Autonomous Road Vehicles

“Autonomous Driving in Urban Environments: Boss and the Urban Challenge.” Chris Urmson et al. (Carnegie Mellon, GM Research)

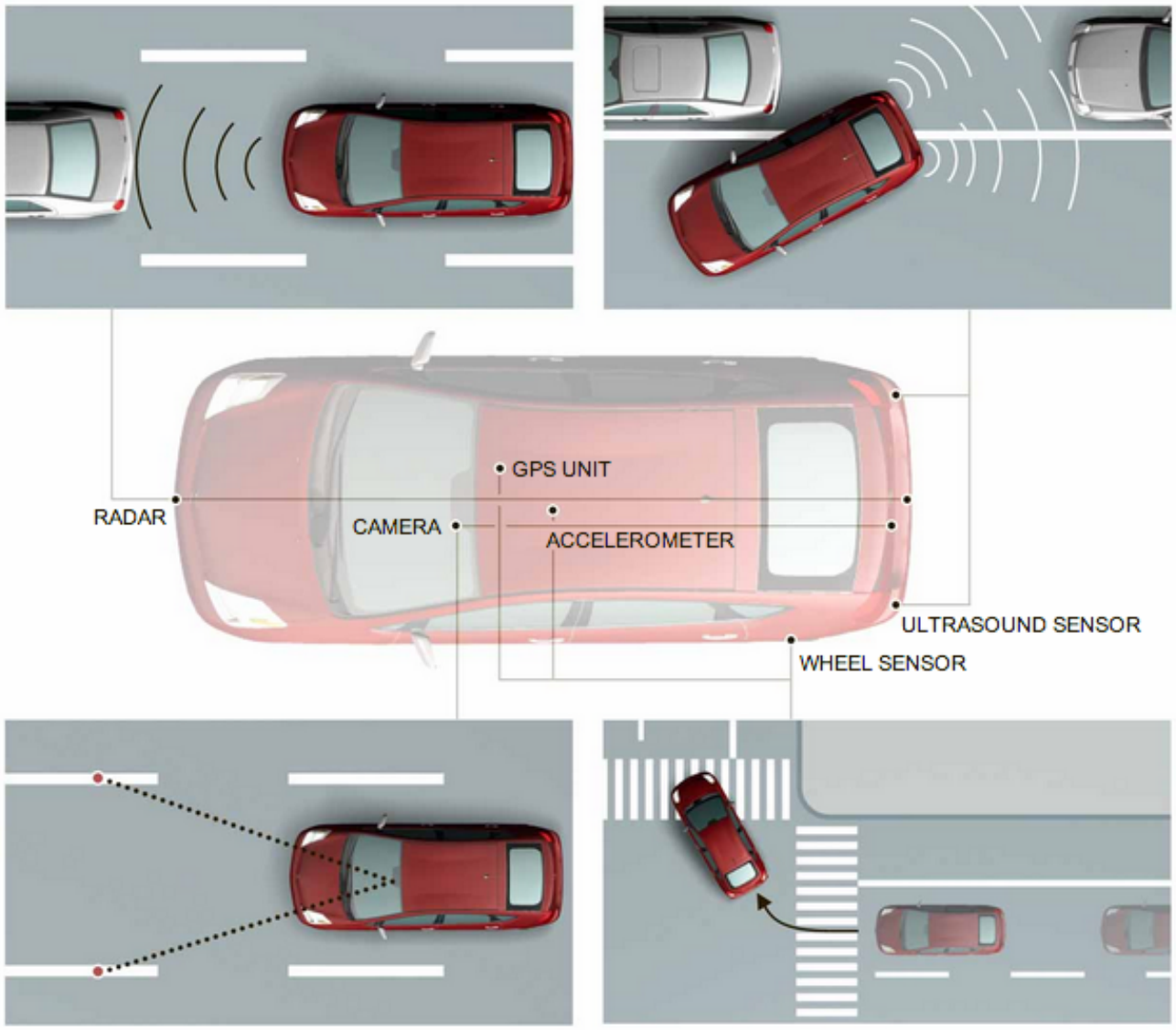
Motivation

- Millions of reported Accidents
  - ~90% due to some degree of human error
  - Over 32,000 deaths in 2010 (in the US)
- Military
- Accessibility
- Efficiency

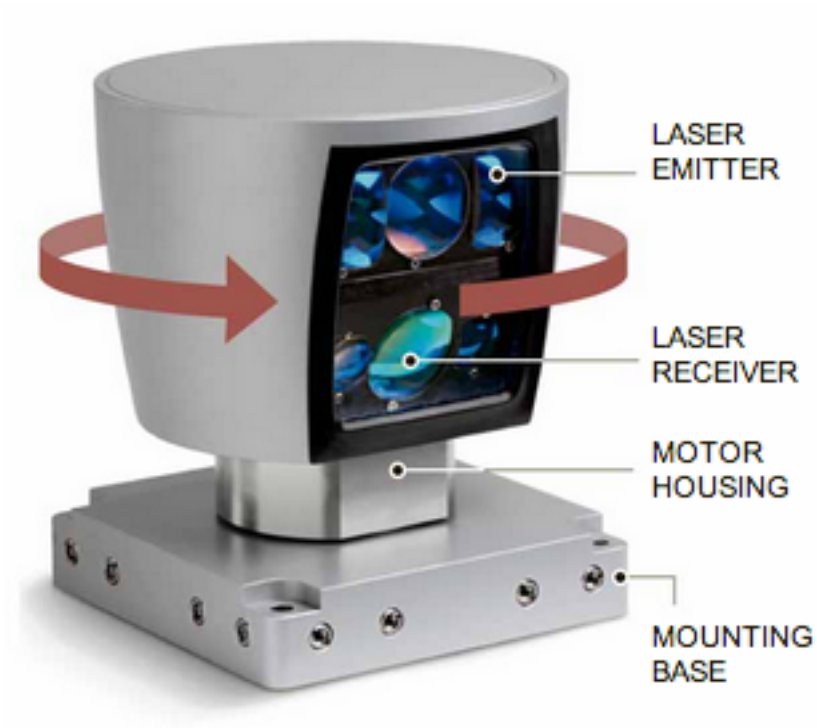
History

- DARPA Grand Challenges
  - Desert roads in 2004-05
  - Urban Challenge introduced in 2006
- Boss (GM & Carnegie Mellon)
  - Junior (Stanford)
- Google
  - 300,000 miles without (computer caused) incident

Sensors

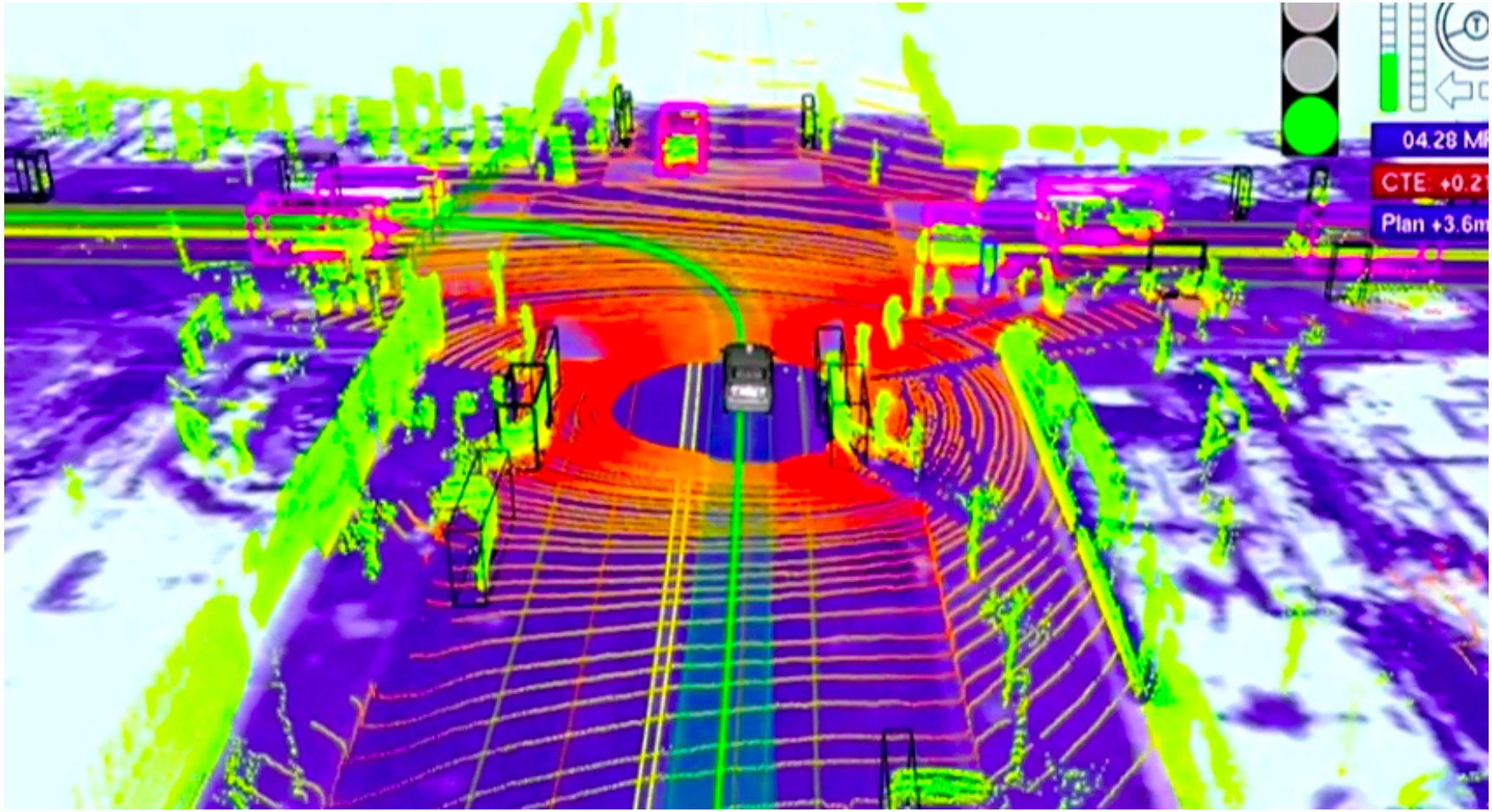

GPS UNIT
RADAR
CAMERA
ACCELEROMETER
ULTRASOUND SENSOR
WHEEL SENSOR

Sensors



- LIDAR – Light Detection and Ranging
  - 64 Lasers and receivers
  - 360 deg. Movement

What the Car Sees



Autonomous Components

- Perception
  - Environment data from sensors
- Motion Planning
  - Vehicle Movement
- Mission Planning
  - Dealing with blockages and rerouting
- Behavioral Reasoning
  - Executing actions determined by Mission Planning

Perception

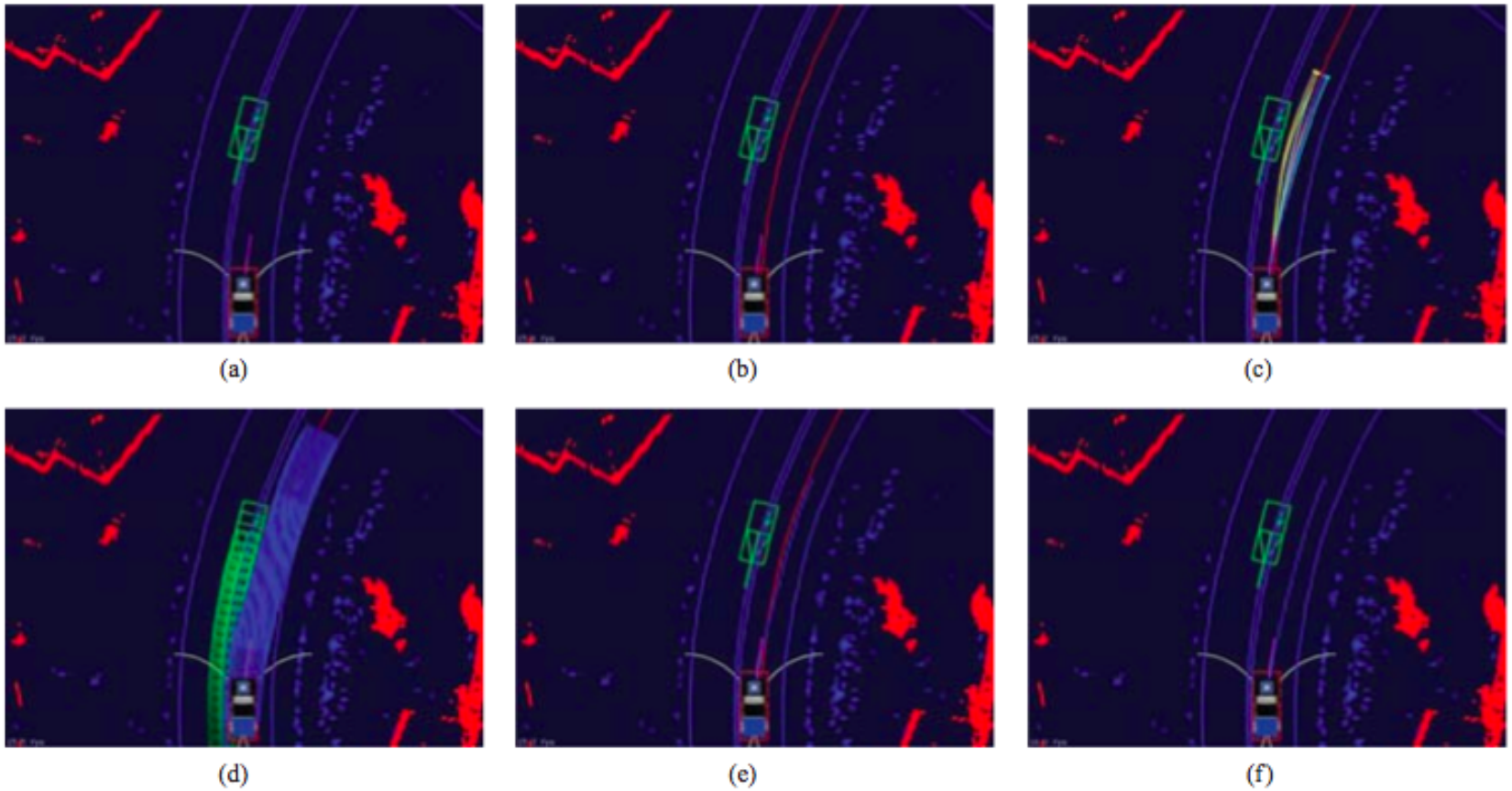
- Sensor Layer / Fusion Layer
  - Sensors send observations to Fusion Layer
  - Fusion Layer produces Object Hypothesis Set
- Object hypotheses
  - Moving / Static
  - Observed Moving / Not Observed Moving
- Prediction for moving objects
  - Based on road constraints or estimated states

Position Errors

- Applannix POS-LV uses GPS and inertial and wheel encoder data
- Discontinuous Errors (Position Jumps)
  - Is the change in position expected
- Continuous Errors (Drift, Road model errors)
  - Adjusts position based on lane center
  - After 5.7km without GPS, 2.5m of error accumlated

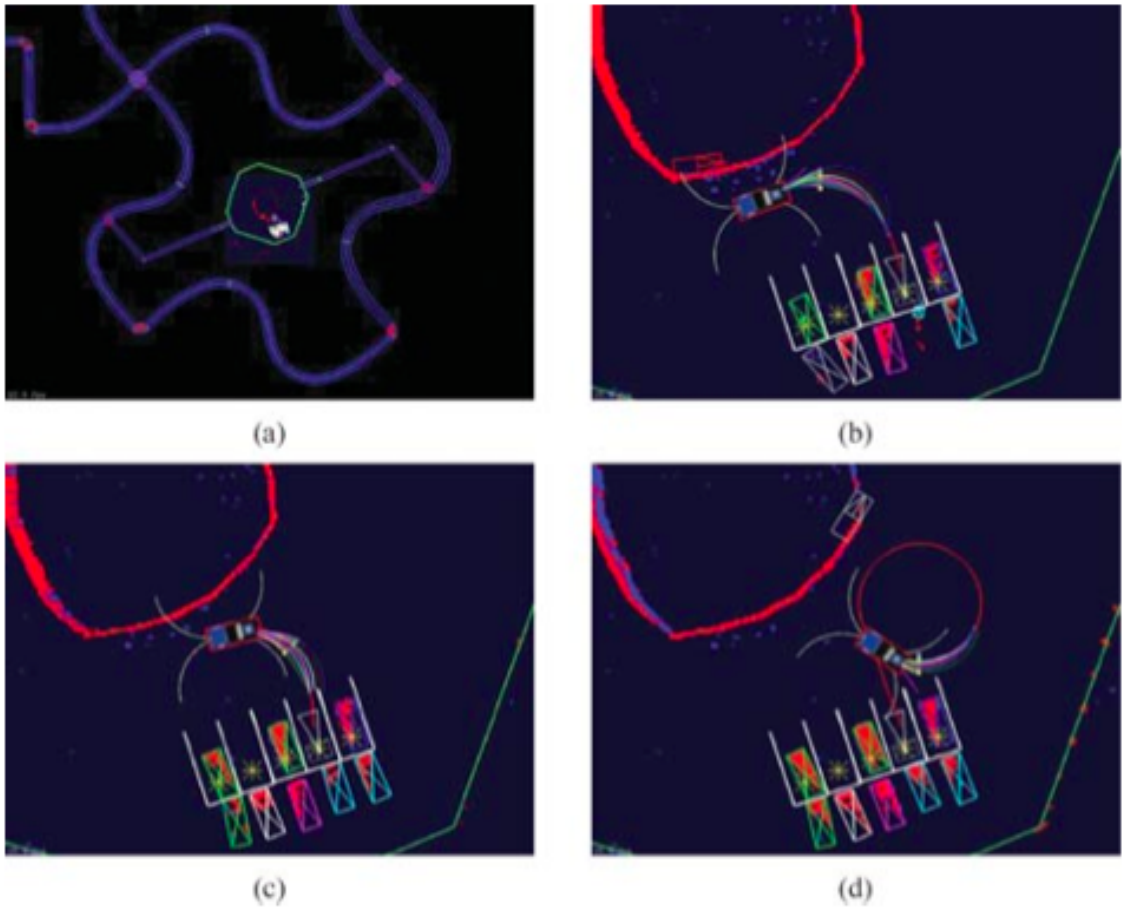
Motion Planning

- Road Navigation



Motion Planning

- Zone Navigation



Mission Planning

- Uses prior knowledge of roadways and their connectivity
- Detects blockages in routes
  - High cost for maneuvering around blockage
  - Favors U-turns and reroutes car
  - Decays over time to allow revisit
  - One way streets – Zone Error recovery

Boss Behavior Architecture

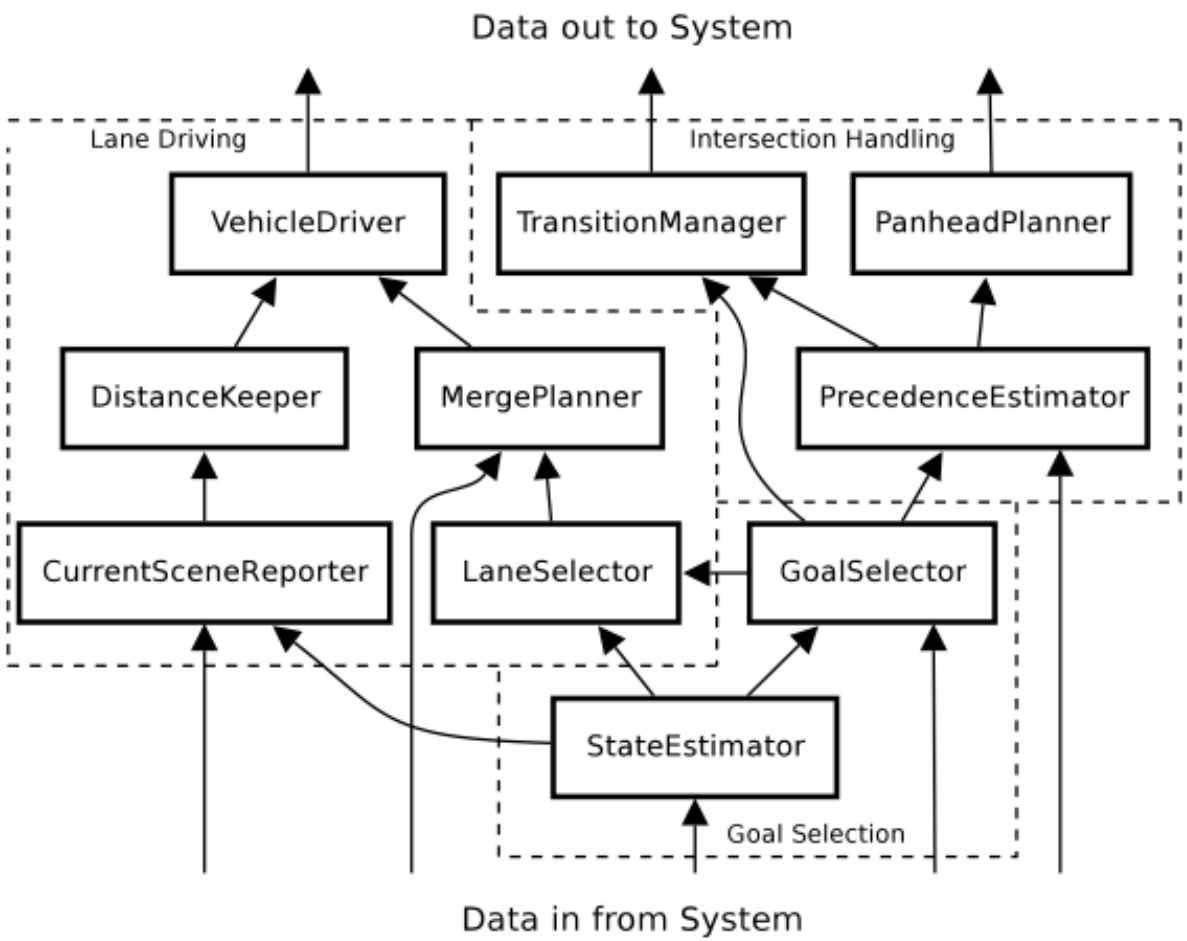
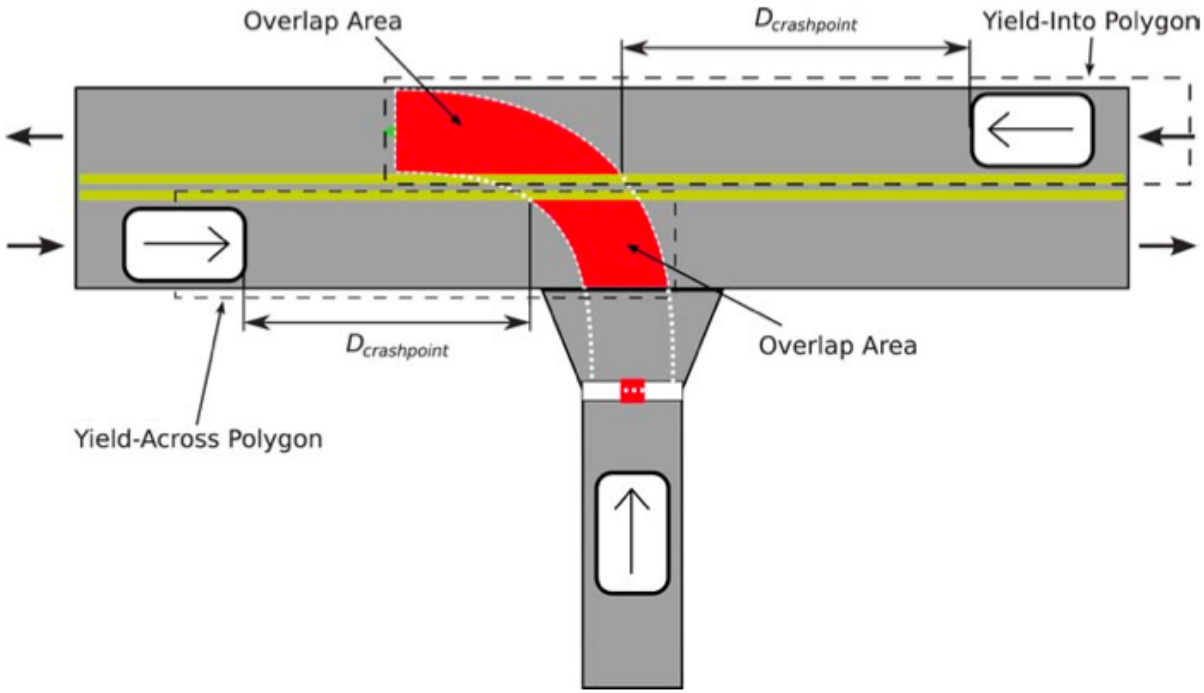


Figure 14. High-level behaviors architecture.

Boss Behavior Architecture

- Intersections
  - Precedence Estimator
- Yielding to moving vehicles
  - Time to.. Cross intersection, reach velocity,



Boss Behavior Architecture

- Distance Keeping, Merge Planning
  - Merge Distance, Minimum Gap, Velocity in merge-to lane
  - N+1 Possible Slots analyzed

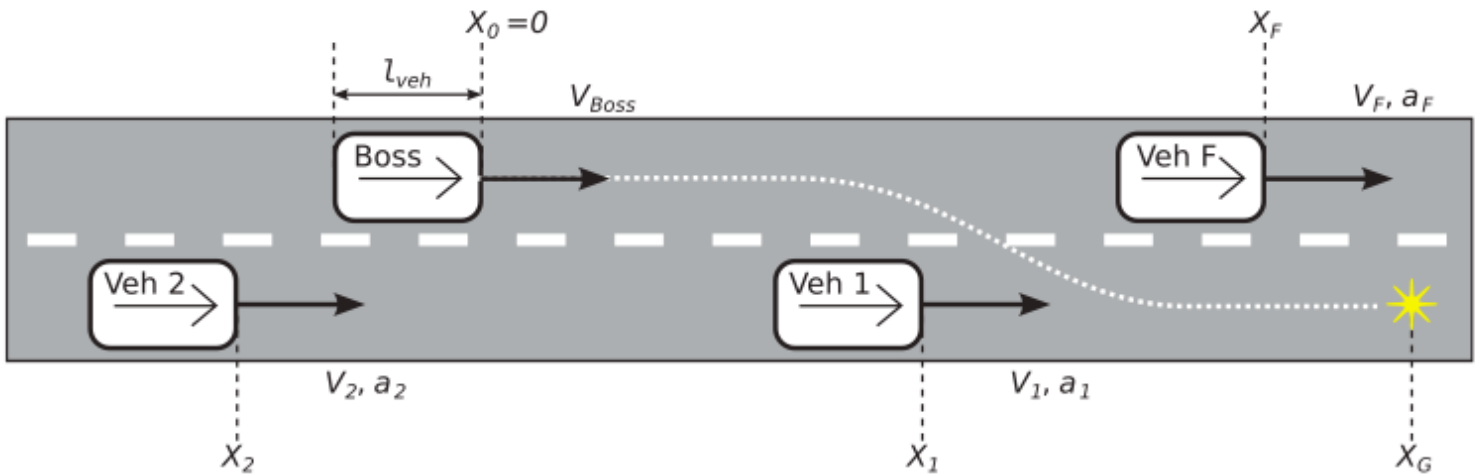


Figure 17. Two-lane merging.

Error Recovery

- Generation of nonrepeating, novel recovery goals in the face of repeated failures
- Multiple sets of recovery goals depending on failure context
- Simple recovery state logic to avoid multiple maneuver recovery schemes

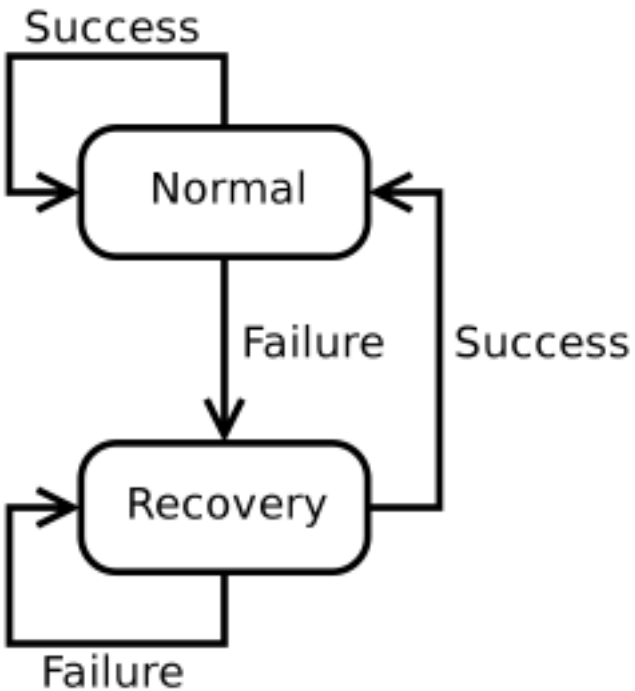


Figure 18. Goal selection state graph.

On-Road Failure

- Causes
  - Small obstacles (traffic cones)
  - Large obstacles (Barrels) detected too late
  - Infeasible Lanes
- Solution
  - Forward Goals in small increments
  - Reverse and try forward with a new perspective
  - Turn around

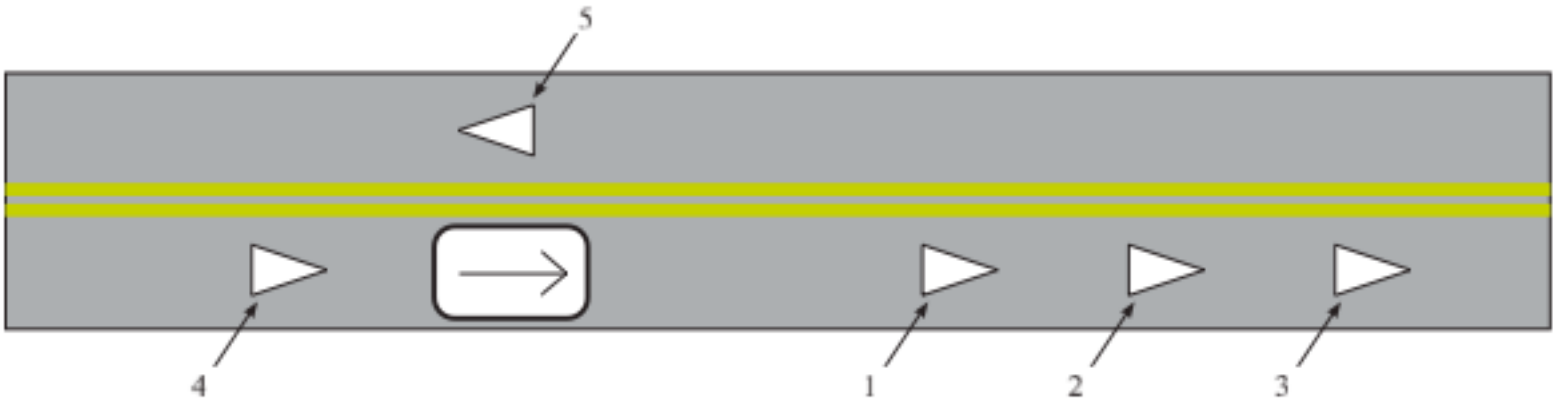


Figure 19. Example shimmy error recovery goal sequence.

Intersection Failure

- Solution
  - Increase Motion Planning 'workspace' (tight turns)
  - Mark path as blocked, check feasibility of other exit paths
  - Reattempt original goal with loose restrictions

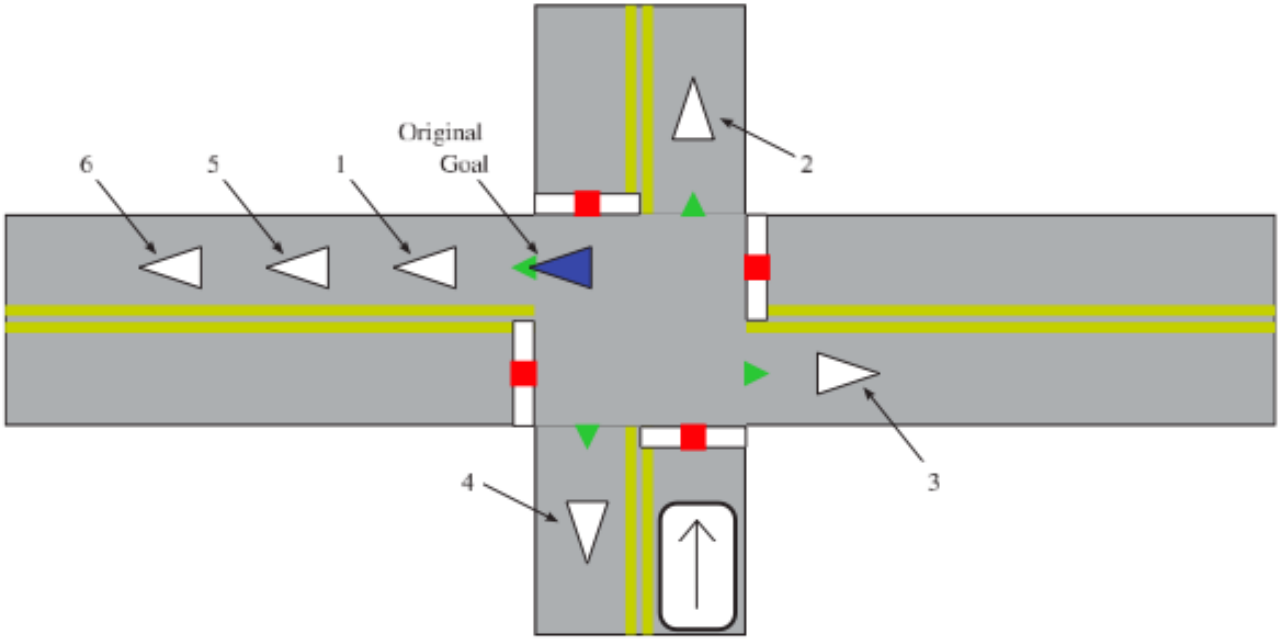


Figure 20. Example jimmy recovery goal sequence.

Zone Failure

- 'Shake' recovery sequence
  - Transient blockage or sensor failure
  - Selects goals in a triangular pattern

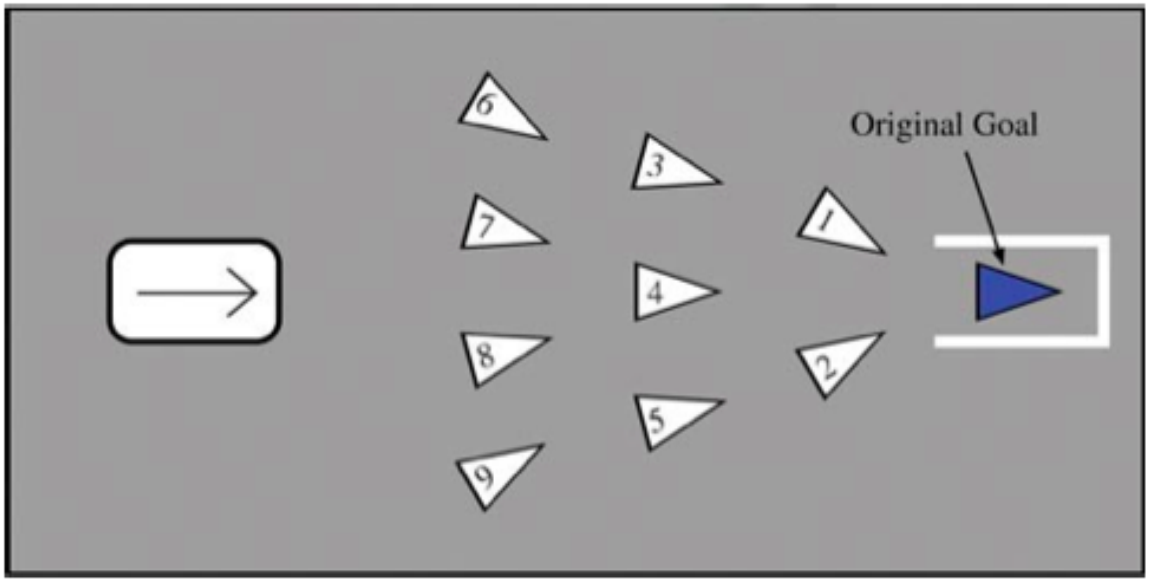


Figure 21. Example shake recovery goal sequence.

Worst-case Scenario

- Cause
  - System has not moved 1m in 5min
- Solution
  - Psuedo-random, approximately feasible goals
  - Restart once a recovery goal is met

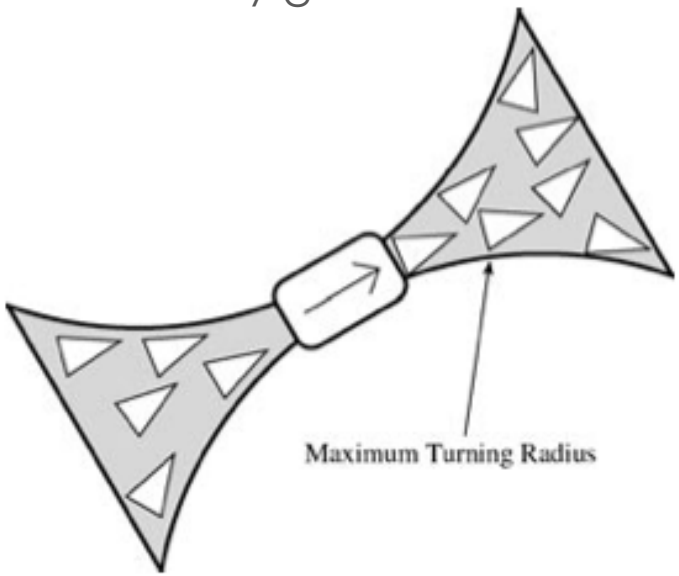


Figure 22. Example wiggle recovery goals.

Conclusions

- Key Features
  - Robust Design
  - Static / Moving object models
  - Behavioral Engine that can throw out rules of the road
- Further Areas
  - DARPA 2007 did not include traffic lights, pedestrians
  - Non-ideal Weather
  - Interaction with human drivers
  - Legal aspects of Autonomous Cars (NV,CA,FL)

Sources

Chris Urmson et al. “Autonomous Driving in Urban Environments: Boss and the Urban Challenge”, Journal of Field Robotics 25(8), 425-466 (2008)

http://www.nytimes.com/interactive/2012/10/28/automobiles/how-an-autonomous-car-gets-around.html