The Road to Autonomous Vehicles

Ryan Eustice, Vice President of Autonomous Driving
Outline

• About Toyota Research Institute (TRI)
• Challenges for Self-Driving Vehicles
• TRI Approach to Automation
• Big Questions to Resolve
TRI Mission

TRI's mission is to use artificial intelligence to improve the quality of human life.

- Vehicle Safety
- Mobility Access
- Robotics
- Discovery in Materials Science
TRI Multi-Campus Strategy

Three Campuses – Close to University Partners
Challenges for Self-Driving Vehicles
Challenges 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
SAE Levels of Automation

0
NO AUTOMATION

1
DRIVER ASSISTANCE

2
PARTIAL AUTOMATION

3
CONDITIONAL AUTOMATION

4
HIGH AUTOMATION

5
FULL AUTOMATION

Level 1
One degree of freedom is controlled, e.g., longitudinal Adaptive Cruise Control

Levels 4/5
Human is always a passenger; the only distinction between 4 and 5 is operational domain (i.e., geofenced vs. unrestricted)

Level 2
Readiness for hand-off requires constant vigilance from driver that may not be sustainable over time

Level 3
Difficult for vehicle to ensure driver has sufficient warning to re-engage in time for hand-off

“None of us in the automobile or IT industries are close to achieving true Level 5 autonomy. It will take many years of machine learning and many more miles than anyone has logged of both simulated ...and real-world testing to achieve the perfection required for Level 5 autonomy.”

-Dr. Gill Pratt, TRI CEO
Consumer Electronics Show, January 2017
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
Precision Mapping

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

• **The problem:** it is extremely difficult 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
Traffic Light Detection
Does Green Always Mean Go?
The Social Dance of Driving
What Do You See in This Picture?
Challenges of Guaranteeing Levels 4/5

Corner of Plymouth and Green Rd

TRI-ANN
TRI Approach to Automation

GOAL: Using Artificial Intelligence, Transform Toyota’s Ability to Improve:

Safety

~ 1,250,000 People / Yr. Worldwide
(~ 35,000 in the US)

Guardian
Safety

• USA – 6.1 million crashes per year\(^1\)
  – Over 35,000 fatalities per year (and rising!)
  – 2.3 million injuries

• Worldwide\(^2\)
  – Over 1.25 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%

TRI Approach to Automation

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Guardian

Access

Chauffeur
Access

Social Impact

• Aging population (both in the US and worldwide)
• Disabled or impaired
TRI Approach to Automation

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Guardian

Access

Chauffeur

Quality of Life

Robotics
Quality of Life

In-Home Robotics

Image Credit: Intuition Robotics

TOYOTA PARTNER ROBOT GROUP
SILICON VALLEY, CALIFORNIA

TRI Approach to Automation: One System, Two Applications

- ABS
- ASC
- NAV
- Side Collision Warn
- Front Collision Warn
- Automatic Emergency Braking
- Lane Departure Warn
- Lane Departure Prevention
- Collision Avoidance Steering
- Collision Avoidance Acceleration

SAE Level

- 0
- 1
- 2
- 3
- 4
- 5

Technology

Guardian

TRI Ultimate Goal

Chauffeur
Guardian Strategy — Build an Uncrashable Car

“Flip” the handoff problem – Human always in control

- Don’t leave the road
- Don’t hit anything
- Don’t get hit
- Understand driver intent

- Inform
- Warn
- Intervene
Chauffeur Strategy – Mobility as a Service (MaaS)

• Mobility as a Service (MaaS) may offer best application for bringing Level 4 to market faster
• Chauffeur for personally-owned vehicles (POV) requires solving the long asymptote for anywhere L4/L5 capability

Geo-fenced, low-complexity, amortized sensor cost

MaaS data aggregation will speed development

Today

Level 5

MaaS

Chauffeur L4, L5

POV

MaaS

Time for Deployment

Maturity

Chauffeur

• No constraints, requires low cost sensors
• Limited drive data spread thinly over larger area
• Fast

$\text{POV \$\$\$}$

$\text{MaaS}$
Big Questions Going Forward

• What are the technical challenges?
  – Maintaining Maps
  – Adverse Weather
  – Interacting with People
  – Robust Computer Vision (towards \(PD=1.0, PFA = 0.0\))

• For Level 2 and Level 3 approaches, can humans be trusted to take control when necessary?

• For Level 4 and Level 5 approaches, can near-perfect false-positive and false-negatives be obtained in a wide variety of demanding settings?

• Can we deploy autonomous vehicle technology sooner?

Human must pay attention, but autonomy will jump in to prevent accidents
Summary

• The potential for automated vehicles is great

• But, the idea has been a bit overhyped in the media and public’s mind – current technology not yet ready for nationwide, all-weather driving

• Human factors, along with rigorous testing and validation, will play a critical role in how this technology is safely brought to market