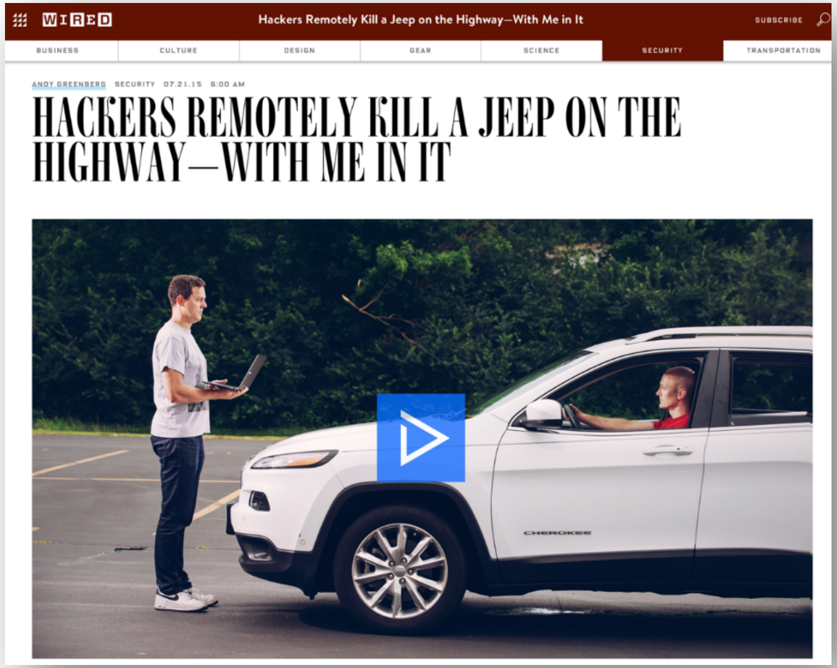

"Uconnect's cellular connection also lets anyone who knows the car's IP address gain access from anywhere in the country."

"From that entry point, the attack pivots to an adjacent chip [..] rewriting the firmware [..] capable of sending commands through the CAN bus, to its physical components like the engine and wheels."

https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/

Collaborative

Conceptualize
- Cross-organization failure effect analysis?
- How to identify and prevent race conditions?
- Robust conflict resolution across an ensemble?
- How to trade off system vs. ensemble safety?

Realize
- Safety of ad hoc rules in collaboration?
- How to perform online safety analysis?
- How much risk to assign to a collaboration?
- How to gracefully enter/exit a collaboration?
- How to ensure ample resources to be safe?
- Can you assign probability to reliance?

Assure
- How do you test? Measure coverage?
- Work outside nominal regions (online derating)?
- Assumptions about collaborating systems?

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BOYDTON JOURNAL Cloud Computing Brings Sprawling Centers, but Few Jobs, to Small Towns

FEATURE Inside Facebook's (Totally Insane, Unintentionally Gigantic, Hyperpartisan)...

Cycling Matches the Pace and Pitches of Tech

Adopted Koreans, Stymied in Search of Birth Parents, Find Hope in a Cotton Swab

TECHNOLOGY

TECHNOLOGY

Google's Driverless Cars Run Into Problem: Cars With Drivers

By MATT RICHTEL and CONOR DOUGHERTY SEPT. 1, 2015

855

A Google self-driving car in Mountain View, Calif. Google cars regularly take the most cautious approach, but that can put them out of step with the other vehicles on the road.

Gordon De Los Santos/Google

The way humans often deal with these situations is that "they make eye contact. On the fly, they make agreements about who has the right of way," said John Lee, a professor of industrial and systems engineering and expert in driver safety and automation at the University of Wisconsin.

http://www.nytimes.com/2015/09/02/technology/personaltech/google-says-its-not-the-driverless-cars-fault-its-other-drivers.html

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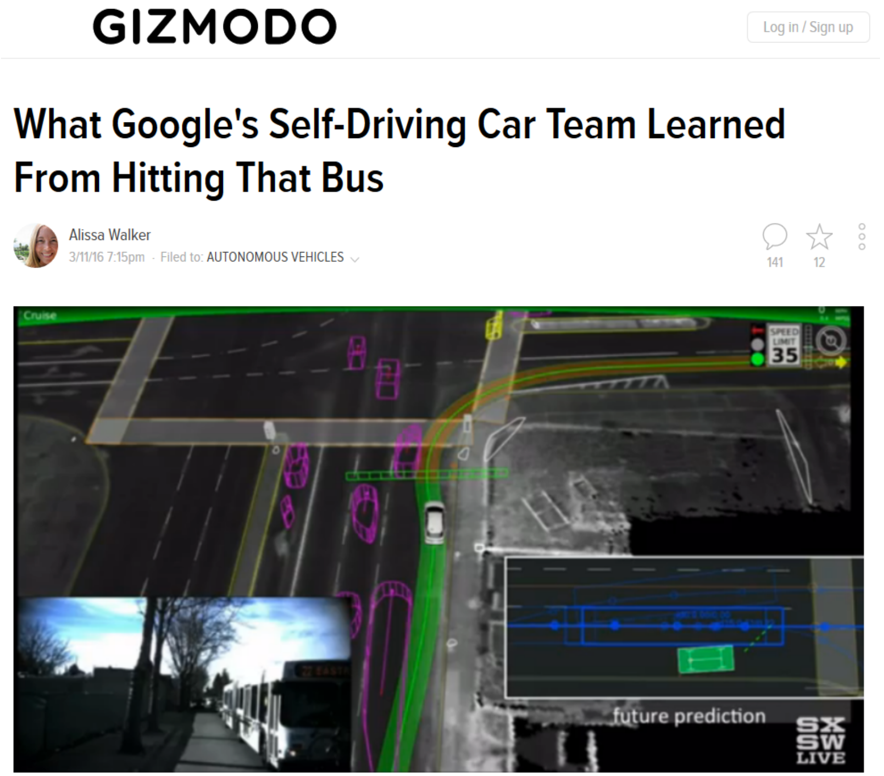
GIZMODO

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What Google's Self-Driving Car Team Learned From Hitting That Bus

Alissa Walker

3/11/16 7:15pm · Filed to: AUTONOMOUS VEHICLES

141 12

The Google car's prediction didn't come true when it struck a bus on Valentine's Day

'Our car was making an assumption about what the other car was going to do,' said Chris Urmson

http://gizmodo.com/what-googles-self-driving-car-team-learned-from-hitting-1764409297

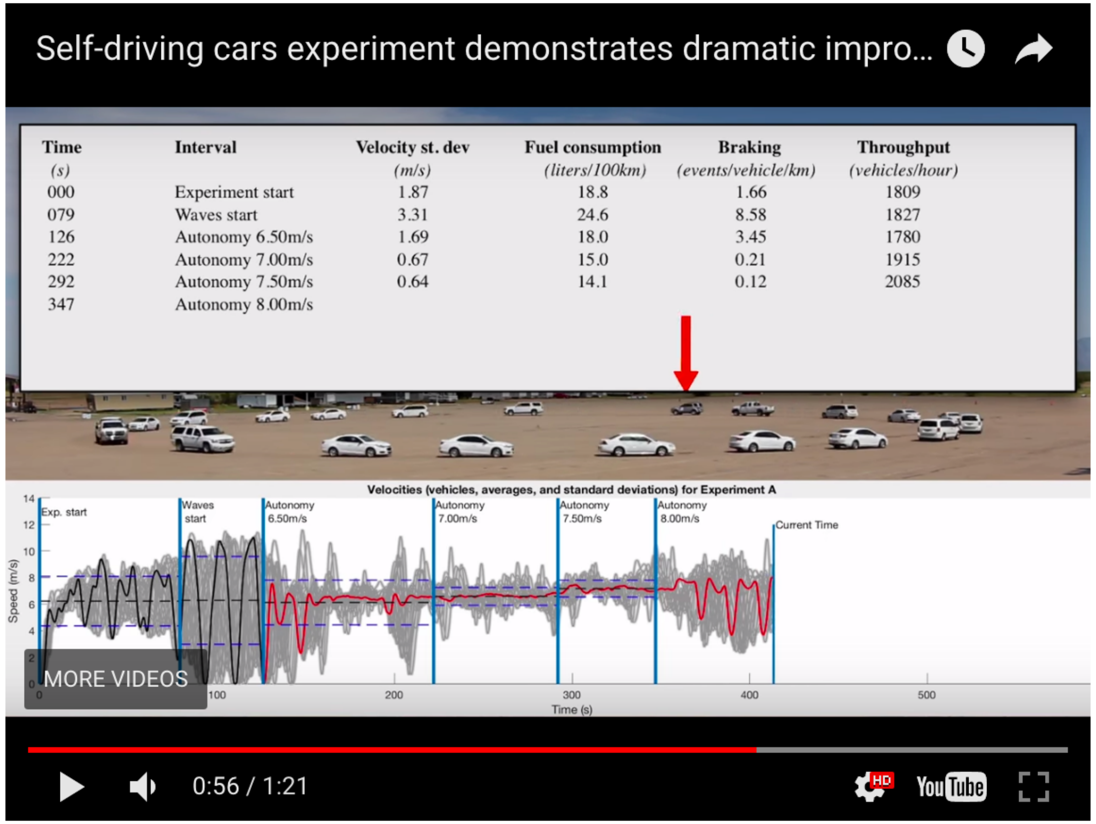
MathWorks

Opportunities

Even one autonomous vehicle can make a big impact!

Experiments show that a few self-driving cars can dramatically improve traffic flow

"Before we carried out these experiments, I did not know how straightforward it could be to positively affect the flow of traffic," Sprinkle said. "I assumed we would need sophisticated control techniques, but what we showed was that controllers which are staples of undergraduate control theory will do the trick."



https://phys.org/news/2017-05-self-driving-cars-traffic.html

https://www.youtube.com/watch?v=2mBjYZTeaTc

Jonathan Sprinkle
Litton Industries John M. Leonis Distinguished Associate Professor
Office: ECE 456N
Phone: 520.626.0737
Email: sprinkle@ece.arizona.edu
Research/Lab Website

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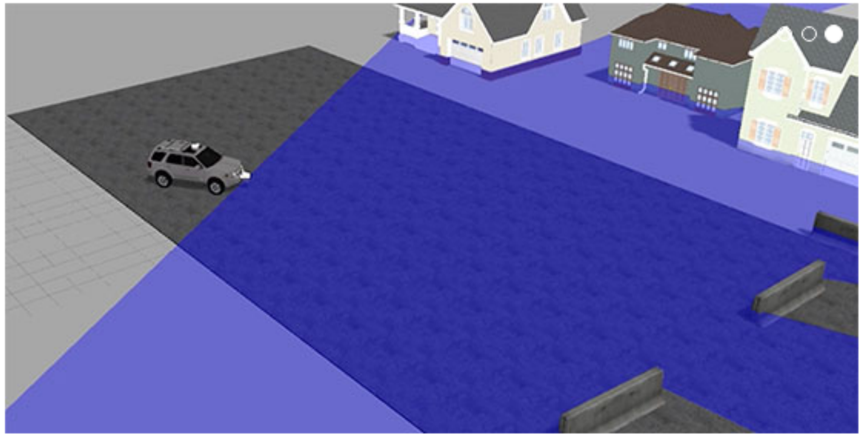
CAT Vehicle Challenge

The CAT Vehicle CPS Challenge 2017 brings together 30 teams, comprised of over 80 students, to use Model-Based Design to develop a software component for controlling a real self-driving car--the University of Arizona's CAT Vehicle. The teams will create ROS software components prototyped using Simulink using real-world data from the CAT Vehicle to compete for tasks such as obstacle identification using fewest sensors possible, velocity computation for trajectory following, and generation of 3D simulation virtual world files in Gazebo from simulation trajectories and actual driving data. Top-performing teams will have an opportunity to see their validated software running on the CAT Vehicle in Tucson, AZ, over a period of 2-3 days.



Getting Started

See all the videos of the CAT Vehicle Simulator in action

» Visualizing the CAT Vehicle

» Taking a Hard Left Turn

» Following a Circular Path

» Generating Code from a ROS Simulink Model

CAT Vehicle Challenge official website (on the CPS-Virtual Organization)

Complimentary Software

MathWorks provides complimentary software for this competition. If your team is participating in this competition and would like to request software contact us.

Request Software

https://www.mathworks.com/academia/student-competitions/catvehiclechallenge.html

Feedback

Student Teams Use MATLAB and Simulink in the AUVSI Foundation RoboBoat Competition

Daryl Davidson, AUVSI Foundation

See how students design fully autonomous boats using Model-Based Design with MATLAB and Simulink in the AUVSI Foundation's RoboBoat Competition.

https://www.mathworks.com/videos/student-teams-use-matlab-and-simulink-in-the-auvsi-foundation-roboboat-competition-98693.html

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