

# Autonomous Vehicles

*From Stanley to Shelly and Carla*

A Journey in Self-Driving Robots & Cars

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# DARPA Grand Challenge

- \* 2004 - Top vehicle completed 7.31 of 150 miles.
- \* 2005 - Five vehicles completed entire 132 miles.



# Google

- \* 2009 - Began at Google X Lab, led by Sebastian Thrun.
- \* 2015 - First fully driverless car ride on public roads.
- \* 2016 - Waymo created.
- \* 2017 - Began testing autonomous minivans without a safety driver.



# Uber

- \* 2015 - Created Advanced Technologies Group near Carnegie Mellon.
- \* 2016 - Purchased Otto for \$625 million.
- \* 2017 - Began carrying passengers (w/ safety driver).
- \* 2018 - First fatal accident.



# Tesla

- \* 2015 - Released “Autopilot” driver-assistance system, developed by Mobileye.
- \* 2016 - Announced all future vehicles had the necessary hardware to enable full autonomy.
- \* 2017 - Gained semi-autonomous capability, including autosteer.



# Traditional Automakers

- \* 2016 - GM purchased Cruise Automation for \$1 billion.
- \* 2017 - Ford invested roughly \$1 billion in a joint venture with Argo AI.
- \* 2019 - BMW & Daimler announce partnership to deliver full self-driving cars by “mid-2020s.”



# SAE Automation Levels

***Human driver monitors the driving environment***

- 0 No Automation
- 1 Driver Assistance (“hands on”)
- 2 Partial Automation (“hands off”)



***Automated driving system monitors the driving environment***

- 3 Conditional Automation (“eyes off”)
- 4 High Automation (“mind off”)
- 5 Full Automation (“steering wheel optional”)

# Sparkfun AVC

- \* 2009 - 2018
- \* National Robotics Competitions



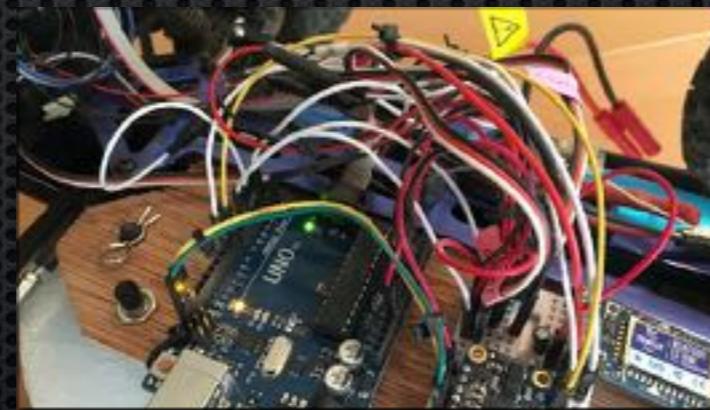
# Rover Rally



- \* 2015 - 2017
- \* Regional Robotics Competitions



# Meet Shelly (Shell Shock)



# Udacity Self-Driving Car Engineer

- \* “Nanodegree” Program
- \* 3 terms (roughly 1 year)
- \* Robotics, Computer vision, deep learning, sensor fusion, control processing



UDACITY



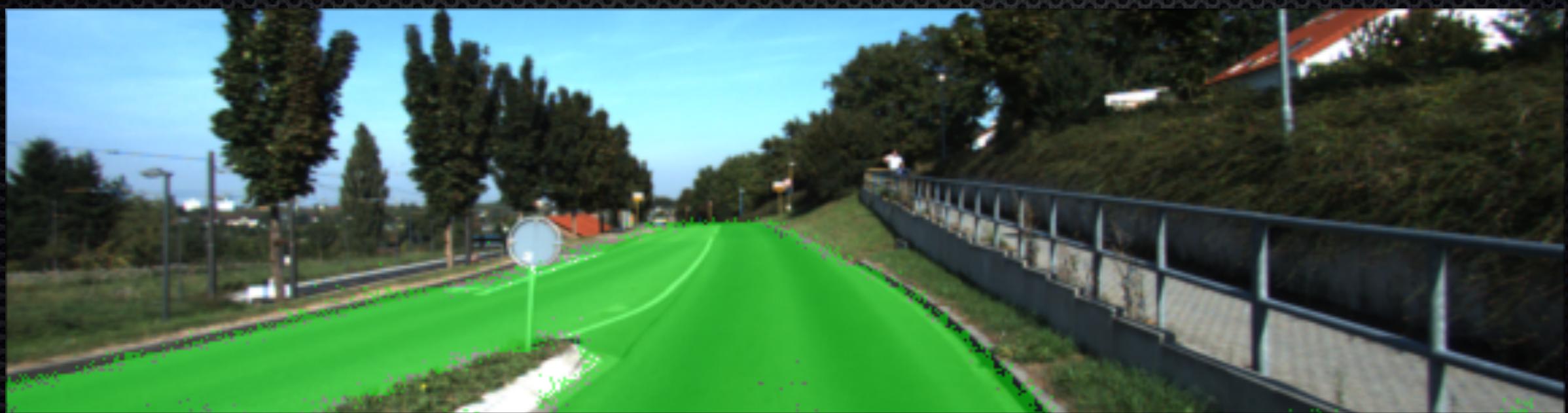


# Project: Finding Lane Lines

Radius of Curvature = 518(m)  
Vehicle is 0.04m left of center



Project: Advanced Lane Finding



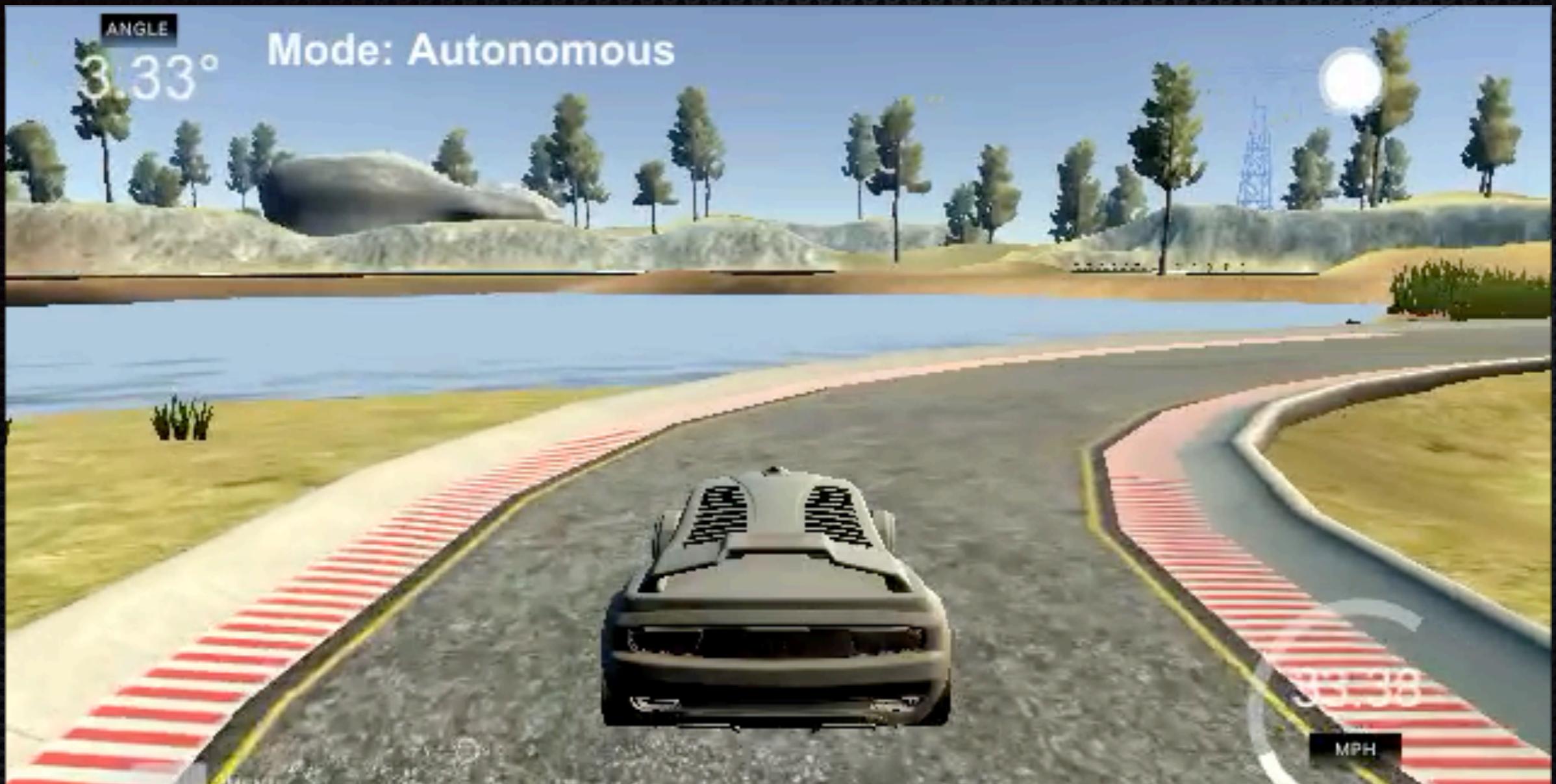
Project: Semantic Segmentation



# Project: Vehicle Detection



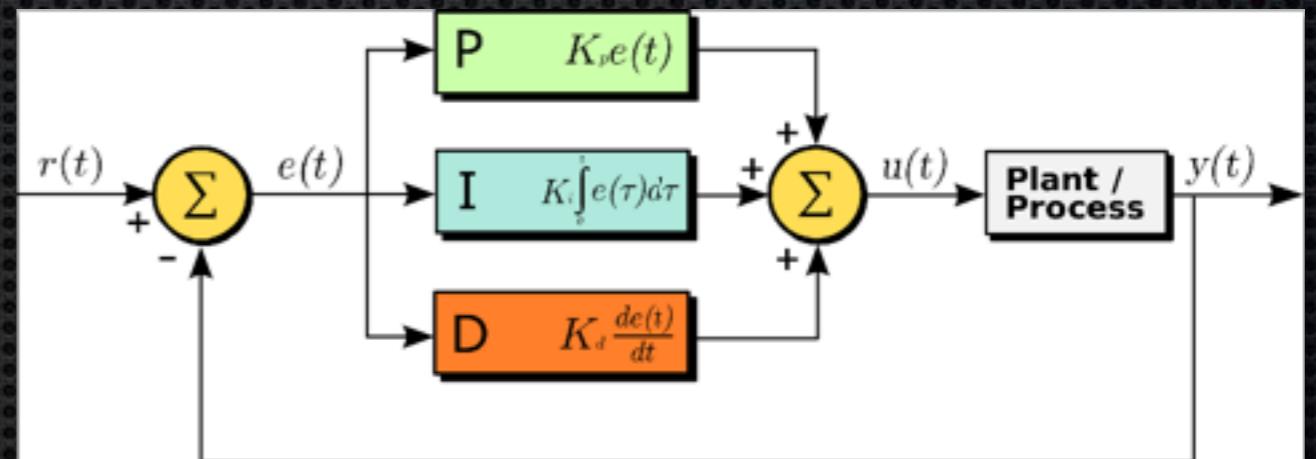
# Project: Behavioral Cloning



# Project: PID Control

# PID Controllers

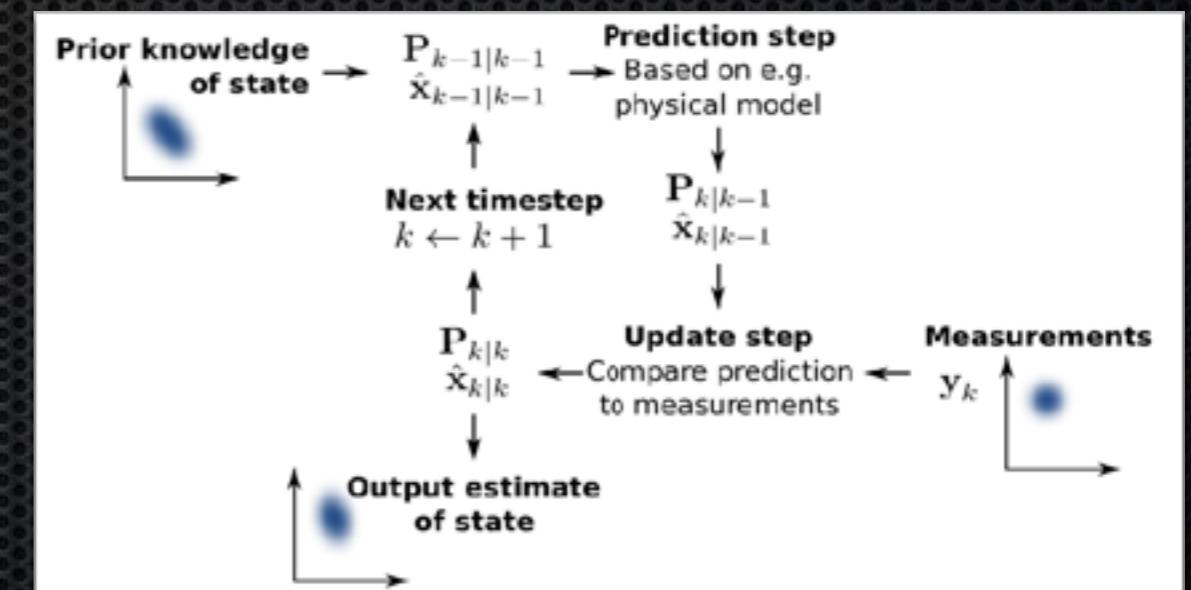
- \* Control loop feedback mechanism
- \* Applies accurate and responsive correction to a control function
- \* proportional, integral, derivative
- \* Error
  - \* amount, time, rate of change



```
previous_error = 0
integral = 0
loop:
    error = setpoint - measured_value
    integral = integral + error * dt
    derivative = (error - previous_error) / dt
    output = Kp * error + Ki * integral + Kd * derivative
    previous_error = error
    wait(dt)
    goto loop
```

# Kalman Filters

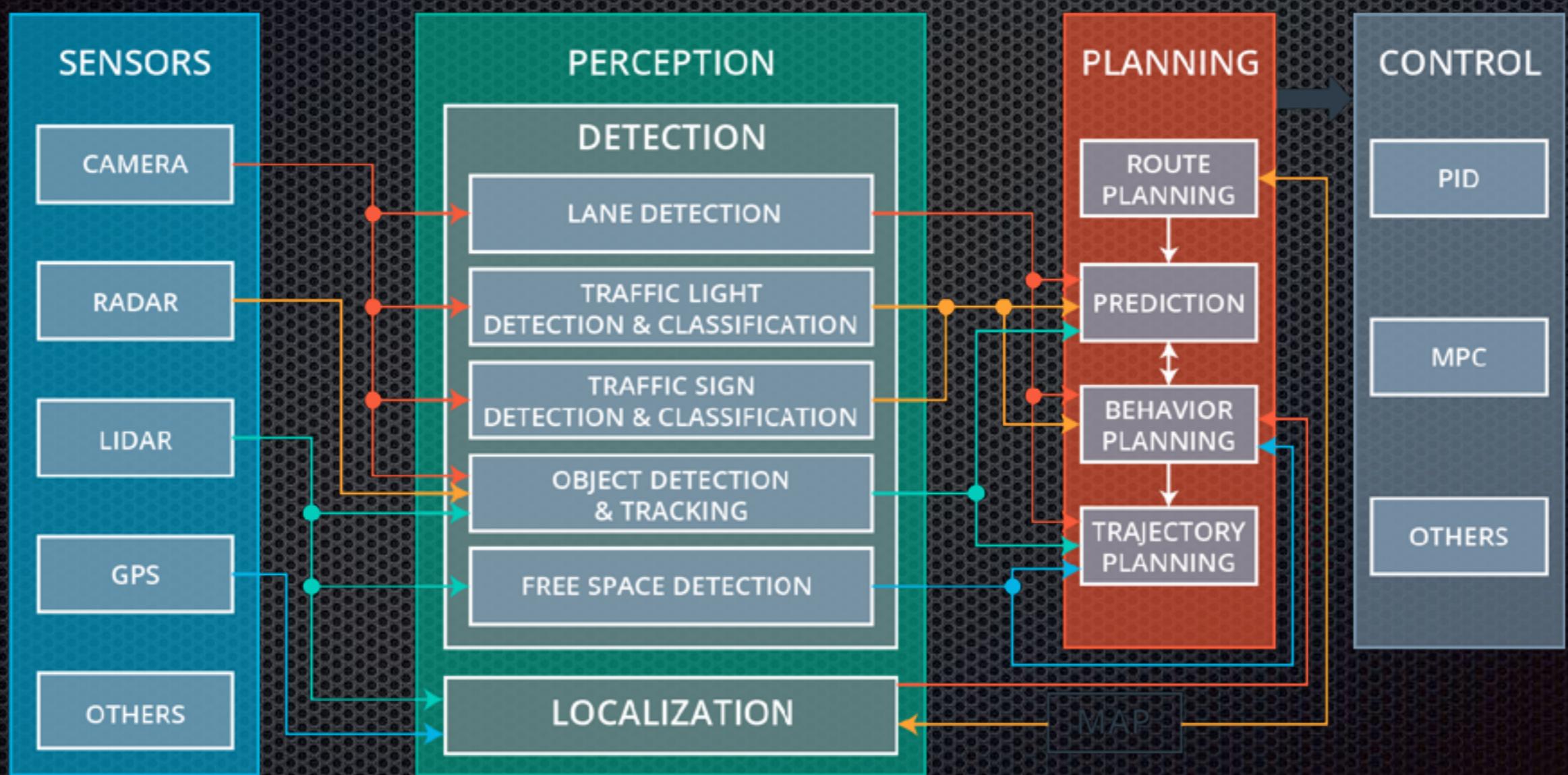
- \* Use a series of measurements over time to produce estimates that are more accurate than those based on a single measurement.
- \* 2 steps
  - \* prediction
  - \* update
- \* Extensions
  - \* Extended Kalman Filters (EKF)
  - \* Unscented Kalman Filters (UKF)



# Meet Carla

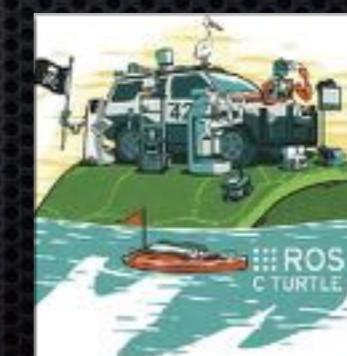


# Carla's Subsystems

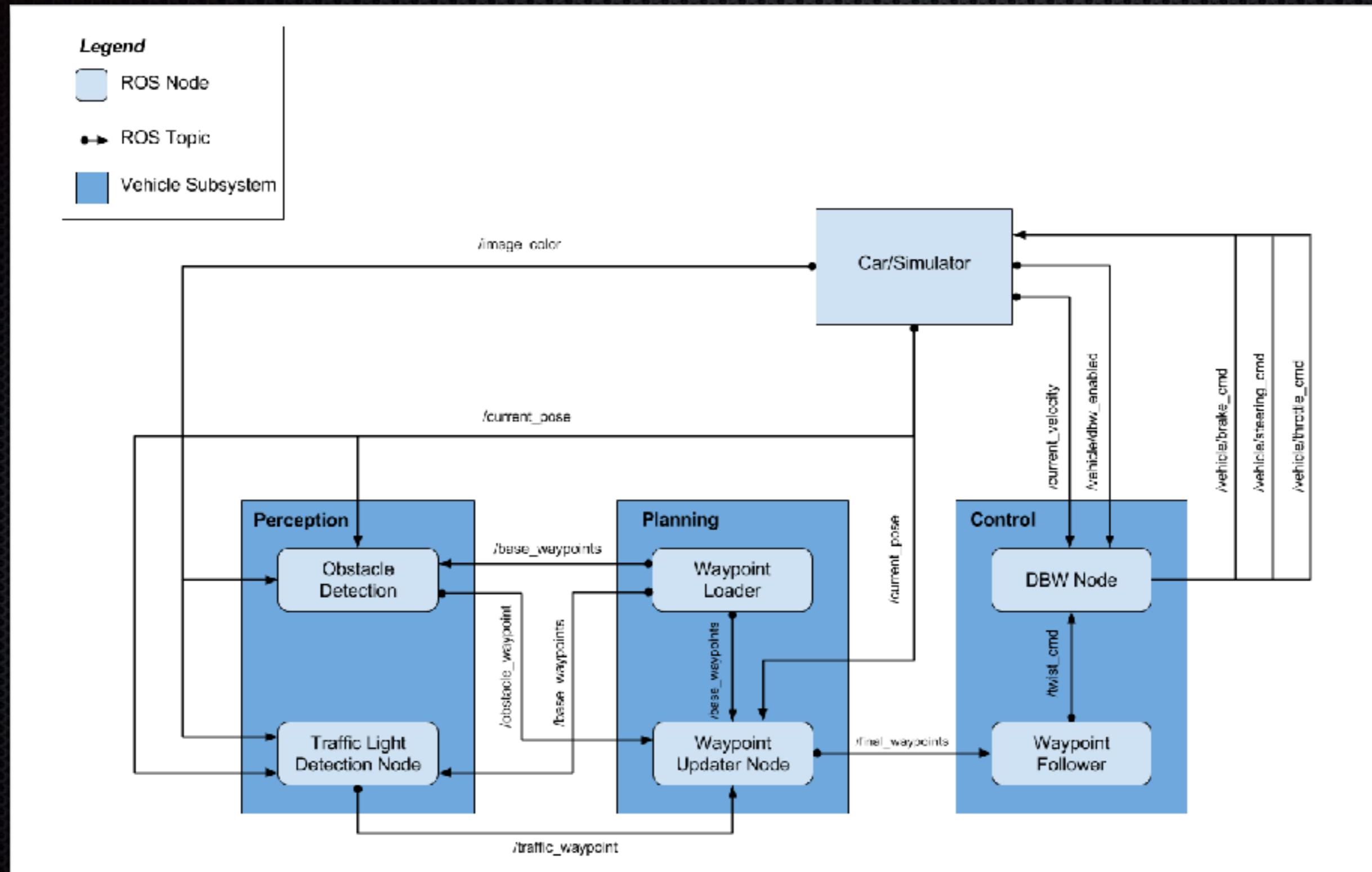


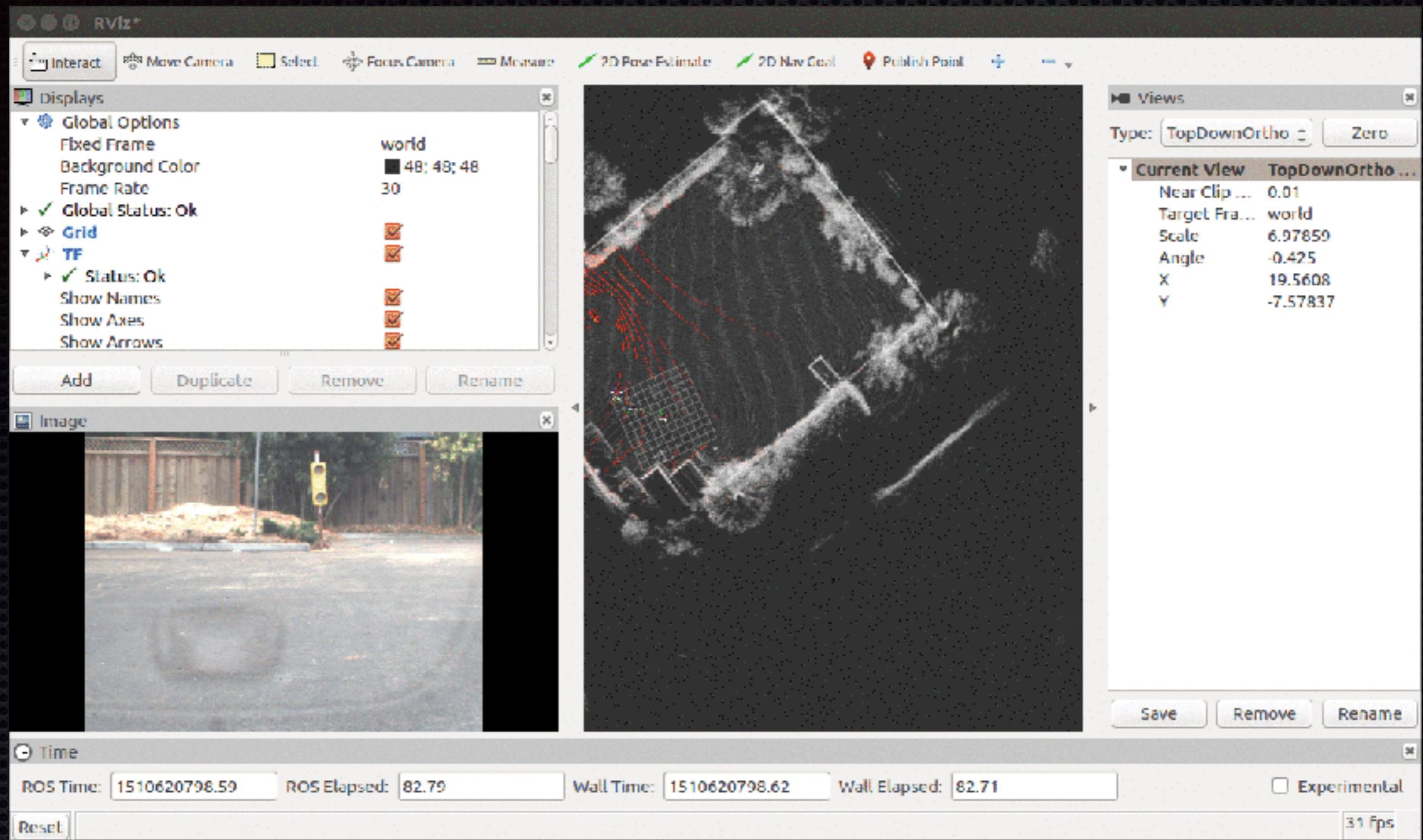
# ROS

- \* Released 2007
- \* Language and platform independent tools:
  - \* Perception
  - \* Decision Making
  - \* Actuation
- \* Client libraries
- \* roscpp, rospy, roslib



# Carla Processing Architecture





# Final Project Output

Winning the DARPA Grand Challenge, Google TechTalks

<https://www.youtube.com/watch?v=TDqzyd7fDRc>

DARPA Grand Challenge (2004-5) driverless car competition (NOVA - The Great Robot Race)

<https://www.youtube.com/watch?v=ihXE1lu5E3o>

“Can you imagine, you're sitting in the back seat and all of a sudden this car is zig-zagging around the corner and you can't stop the f---ing thing?”

“Self-driving cars will never work.”

“I would never get in a self-driving car. ... I don't trust some computer to drive me around.”

*—Donald Trump*

