University of Michigan’s Work Toward Autonomous Cars

RYAN EUSTICE

NAVAL ARCHITECTURE & MARINE ENGINEERING
MECHANICAL ENGINEERING, AND COMPUTER SCIENCE AND ENGINEERING
Roadmap

- Why automated driving?
- Next Generation Vehicle project with Ford Motor Company
- Critical challenges ahead
Roadmap

- Why automated driving?
- Next Generation Vehicle project with Ford Motor Company
- Critical challenges ahead

Diagram: Safety, Social, Economic
Roadmap

- Why automated driving?
- Next Generation Vehicle project with Ford Motor Company
- Critical challenges ahead
Why vehicle automation?

Safety

Social

Economic
Why vehicle automation?

For Safety!

- USA - Over 5 million crashes per year\(^1\)
  - Over 33,500 fatalities per year
  - 2.3 million injuries

- Worldwide\(^2\)
  - Over 1.24 million deaths per year
  - 50 million injuries

- 93\% of accidents have human error as the primary factor\(^3\)
  - Speeding: 21\% (by dollar)
  - Drunk: 18\%
  - Distracted: 17\%

---

\(^1\) NHTSA, Traffic Safety Facts, 2012 Statistics
\(^2\) Association for Safe International Road Travel (ASIRT), 2008
\(^3\) NHTSA, The Economic and Societal Impact Of Motor Vehicle Crashes, 2010
Why vehicle automation?

**Social Impact**
- Aging population (both in the US and worldwide)
- Disabled or impaired

![Age pyramid comparison](Image Credit: Google)

*Source: National Institute of Population and Social Security Research*
Why vehicle automation?

**Economic Benefits**

- Over $2 trillion per year in revenue

*Forbes*  
http://onforbes.com/10Dyaf1

**Fasten Your Seatbelts: Google's Driverless Car Is Worth Trillions (Part 1)**

*Comment Now*

*Part One of a Seven-Part Series*

Much of the reporting about Google’s driverless car has mistakenly focused on its science-fiction feel. While the car is certainly cool—just watch the video below about a 95%-blind man running errands—the gee-whiz focus suggests that it is just a high-tech dalliance by a couple of brash young multibillionaires, Google founders Larry Page and Sergey Brin.

In fact, the driverless car has broad implications for society, for the economy and for individual businesses. Just in the U.S., the car puts up for grab some **$2 trillion a year in revenue** and **even more market cap**. It creates business opportunities that dwarf Google’s current search-based business and unleashes existential challenges to market leaders across numerous industries, including car makers, auto insurers, energy companies and others that share in car-related revenue.

Why vehicle automation?

**Economic Benefits**
- Increased Road Network Efficiency
- Recovery of Time Lost due to Commuting
- Reduced Need for Parking in Cities
- Radically New Models for Personal Mobility and the Distribution of Goods and Services

**Why not?**

Image Credit: Rinspeed XchangE
Roadmap

- Why automated driving?

- Next Generation Vehicle project with Ford Motor Company

- Critical challenges ahead
Next Generation Vehicle Project

With the help of many others...

Jim McBride
Ford Motor Company

Ryan Eustice
University of Michigan

Edwin Olson
University of Michigan
Timeline

2007 DARPA Urban Challenge

2011

2014
What makes it work?
Platform Base: 2014 Ford Fusion Hybrid

- Rear Camera
- Lane-Keeping System
- Driver Alert System
- Blind Spot Indicator System with Cross-Traffic Alert
- Adaptive Cruise Control
- Pull-Drift Compensation
- Active Park Assist
Additional Sensing and Computation

3D Lidars  Radars  Cameras  INS  Compute

Robotics and AI vehicles with various sensors and computing hardware.
Cameras help read traffic light signals and provide additional sensing queues.

Wheel-hub sensor that detects revolutions to help measure the vehicle's motion.

 Orientation sensors measure the car's attitude and balance.

GPS provides a coarse measure of the vehicle's position.

Lasers sense 360 degrees around the vehicle for objects and localization.

Radar measures the speed and range to vehicles ahead.

Computers read data and regulate vehicle behavior.
The Basic Architecture

3D Map (Prior)

Localization

Planning

Control

IMU: GPS, Gyroscope, Wheel Encoders

Sensing: Lasers, Cameras, Radars

Obstacle Detection/Classification
Mapping & Localization
Planning & Control
The Basic Architecture

IMU: GPS, Gyroscope, Wheel Encoders

3D Map (Prior)

Localization

Planning

Control

Sensing: Lasers, Cameras, Radars

Obstacle Detection/Classification
Why precision mapping?

- **Humans don’t need precision maps, nor centimeter-scale localization. Why should cars?**

- **The problem:** currently beyond the state of the art to decode roads reliably and in real time with the level of accuracy required

- **The solution:** bake all of this information into a prior map – expect the expected

- **BUT:** now, the car needs to know exactly where it is

- For this localization, centimeters matter
Expect the expected

Reason about what’s different

- Roadways a very **controlled** environment
- Some of the hard part can be done in advance
  - e.g., know in advance where to look for a traffic light
- **Trade *some* of the real-time perception problem for localization within a prior map**
Before we drive
Before we drive
Before we drive
Sensing & Tracking
Roadmap

- Why automated driving?
- Next Generation Vehicle project with Ford Motor Company
- Critical challenges ahead
Questions for self-driving vehicles

**Adoption Challenges**
- Technological
- Economic
- Employment
- Ethical
- Legal
- Security
- Energy and the environment

**Technical Challenges**
- Maintaining Maps
- Adverse Weather
- Interacting with People
- Better Sensors
- Human Factors
Perception
Difficult Situations for Self-Driving

- Left turn across traffic
- Changes to road surface markings
- Traffic cops, crossing guards, police/fire
- All weather driving

Courtesy: J. Leonard, MIT
Human factors
So is “mostly” autonomous…

- Often suggested that self-driving cars will do “most” of the driving, with humans only intervening as necessary.

- NHTSA “Preliminary Statement of Policy Concerning Automated Vehicles” defines levels of automation:
  - Level 0 – No-Automation
  - Level 1 – Function-specific (independent) Automation
  - Level 2 - Combined Function Automation
  - Level 3 - Limited Self-Driving Automation (Human fallback)
  - Level 4 - Full Self-Driving Automation
Human Factors

- Humans cannot be trusted to intervene at low rates.

no-man’s land for automated cars

- cruise control + lane keep assist
- Car drives kids to school
- MTBI

seconds  minutes  hours  days  months  infinity

Image Credit: Volvo
It’s worse than inattention

- Less frequent human interventions lead to:
  - Decreasing innate “feel” for the vehicle
  - Less practice → lower skill level
  - Decreasing understanding of how to work with autonomous systems

- And you’re asking them to deal with the nastiest of the nasty!
So what do we do?

- “Mostly autonomous vehicles”

- **Fully autonomous vehicles** can reduce danger by limiting scenarios & speed. Many exciting research problems here!

- Keep human “artificially engaged” in driving
data: huge near-term potential for safety. Doesn’t address non-safety goals well.
Key to this will be testing venues like Mcity

- Safe, off-roadway test environment for AVs: simulated city
- Technology research, development, testing, and teaching
  - $6.5M+ project
  - Grand opening July 20, 2015
Mcity
Summary

- The potential for automated vehicles is great.
- The idea has been a bit overhyped in the media and public’s mind in terms of where the technology is really at in terms of nationwide, all-weather, driving.
- UM is making a large investment in doubling down on connected and automated vehicle research through its creation of the MTC and Mcity.
- Human factors, along with rigorous testing and validation, will play a critical role in how we safely bring about this technology to market.