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Accident avoidance by active intervention for Intelligent Vehicles

Towards Affordable Autonomy in Urban Settings

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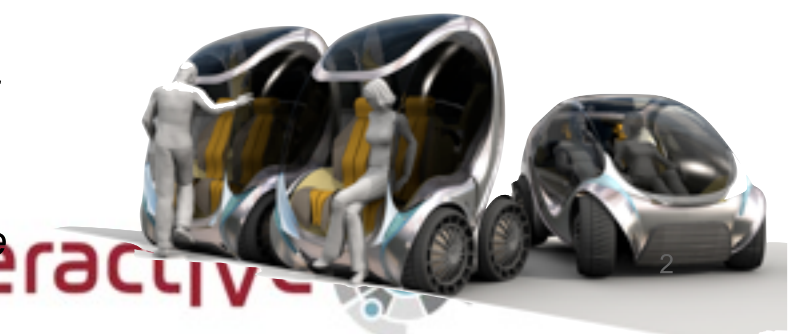
Why Autonomy?

Autonomous driving capabilities will play a fundamental role in future mobility systems:

- **Safety/comfort:** provide mobility to people who cannot, should not, or prefer not to drive (elderly, youth, disabled, ...). Driver assistance systems: leverage autonomy to enhance safety of human driven vehicles.

- **Efficiency/throughput:** autonomous vehicles can coordinate among themselves and with traffic control infrastructure to minimize the effects of congestion
- **Environment:** Autonomous driving can reduce emissions as much as 20-50%, and/or efficiently interface with smart power grids and hybrid engines
- **Automobile 2.0:** Autonomy can enable new ways of thinking about automobiles and transportation systems in general.
  For example, enable adaptive and self-reconfigurable mobility-on-demand systems



State of the art: bleeding edge

- Google “driverless” car
  - Drove > 200,000 Km in traffic
  - Human safety driver in the driver seat

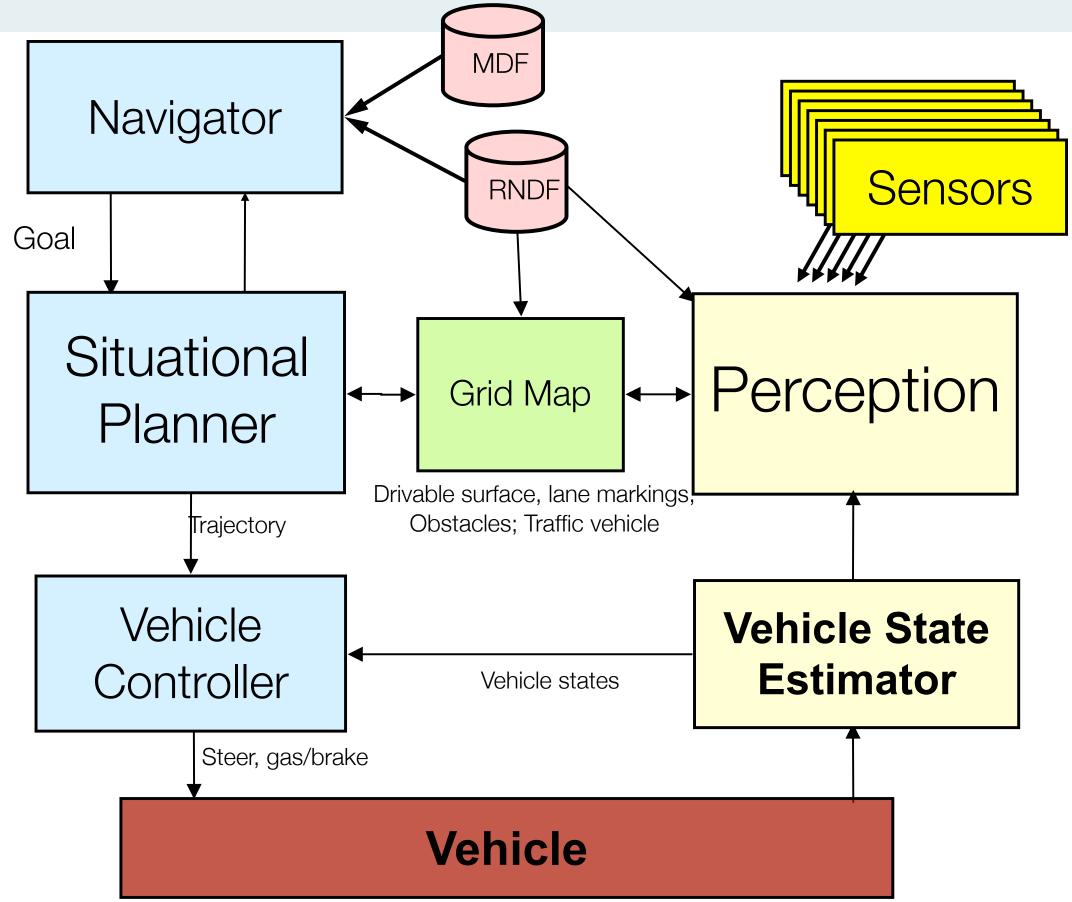
Autonomous driving technologies

- Several projects since the 80's: Eureka, PATH, etc.
- Rapid development pushed by DARPA Grand Challenge events ('04,'05, '07)
- All successful vehicles used essentially the same technologies.

System Architecture

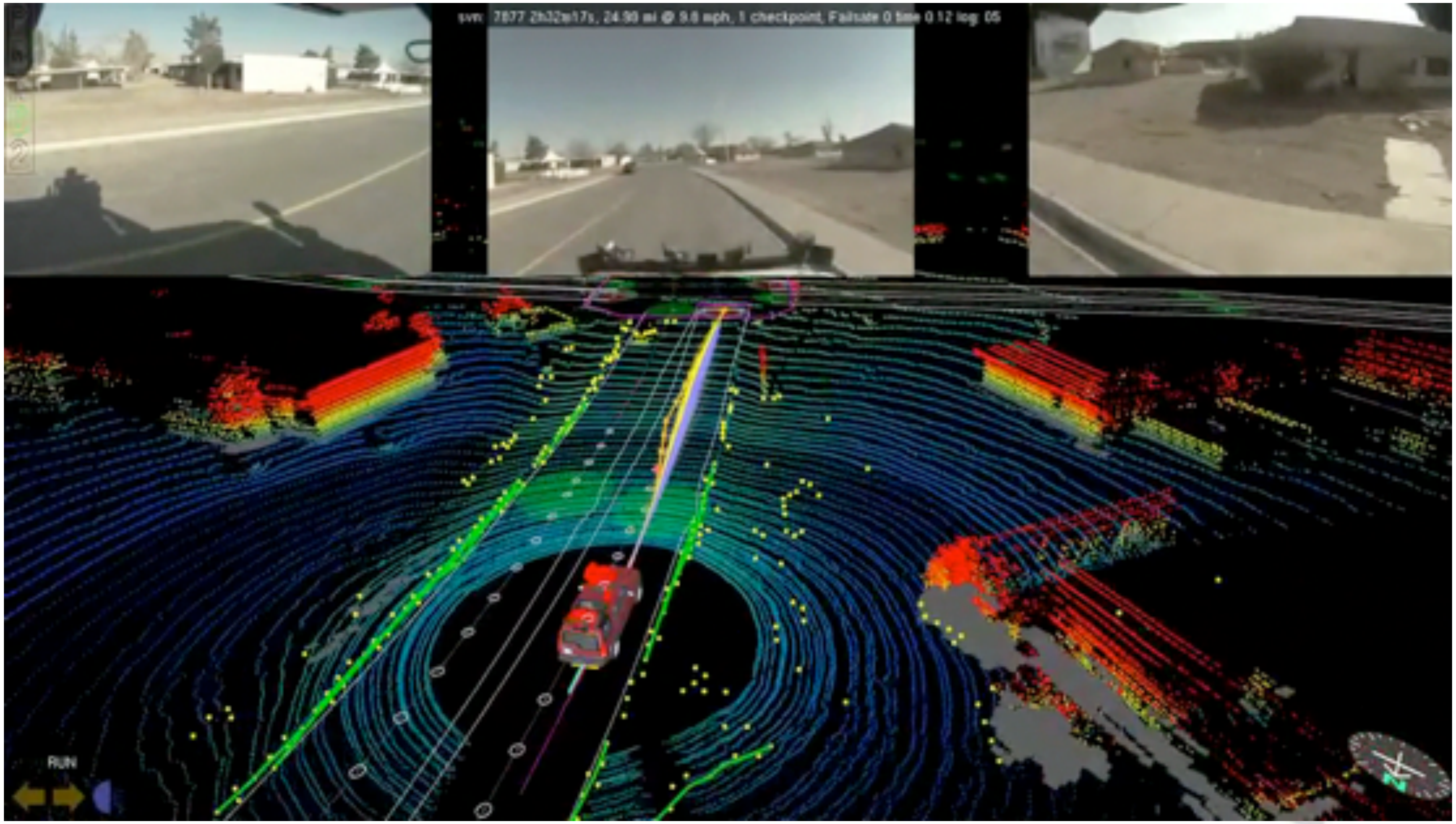
- Perception
  - What the environment looks like
  - Where we are
- Planning & Control
  - How to reach the goal

AEVIT Vehicle Conversion (EMC)
Continuous signal (steering, gas/brake)
Discrete signal (turn signals, gear shift)



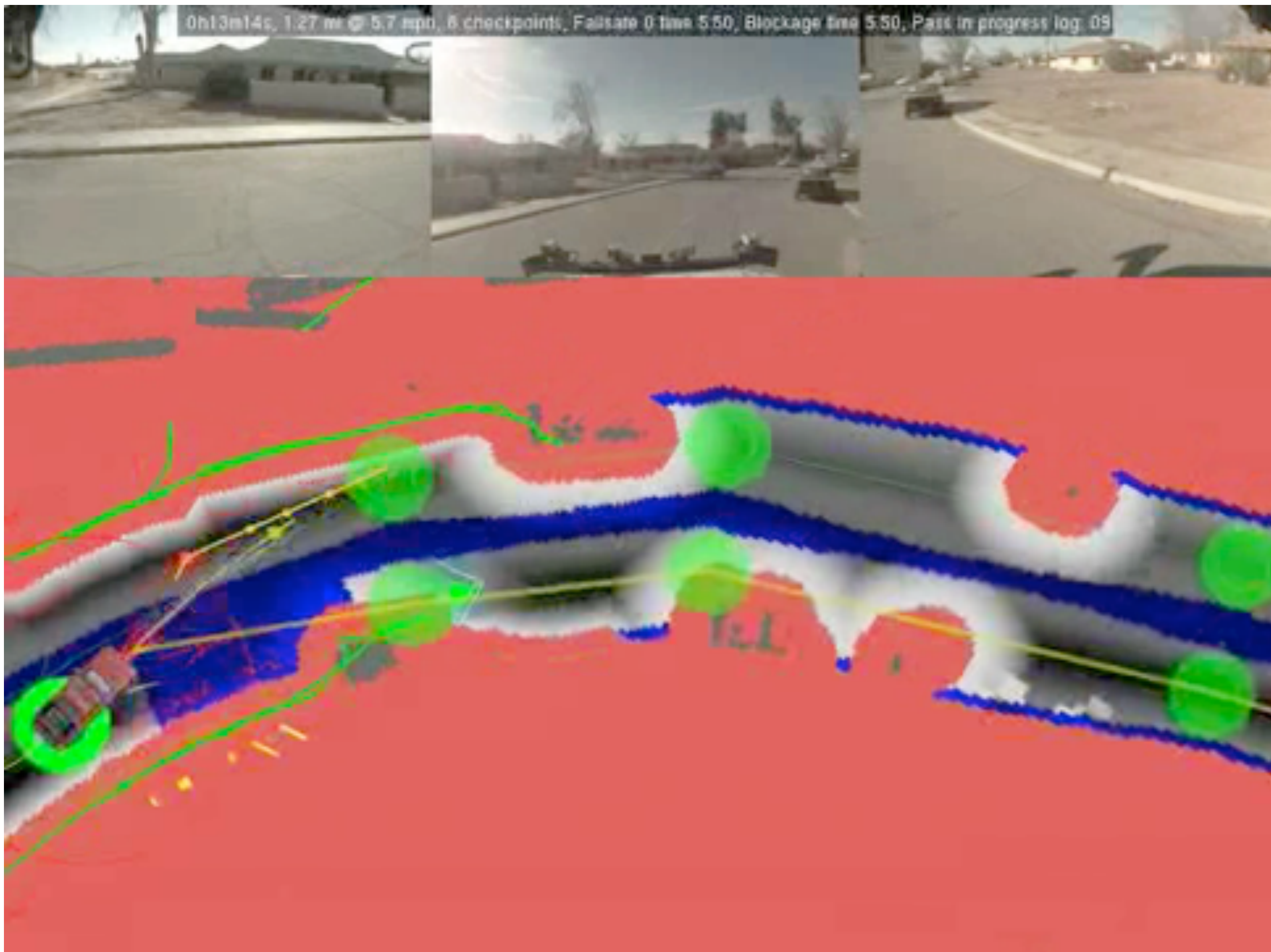
Perception

- Different sensors used for different purposes
    - Skirt Lidars, Velodyne: static obstacles
    - Push-broom Lidars, Velodyne: curbs
    - Radars: moving objects
    - Cameras: lane markings



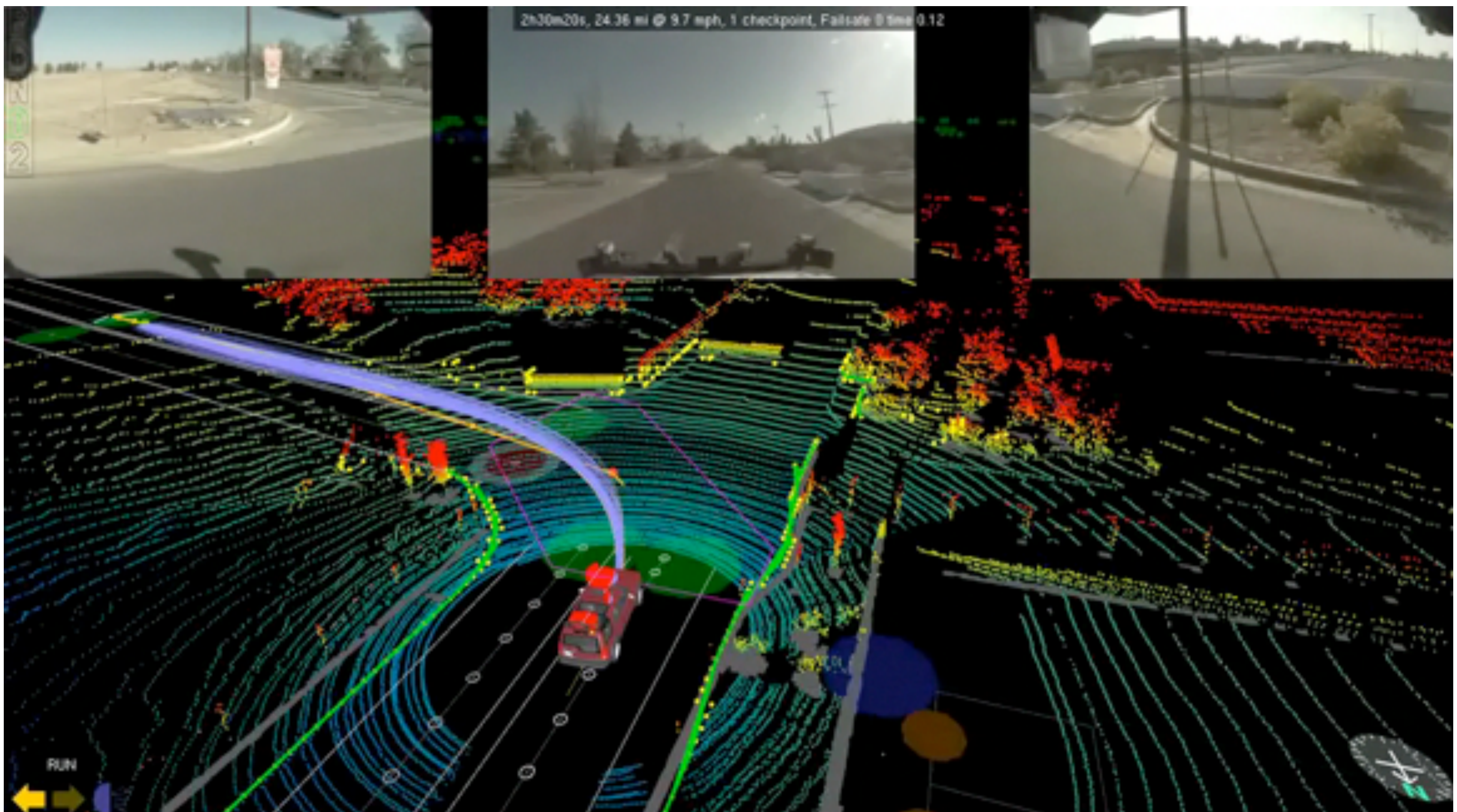
Drivability/Grid Maps

- Two maps: obstacles and lanes
- Cost function for motion planner

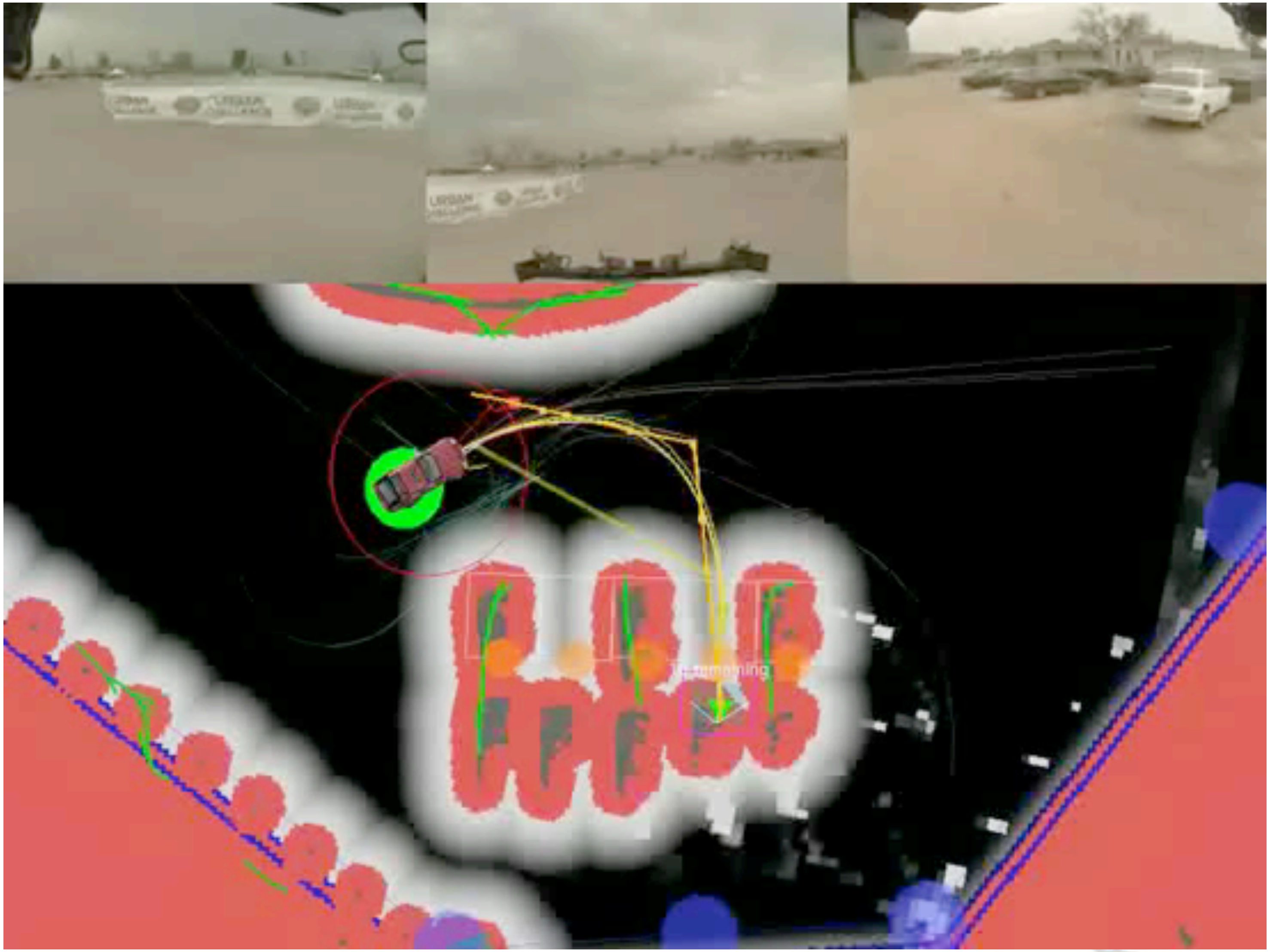


Basic Driving

- Safe driving by default for various driving conditions:
- Behaviors naturally emerge from RRT planner:
  - Slow down near turns, yield and merge into traffic
  - Passing other vehicles, 3 point turn to change direction, etc.

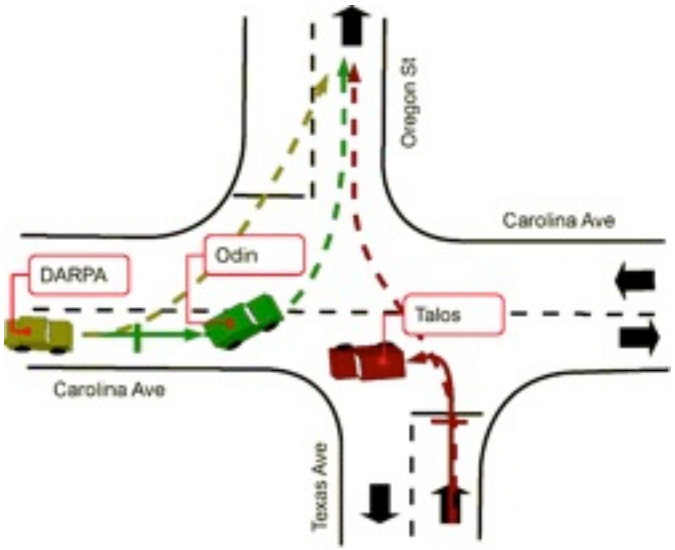


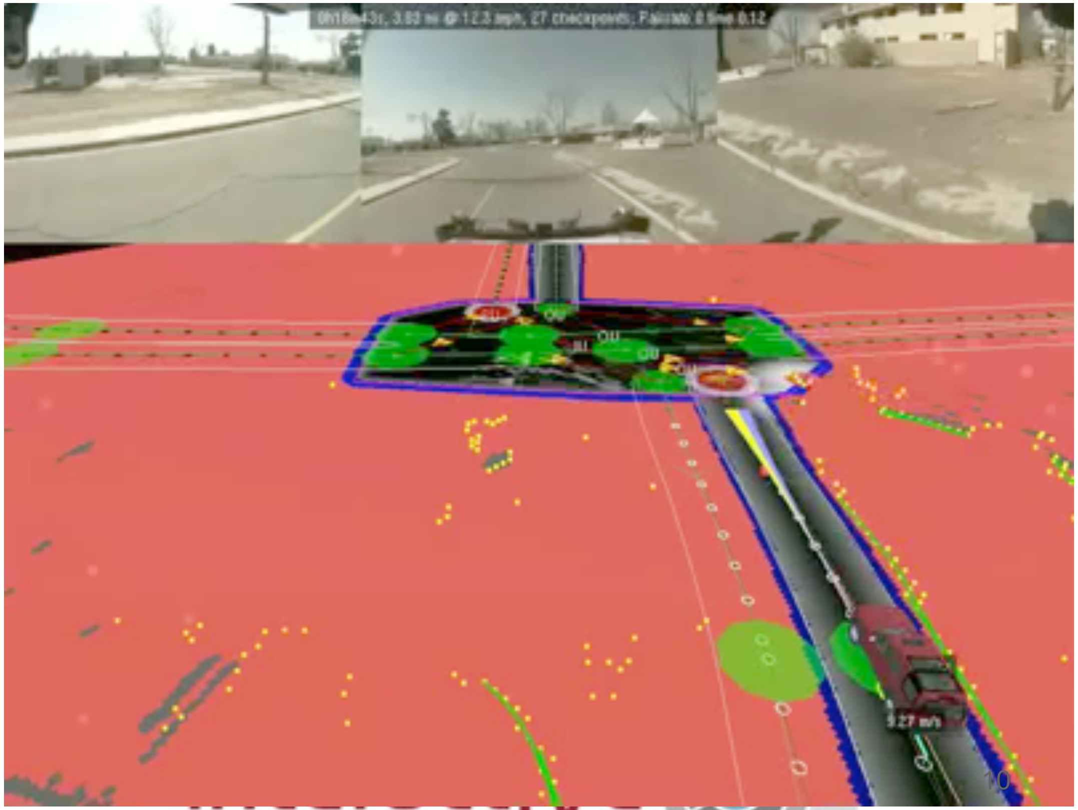
Parking



Evasive Maneuvering

- Intention of other cars not always clear
  - Have to believe that other vehicles will behave rationally
  - Still need to be able to avoid accordingly
- Video shows safe avoidance maneuver





Critical Challenge #1: Legal/Regulatory Aspects

- Autonomous driving is a (technological) reality
- However, "The technology is ahead of the law in many areas" (California DMV)
- On **June 16, 2011**, Nevada passed a law requiring its DMV to set out minimum safety and insurance requirements for autonomous vehicles.
- On **May 7, 2012**, the first "autonomous vehicle" test license was issued to Google.

Assembly Bill No. 511–Committee on Transportation

CHAPTER..........

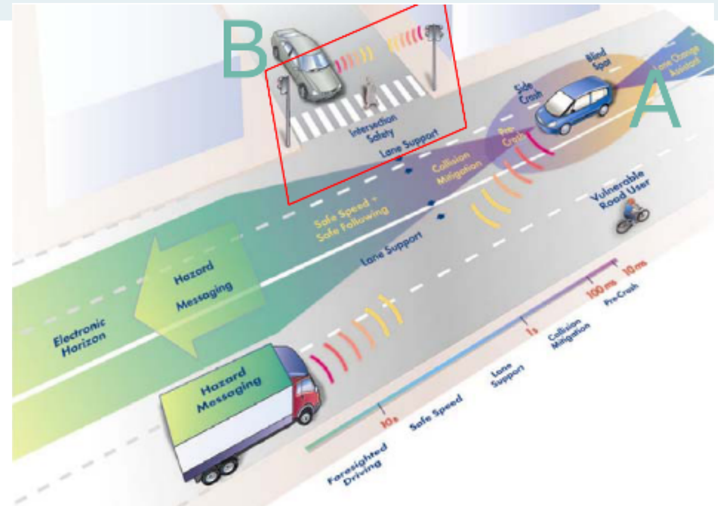
AN ACT relating to transportation; providing certain privileges to the owner or long-term lessee of a qualified alternative fuel

SENATE AND ASSEMBLY, DO ENACT AS FOLLOWS:

Section 1. (Deleted by amendment.)
Sec. 2. Chapter 483 of NRS is hereby amended by adding thereto a new section to read as follows:
1. The Department shall by regulation establish a driver's license endorsement for the operation of an autonomous vehicle

Critical Challenge #2: Affordable autonomy

Affordable autonomy exploiting information exchange/ coordination with:
- other vehicles (smart cars, buses, possibly private vehicles, smartphones on vehicles/pedestrians)
- fixed “cyber”-infrastructure (sensors, assisted GPS, e.g. iPhone)
- Reduction of on-board sensing+computing needs
- Cooperation with other vehicles (robotic or human controlled)share route with buses, automated platooning
- Autonomous reconfiguration in case of vehicle/route failures
- Smart grid integration: Autonomously schedule charging/redeployment according to energy pricing



Future urban mobility systems

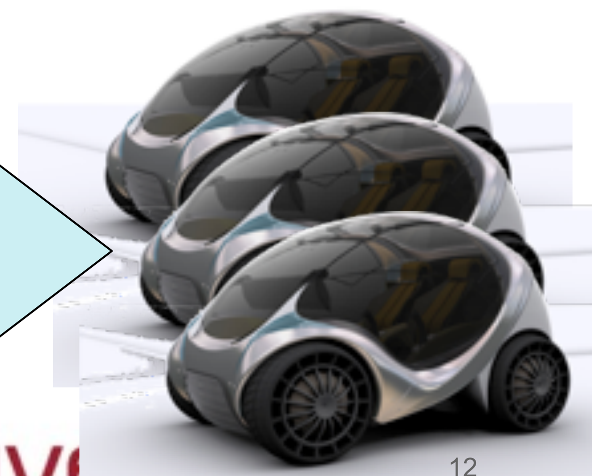
DARPA Urban Challenge

~500,000$ (US)

CityCar prototype

~50,000$ (US)

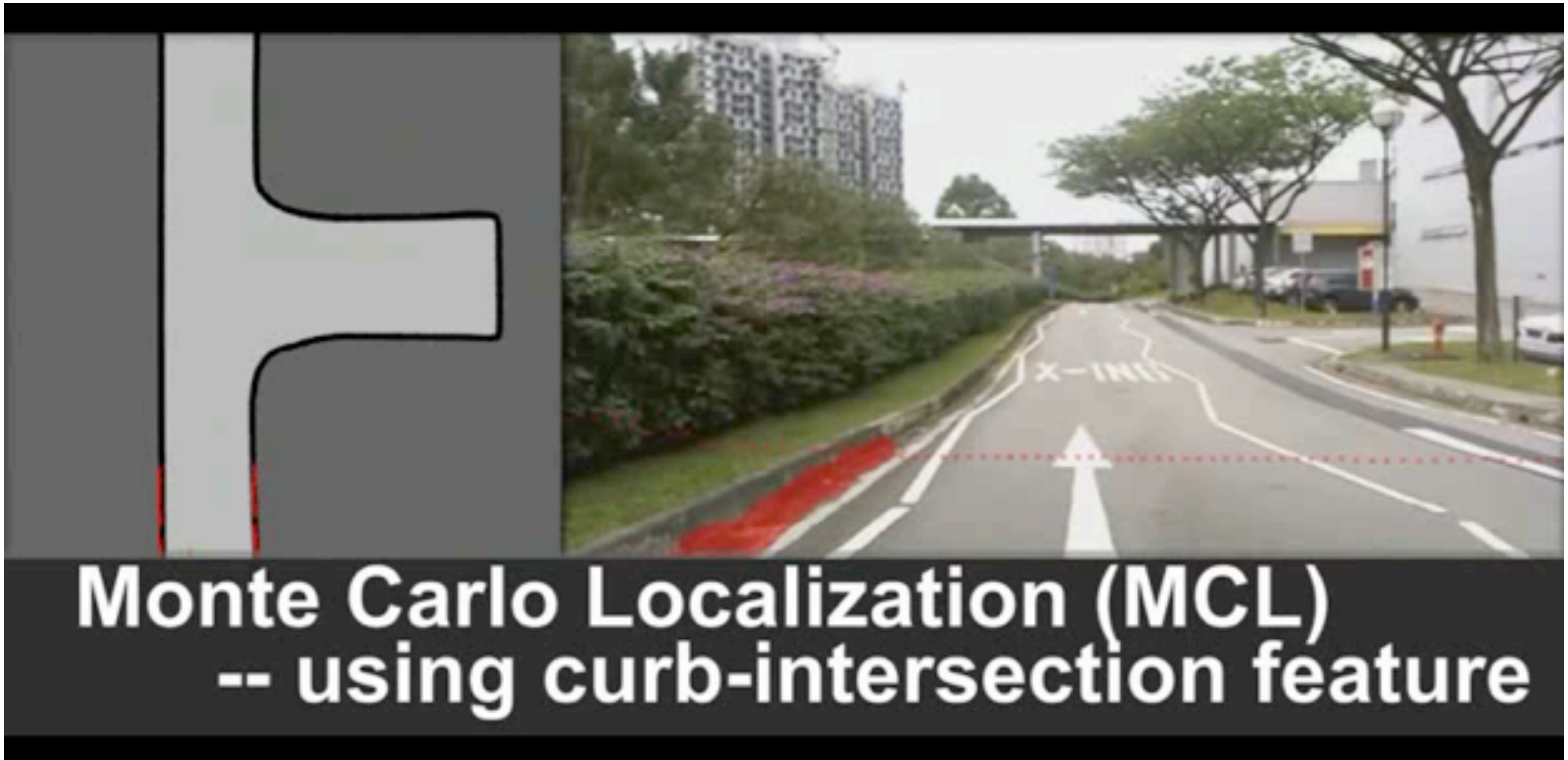
?



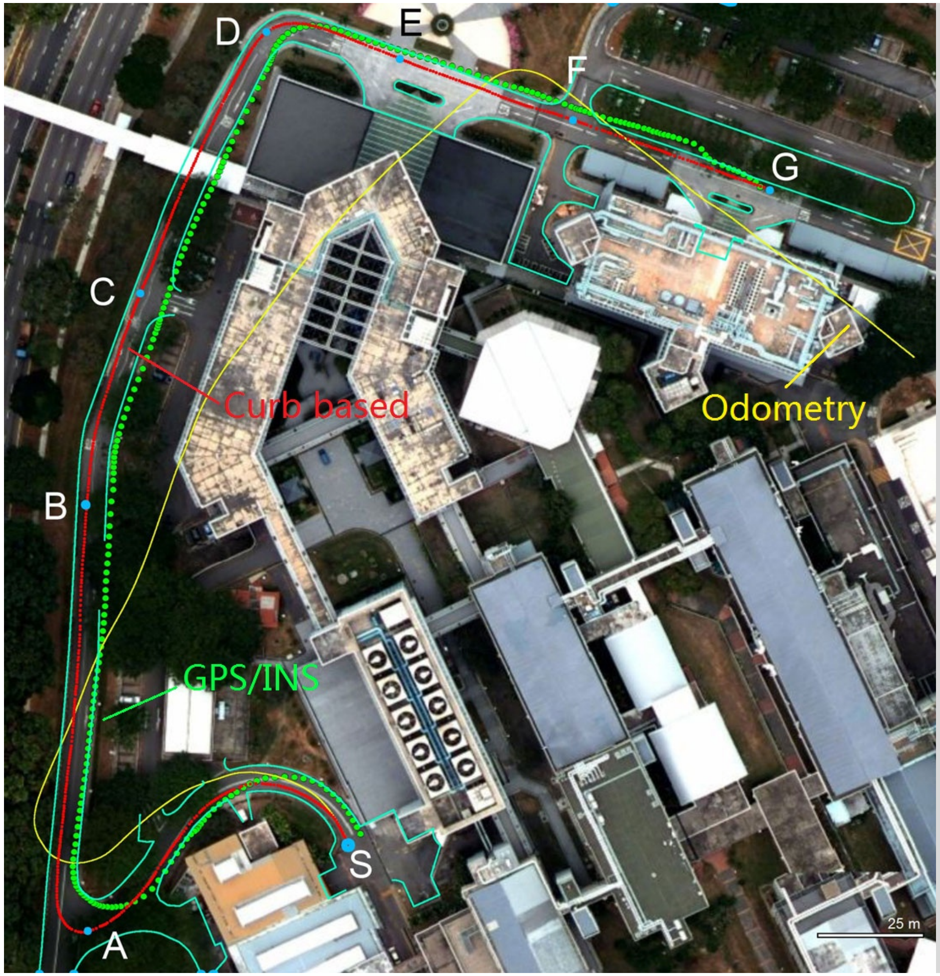
~5,000$ each (US)

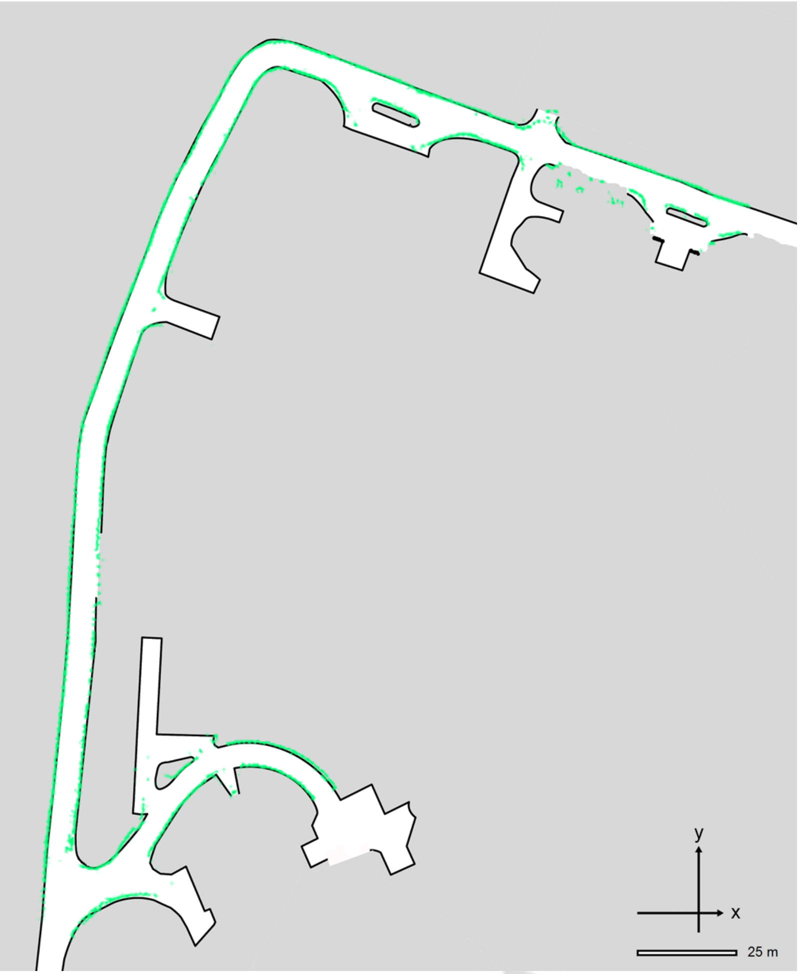
Curb-based localization

- GPS localization is cheap but unreliable
- 3D LIDAR/vision-based SLAM is good but expensive/difficult
- Is curb sensing by planar LIDAR sufficient for localization?



Some results





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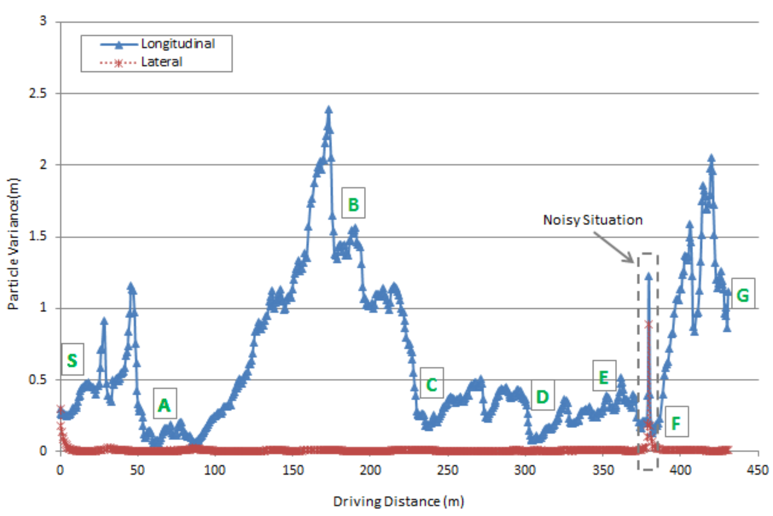
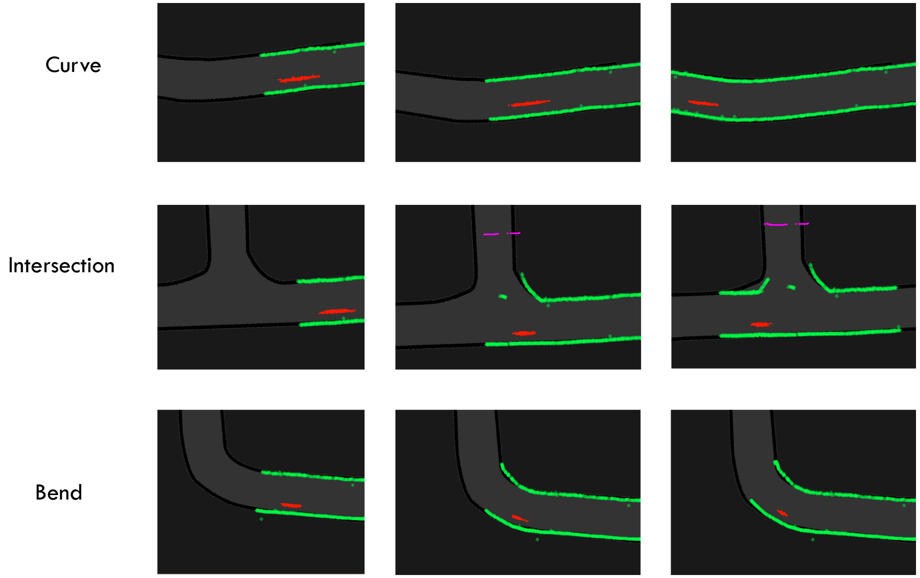
Some results

- Excellent lateral accuracy (error ~ 0.05 m)
- Excellent longitudinal accuracy **when needed**!

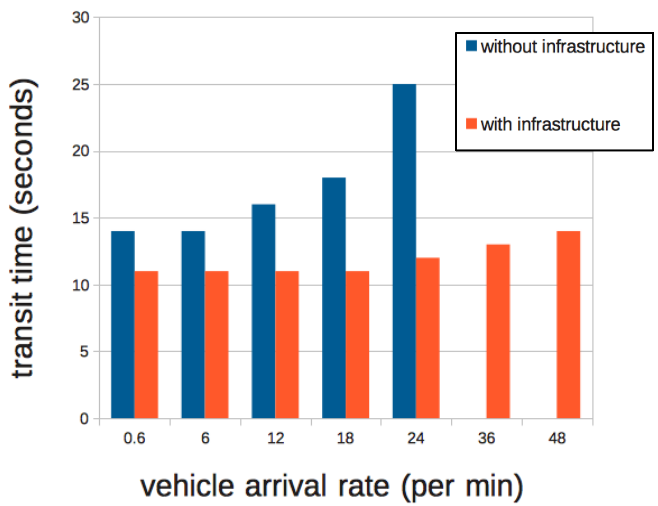
Marked Points	A	B	C	D	E	F	G
Position Error (m)	0.20	0.55	0.06	0.20	0.32	0.06	0.08
Orientation Error (degree)	< 3						



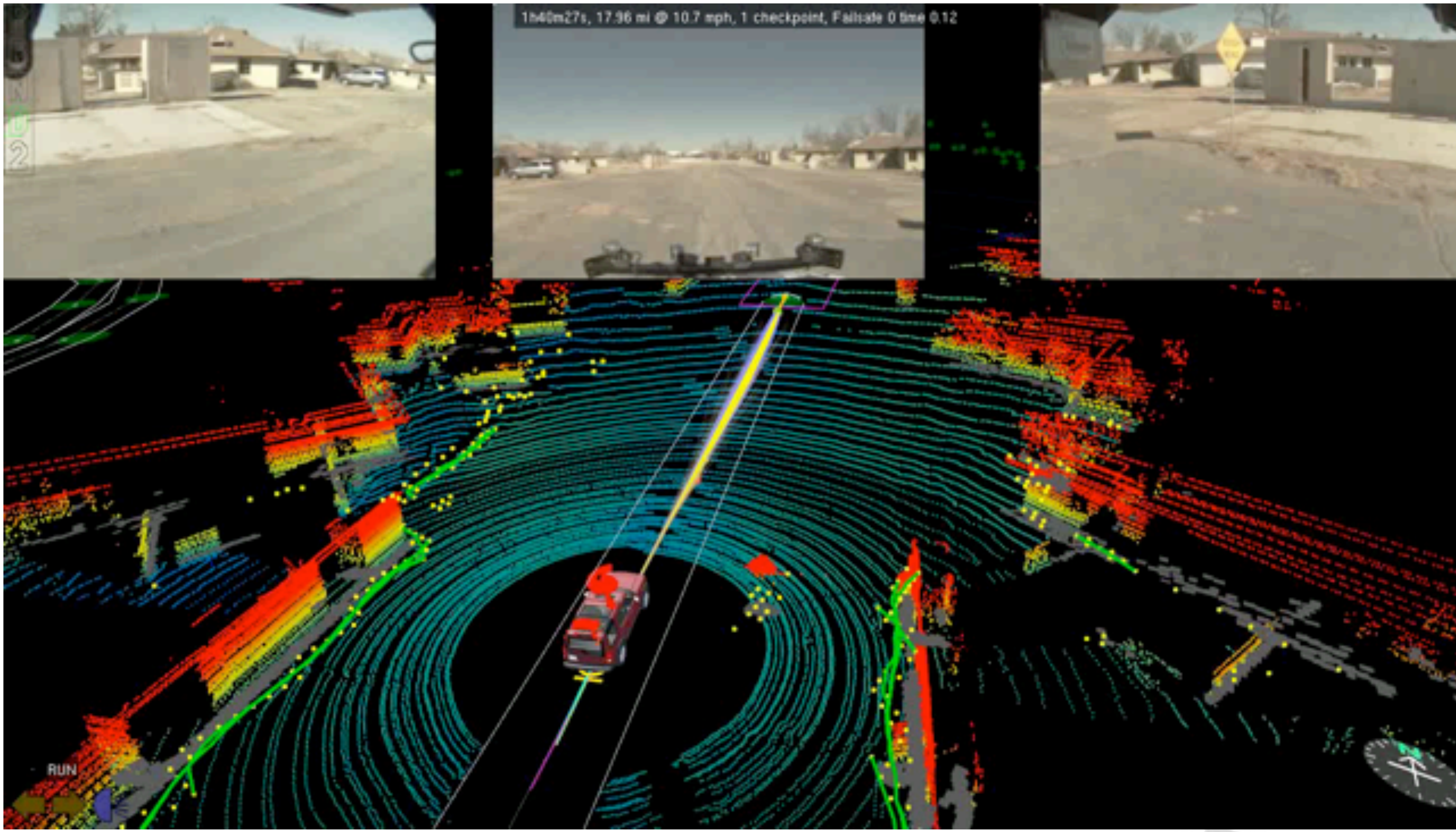


Multi-platform sensor fusion

- Simple sensor packages do not provide complete information at intersections, or because of occlusions.
- Can we use information from sensor in the infrastructure and/or other vehicles?

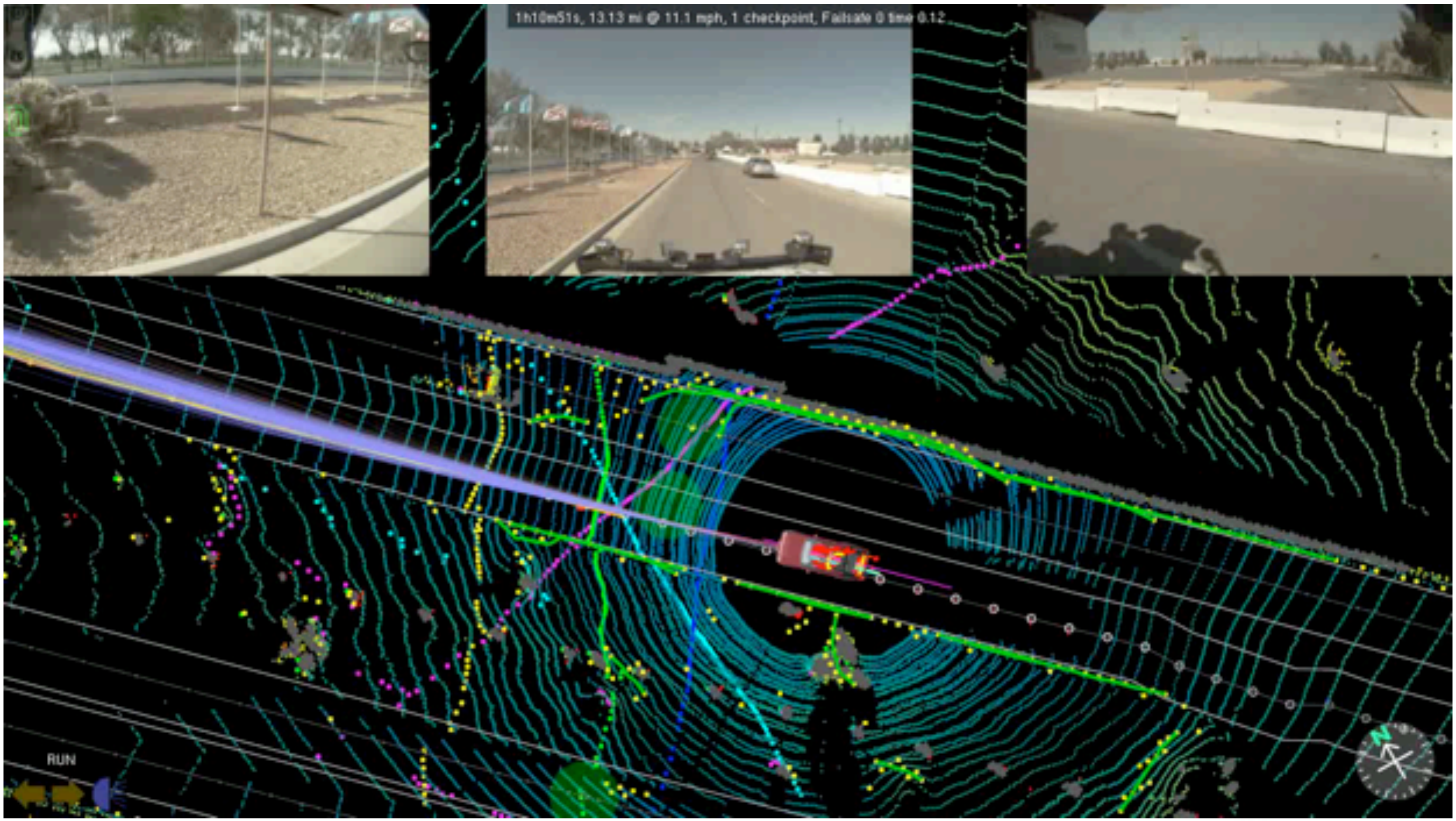


Critical Challenge #3: Semantics and intent inference



The CAROLO incident

Critical Challenge #3: Semantics and intent inference (cont'd)



The Cornell Incident

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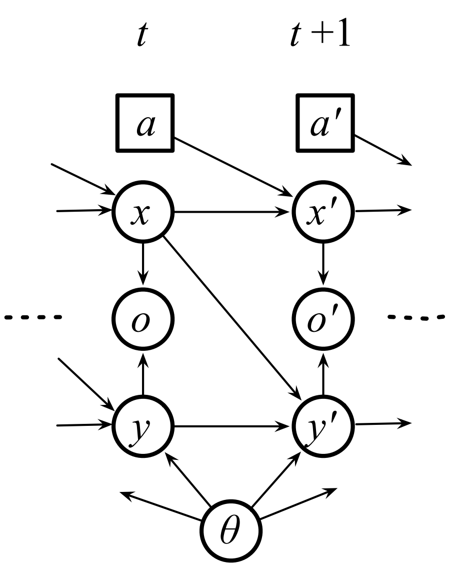
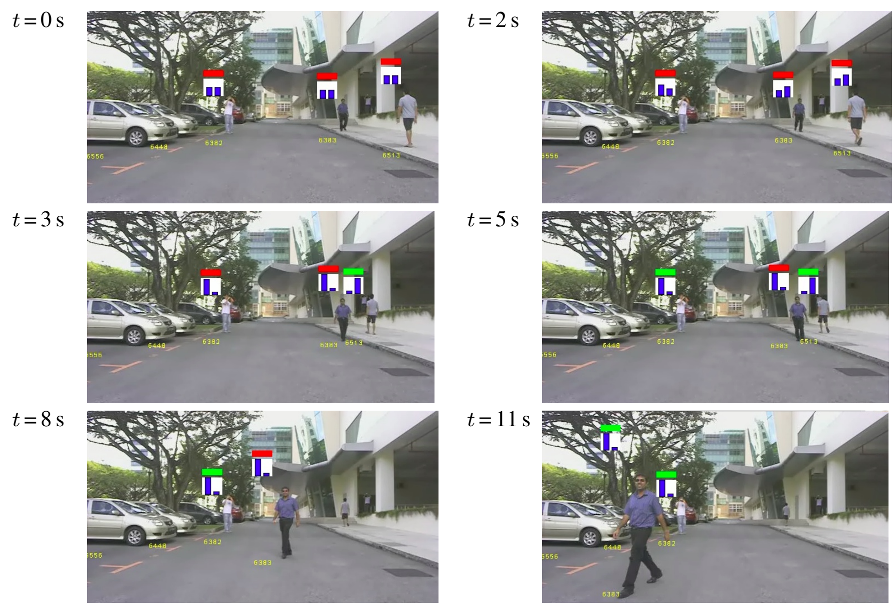
Interaction with pedestrian on a university campus

- There were no pedestrians in the DUC
- Pedestrian detection algorithms combine LIDAR with computer vision
- Intent inference is the main challenge when interacting with humans

Intention-aware motion planning [WAFR 2012]

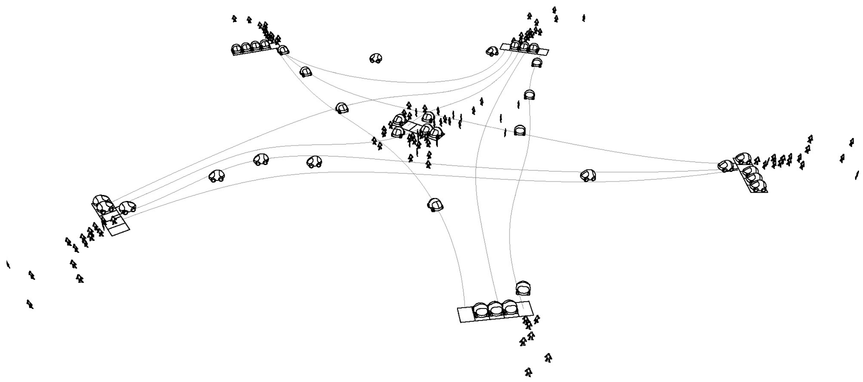
- Mixed-Observability Markov Decision Process
    - Pedestrian's intention is not observable
- Online calculation of efficient+safe strategies, outperform other methods (e.g., Bayesian or ML) in the literature
- Extensions to intersections and vehicle-to-vehicle interactions





Opportunity: Vehicle Sharing systems

- Key idea: **increase vehicle utilization**
- Currently, we pay dearly for the privilege of **NOT** using expensive vehicles
- Parking congestion can be more severe than traffic congestion.

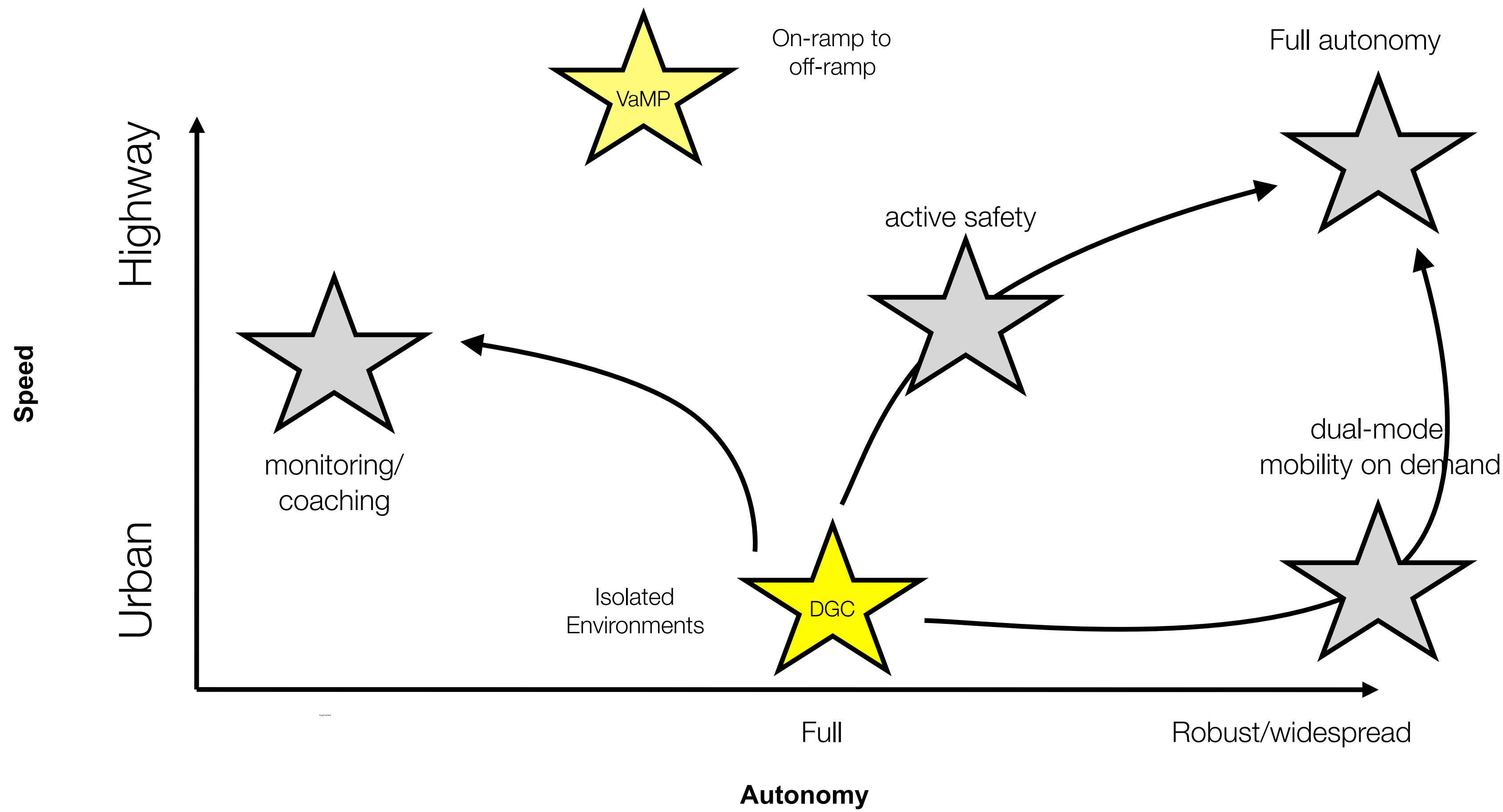


- **Two-way rentals**: zipcars, etc.
- **One-way rentals**: bicycles, several cities in Europe and elsewhere.
- **Rebalancing** is a major issue

D. Papanikolau, 2010

Mobility-on-Demand demo in Singapore [IROS 2012]

Path(s) Forward



Conclusions

- **Autonomy and driver assistance no longer science fiction**
    - DARPA Urban Challenge (and follow-ups) great success
    - Helped mature key perception, planning, and control technologies
    - Spurred significant US interest in autonomous vehicles
- Many **significant hurdles** to overcome
    - Safety / certification issues
    - Affordability
    - Robust semantics and intent inference
- Expect incremental advances similar to auto parking and adaptive cruise control
- Enable **innovative concepts for (urban) mobility**, at little/no cost for the infrastructure.

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Thank you.

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