KENNESAW STATE
UNIVERSITY

Module 12:

Autonomous Vehicles Overview

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Agenda

- What is Autonomous Vehicle?
- Why is it important?
- How autonomous vehicle operates?

What is an Autonomous Vehicle?

One of the first forms of automated transportation was the elevator

Introduction

- Unmanned Vehicles:
- No driver on-board the vehicle
  - Teleoperated
    - Driven by an operator viewing video feedback Toy remote control car
  - Autonomous
    - Driven by on-board computers using sensor feedback and automatic controls
- Usage:
  - Dangerous tasks
  - Repetitive tasks
  - Dirty tasks

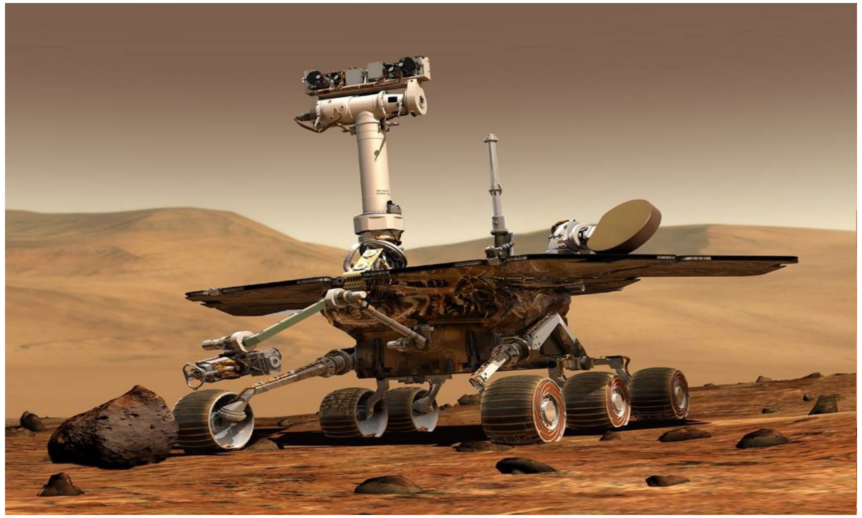
Examples (1)

- DEPTHX:
- Autonomous under-water robot to explore water-filled sink holes in Mexico. The image shows a 318 meter deep sink hole.

Source: IEEE Spectrum, Sep-2007

Examples (2)

- Mars Rover by NASA



Source: http://marsrover.nasa.gov/

Source:Thrun et al. “Stanley: The robot that won the DARPA Grand Challenge”

Why Smart and Autonomous Vehicle?

- Travelling by car is currently one of the most deadly forms of transportation, with over a million deaths annually worldwide

- As nearly all car crashes (particularly fatal ones) are caused by human driver error, driverless cars would effectively eliminate nearly all hazards associated with driving as well as driver fatalities and injuries

Source:http://www.ivtt.org/IVTT

Levels of Automation (SAE J3016)

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**

Examples Systems at each level

SAE Level	Example Systems	Driver Roles
1	Adaptive Cruise Control OR Lane Keeping Assistance	Must drive <u>other</u> functions and monitor driving environment
2	Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist	Must monitor driving environment (system nags driver to try to ensure it)
3	Traffic Jam Pilot Automated parking Highway Autopilot	May read a book, text, or web surf, but be prepared to intervene when needed
4	Closed campus driverless shuttle Valet parking in garage ‘Fully automated’ in certain conditions	May sleep, and system can revert to minimum risk condition if needed
5	Automated taxi Car-share repositioning system	No driver needed

Contests and Programmers

- EUREKA Prometheus Project (1987-1995) ARGO Project, Italy (2001)
- DARPA Grand Challenge (2004-2007) European Land-Robot Trial (2006-2008)
- VaMP and VITA-2 vehicles (1994)
  - 1000 km on a Paris multi-lane highway in heavy traffic at up to 130 km/h
  - Autonomous convoy driving, vehicle tracking, lane changes, passing of other cars
- Autonomous Mercedes S-Class in 1995
  - 1000 km on the German Autobahn at 175 km/h
  - Not 100% autonomous. A human safety pilot was present Car drove upto 158 km without intervention

DARPA Grand Challenge

- US Department of Defense conducts the autonomous vehicle challenge
- 2004: Mojave Desert, United States, along a 150-mile track 2005: 132 mile off-road course in Nevada
- 2007: 'Urban Challenge' at George Air Force Base

Typical Challenges to meet

- Navigate desert, flat and mountainous terrain
- Handle obstacles like bridges, underpasses, debris, potholes and other vehicles
- Obey traffic laws
- Safe entry into traffic flow and passage through busy intersections
- Following and overtaking of moving vehicles
- Drive an alternate route when the primary route is blocked Correct parking lot behaviour
- Most important rule: No Collisions

Source:Google Videos: The Car That Won The DARPA Grand Challenge: 2006”

DARPA 2007 Track

Source:DARPA Urban Challenge Participants Conference Presentation

What should an autonomous vehicle do?

- Understand its immediate environment (Perception)
- Find its way around obstacles and in traffic (Motion planning)
- Know where it is and where it wants to go (Navigation)
- Take decisions based on current situation (Behavior)

Early Deployment Opportunities

- Driver assistance functions
- Low speed shuttles
- Truck platooning

Smart City Challenge

- 78 applicants, 7 finalists
- Winner: Columbus, Ohio
- $40 million Federal funding plus private funding
- Automated vehicles
  - First-mile / last mile deployment of several electric automated vehicles on public roadways
  - Heavy truck (tractor) platooning

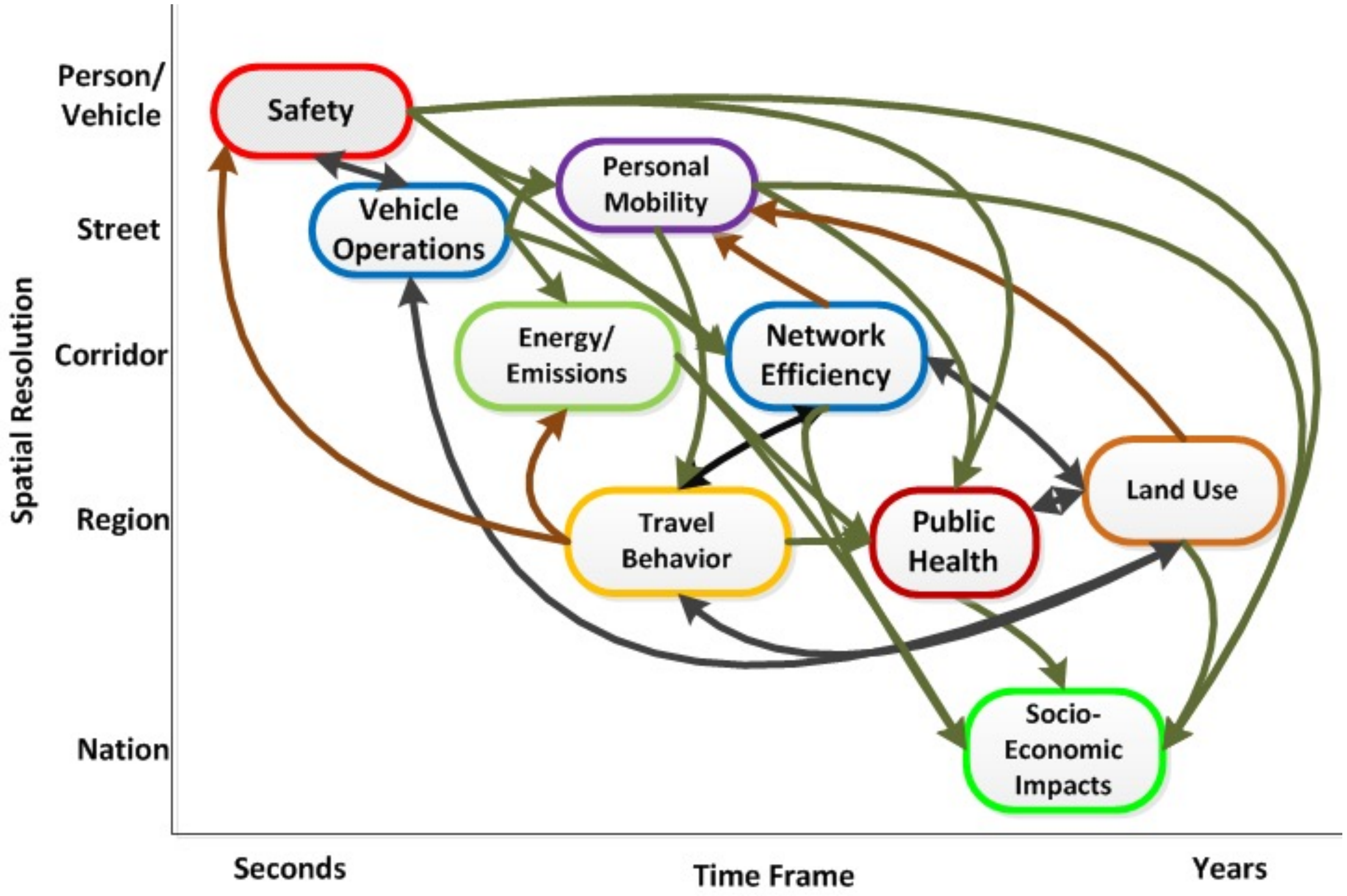
Federal Automated Vehicle Policy

- Focuses on Highly Automated Vehicles (SAE level 3 – 5)
- "…sets out a proactive safety approach that will bring lifesaving technologies to the roads safely while providing innovators the space they need to develop new solutions. "
- Consistent with NHTSA's mission, it focuses on vehicles and drivers
- Does not explicitly address role of MPOs, transit, land use, etc.
- Four components
  - Vehicle Performance Guidance
  - Model State Policy
  - Current Regulatory Tools
  - Modern Regulatory Tools
- www.transportation.gov/AV

Conferences and Mailing Lists

- Automated Vehicles Symposium
  - Annual conference sponsored by TRB and AUVSI
  - 1200 attendees in July 2016
  - http://www.automatedvehiclessymposium.org
- Examples of mailing lists
  - Smart Transportation Dispatch (Carnegie Mellon University)
  - Smart Driving Cars (Alain Kornhauser)

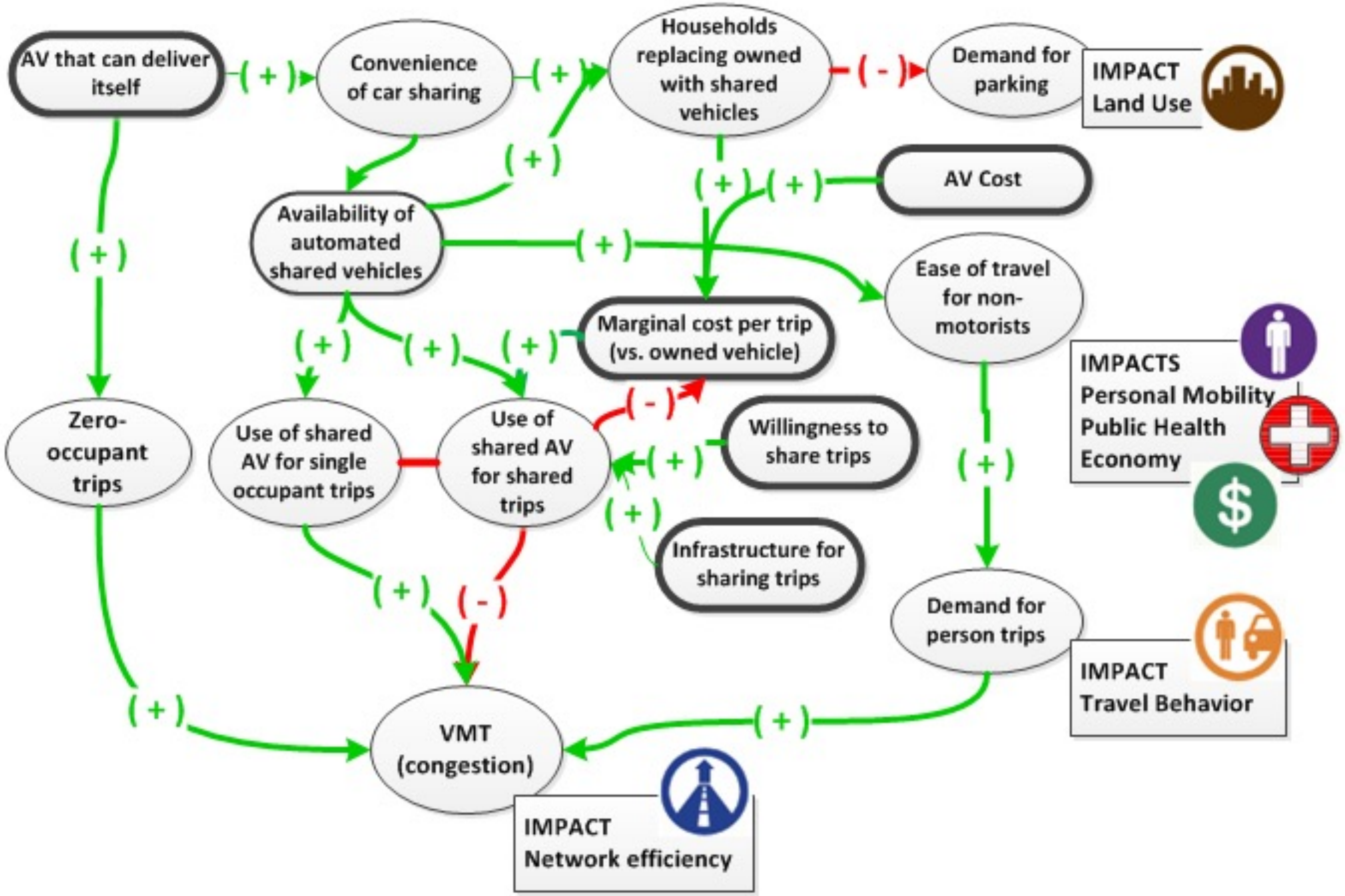
Impacts of AVs



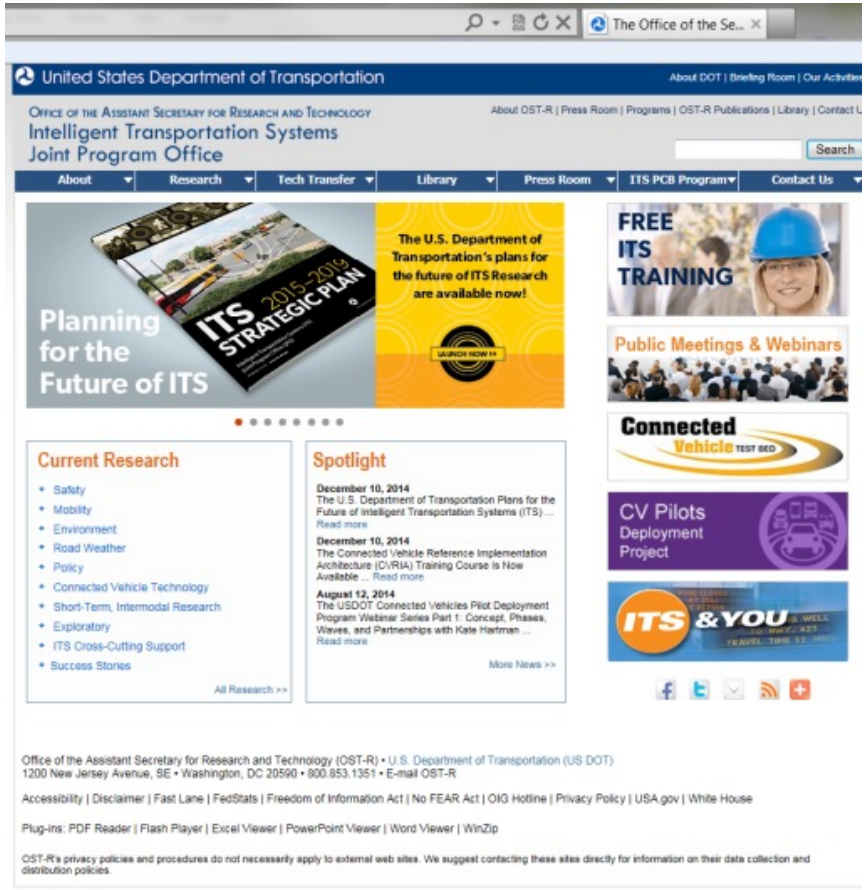
Direct and Indirect Impacts

- Cost
- Infrastructure
- Safety
- Vehicle Operations
- Energy / Emissions
- Personal Mobility
  - Multi-tasking
  - Accessibility
- Asset Management
  - Lanes and lane widths
  - V2I infrastructure
  - Size and weight
- Network Efficiency
- Travel Behavior
- Public Health
- Land Use
- Socio-Economic

Going from Direct to Indirect Impacts



For More Information



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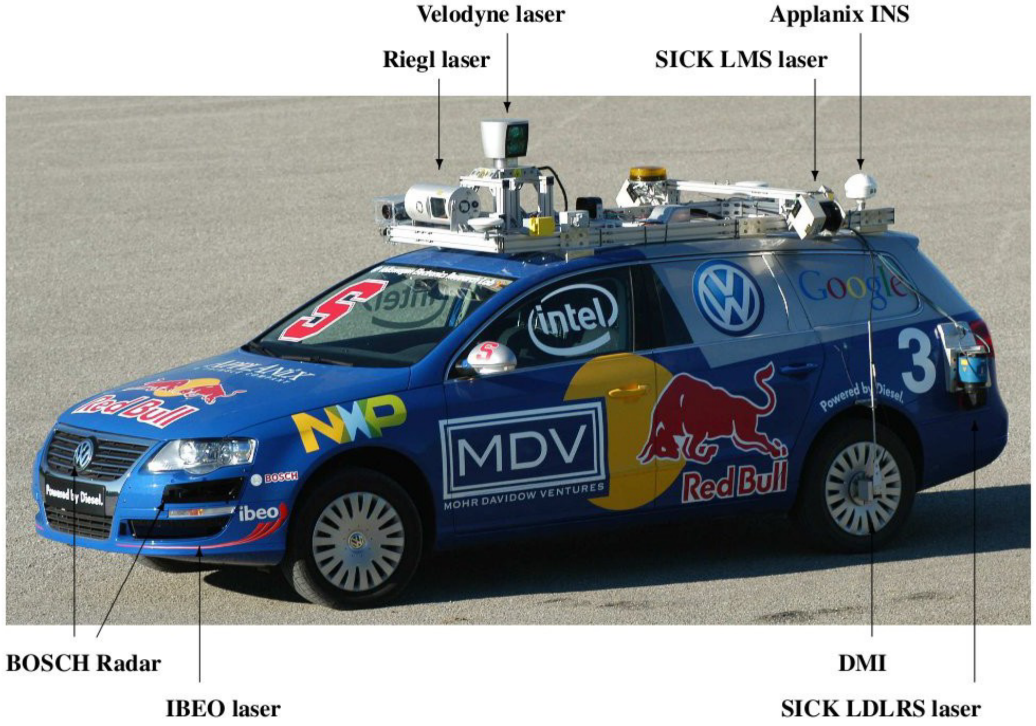
Perception

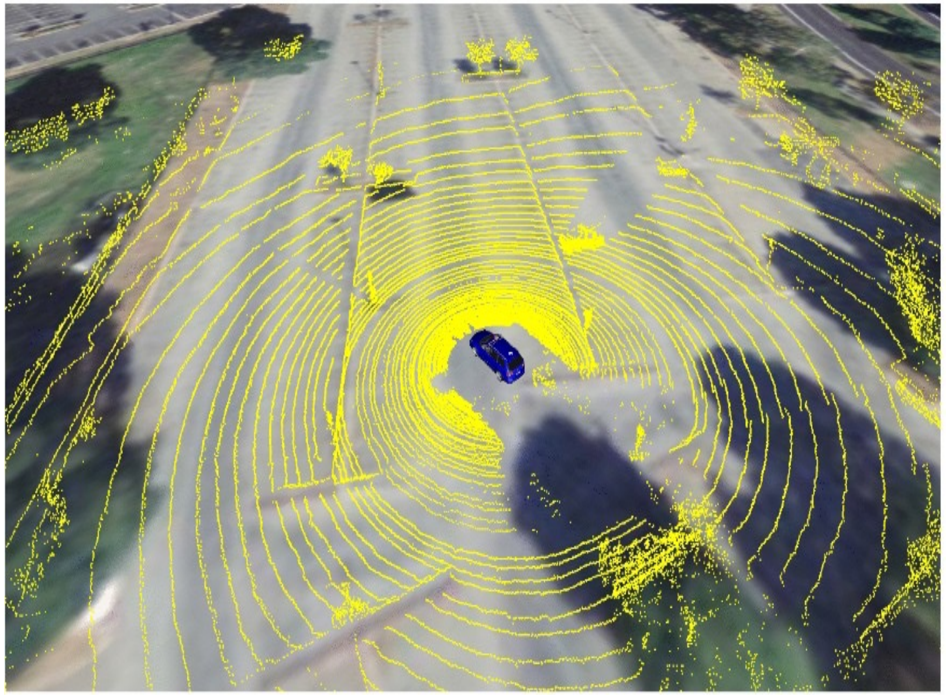
- LIDAR (Light Detection and Ranging)
- RADAR
- Vision GPS
- Inertial navigation system



Source:Thrun et al. “Stanley: The robot that won the DARPA Grand Challenge”

LIDAR – Obstacle Detection

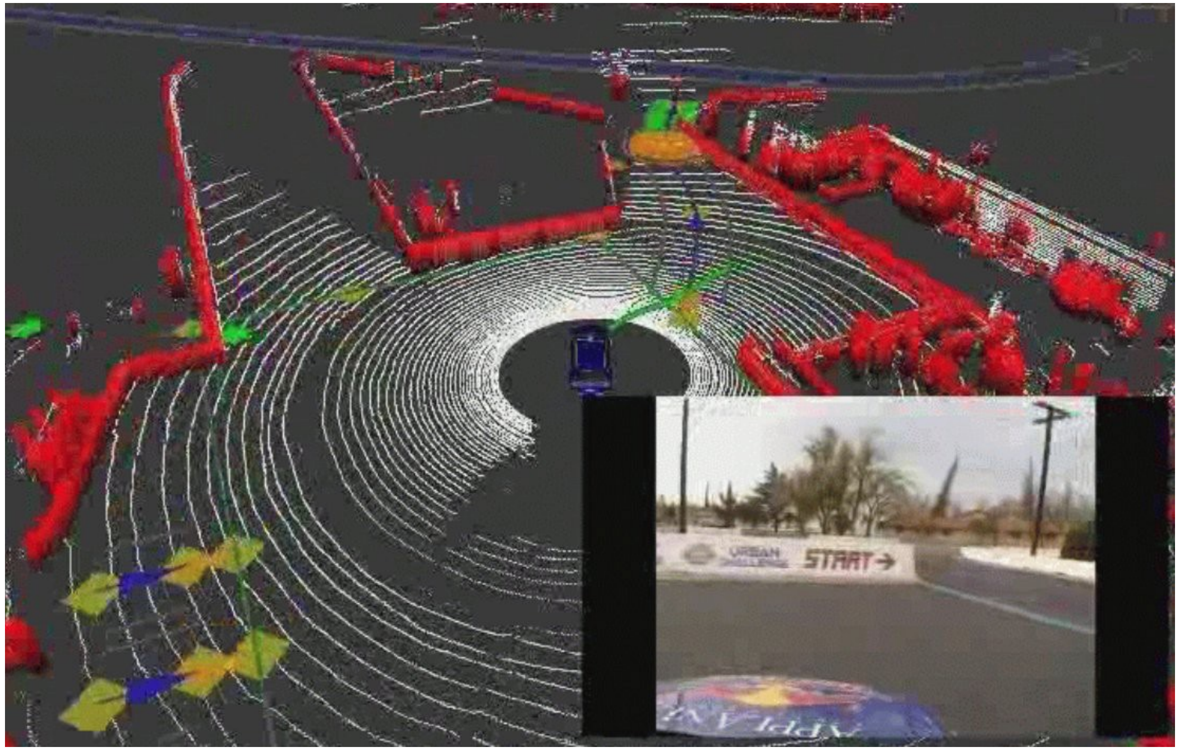
- Long range scanner has several lasers, each with a scanning ring
- Compare radius of adjacent rings to identify height of objects
- Use multiple short range LIDARs to cover blind spots
- Generate a point cloud based on LIDAR data
- Apply thresholds to this data to eliminate overhanging and low objects



Source:Thrun et al. “Junior: The Stanford Entry in the Urban Challenge”

Handling Occlusion

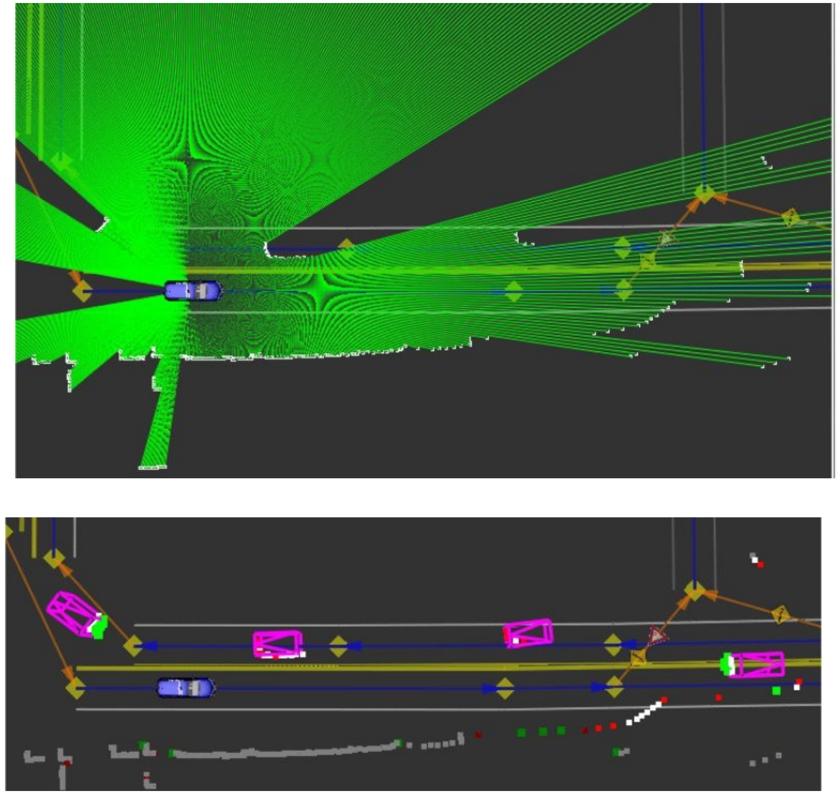
- Objects may not be always visible
- Integrate range data over time, to keep track of objects that may be temporarily occluded
- What about Moving objects?
- Integrate data only in those regions that are currently occluded



Source:Thrun et al. “Junior: The Stanford Entry in the Urban Challenge”

Object Tracking

- Identify and label distinct moving objects
- Obtain information about these objects, such as size, heading and velocity
- Continue to track these objects (even when they are occluded)
- Identify areas of change
- Initializes a set of particles as possible object hypotheses
- These particles implement rectangular objects of different dimensions, and at slightly different velocities and locations
- A particle filter algorithm is then used to track such moving objects over time



Source:Thrun et al. “Junior: The Stanford Entry in the Urban Challenge”

Further Challenges in Perception

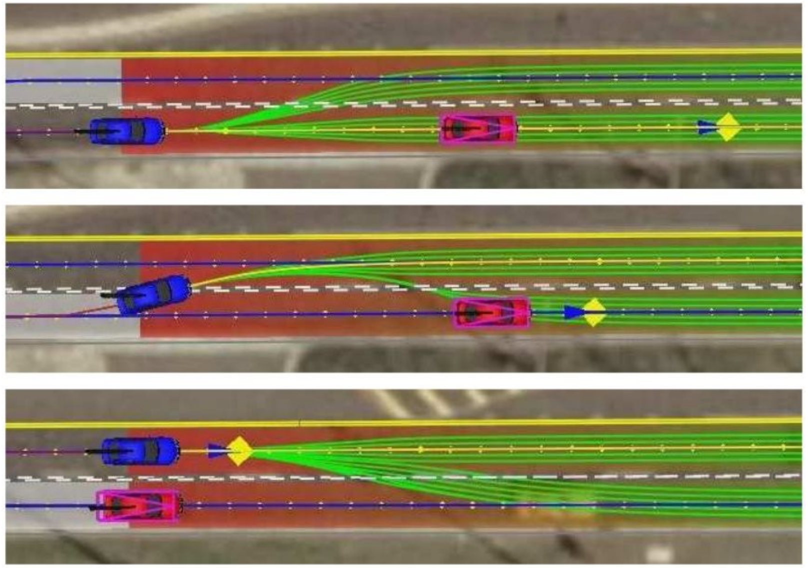
- What is a road?
- Self Localization
- Bad/Noisy data
- Sensor failure (ex: GPS outage)
- Setting ’good’ thresholds

Motion Planning

- Motion planning involves performing low level operations towards achieving some high-level goal
- Path Variables:
  - Steering (direction)
  - Speed
- Planning:
  - Vary these parameters and generate multiple local paths that can be followed
  - Assign costs to paths based on time taken, distance from obstacles, and other constraints
  - Choose the best path from the various possible paths

Varying Direction

- Direction is varied by tracing possible paths from current position to a set of (temporary) local goals. These goals are slightly spread out to be able to navigate around obstacles. Paths of greater length, paths that are near obstacles incur higher cost.



Source:Thrun et al. “Junior: The Stanford Entry in the Urban Challenge”

Applications

- Military uses:
  - Surveillance and Reconnaissance
  - Clearing Mines
  - Transporting Supplies/troops
- Civilian uses:
  - Robots dont drink/sleep/use cellphones...
  - Help incapacitated people to drive
  - Increase productivity
  - Increase road throughput