

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



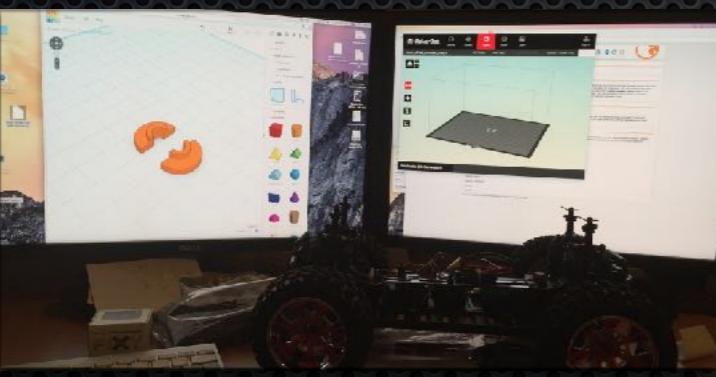
Rover Rally



- * 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



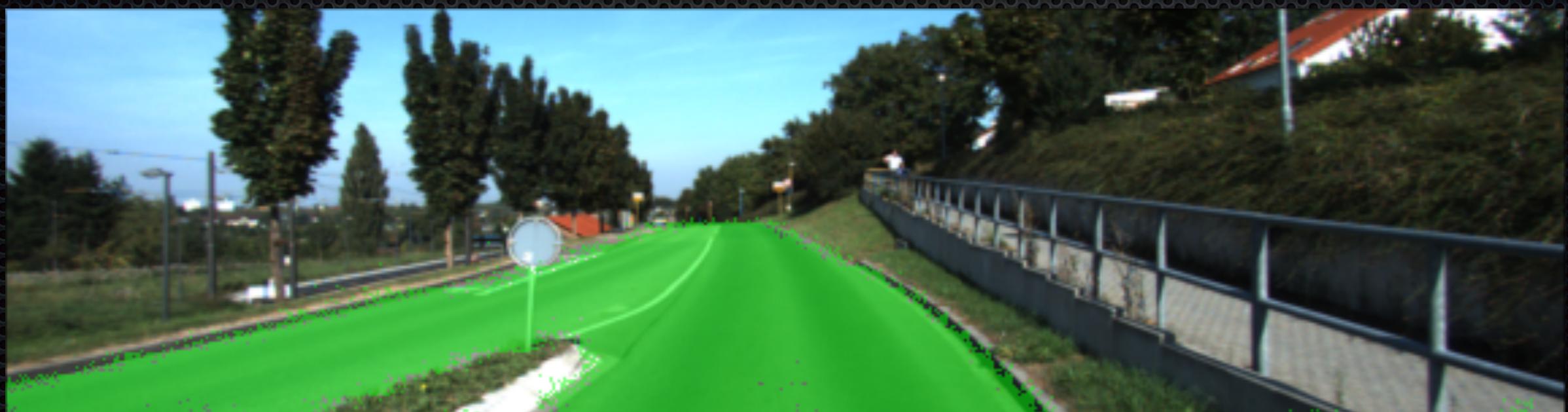


Project: Finding Lane Lines

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



Project: Advanced Lane Finding



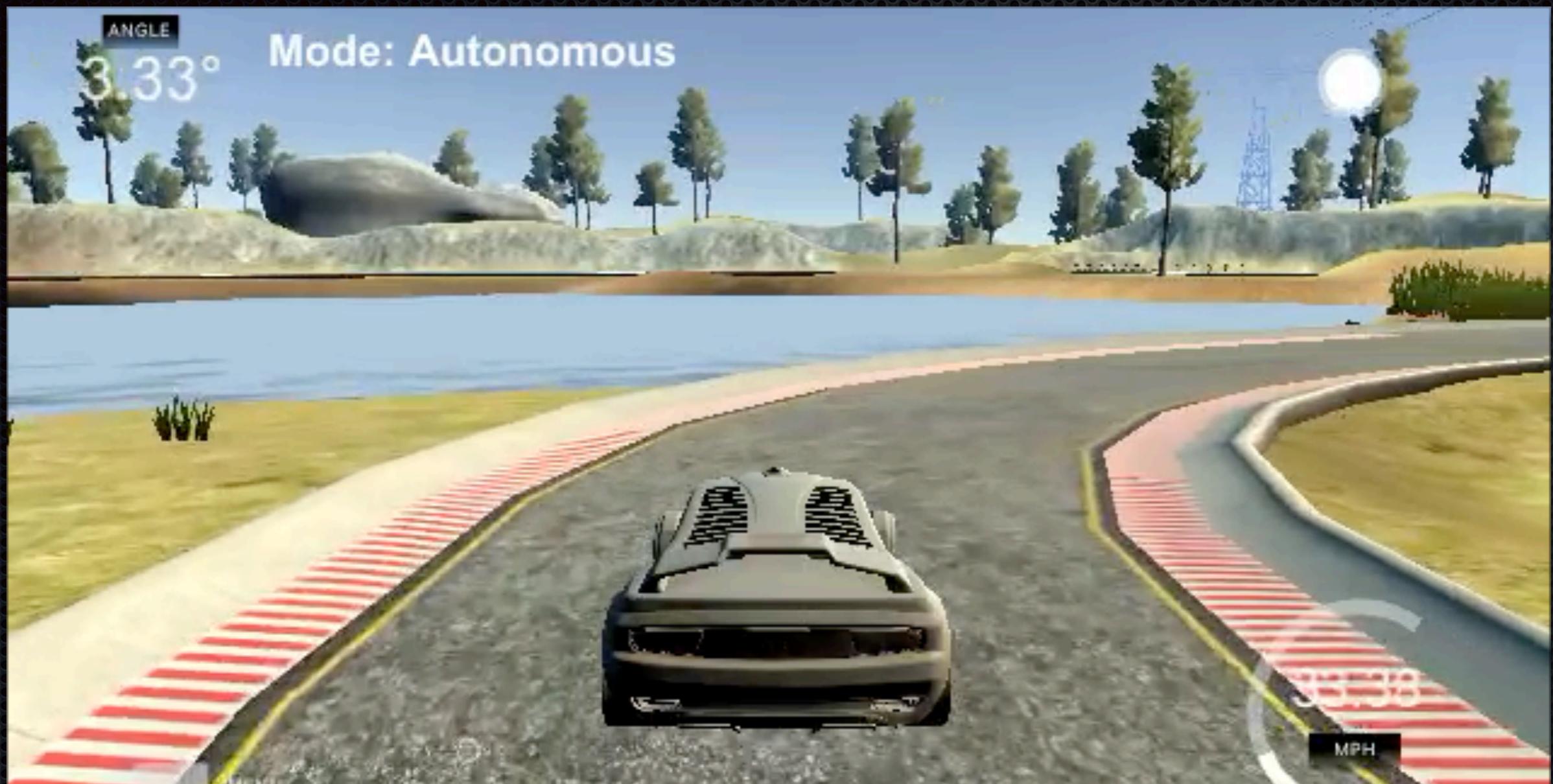
Project: Semantic Segmentation



Project: Vehicle Detection



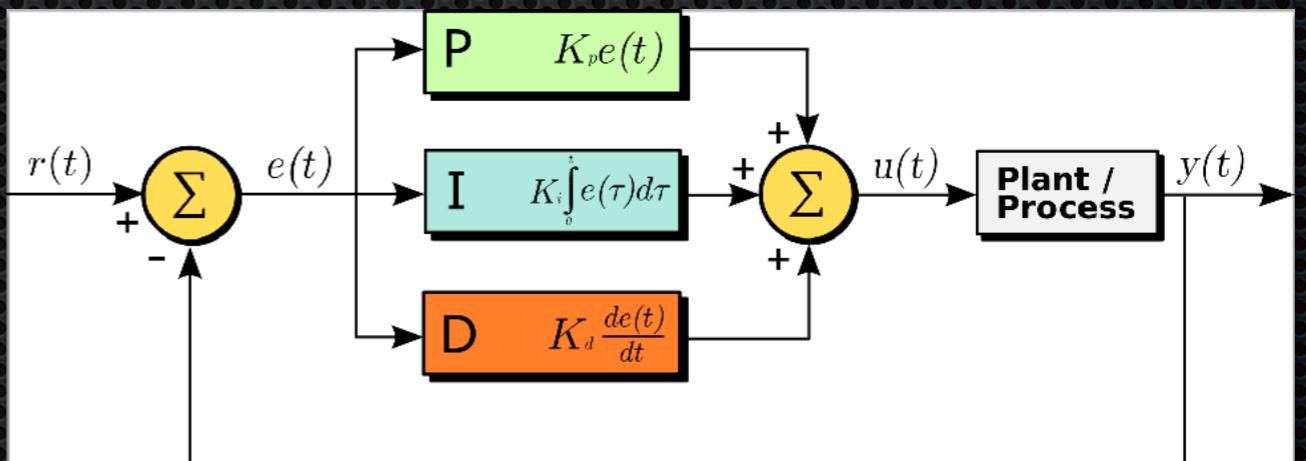
Project: Behavioral Cloning



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

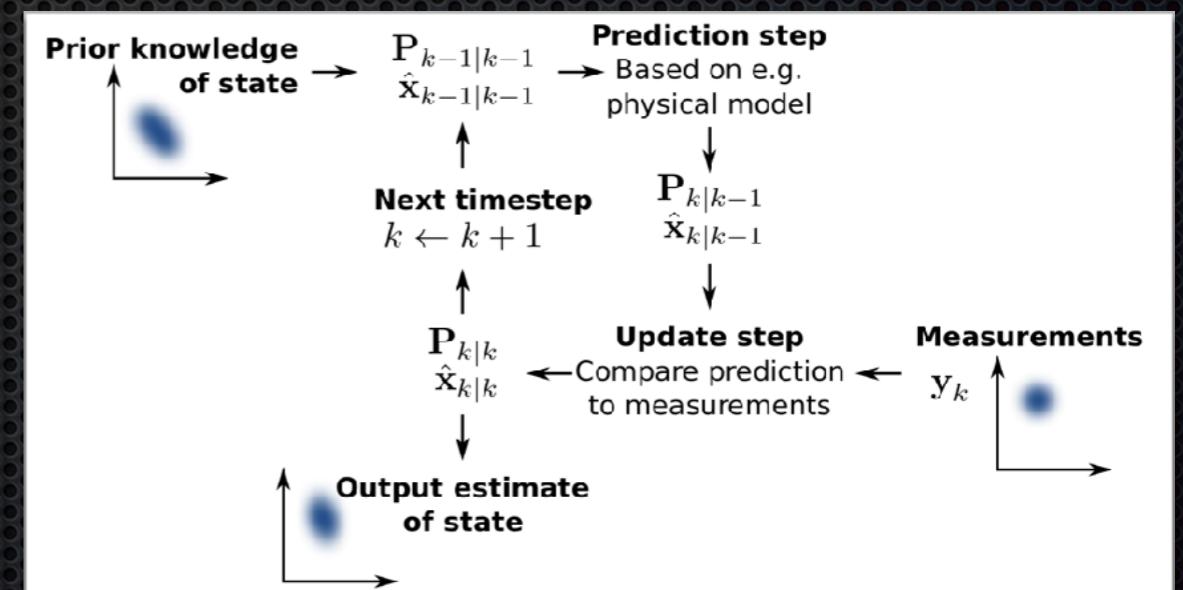


```
previous_error = 0  
integral = 0  
loop:
```

```
    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

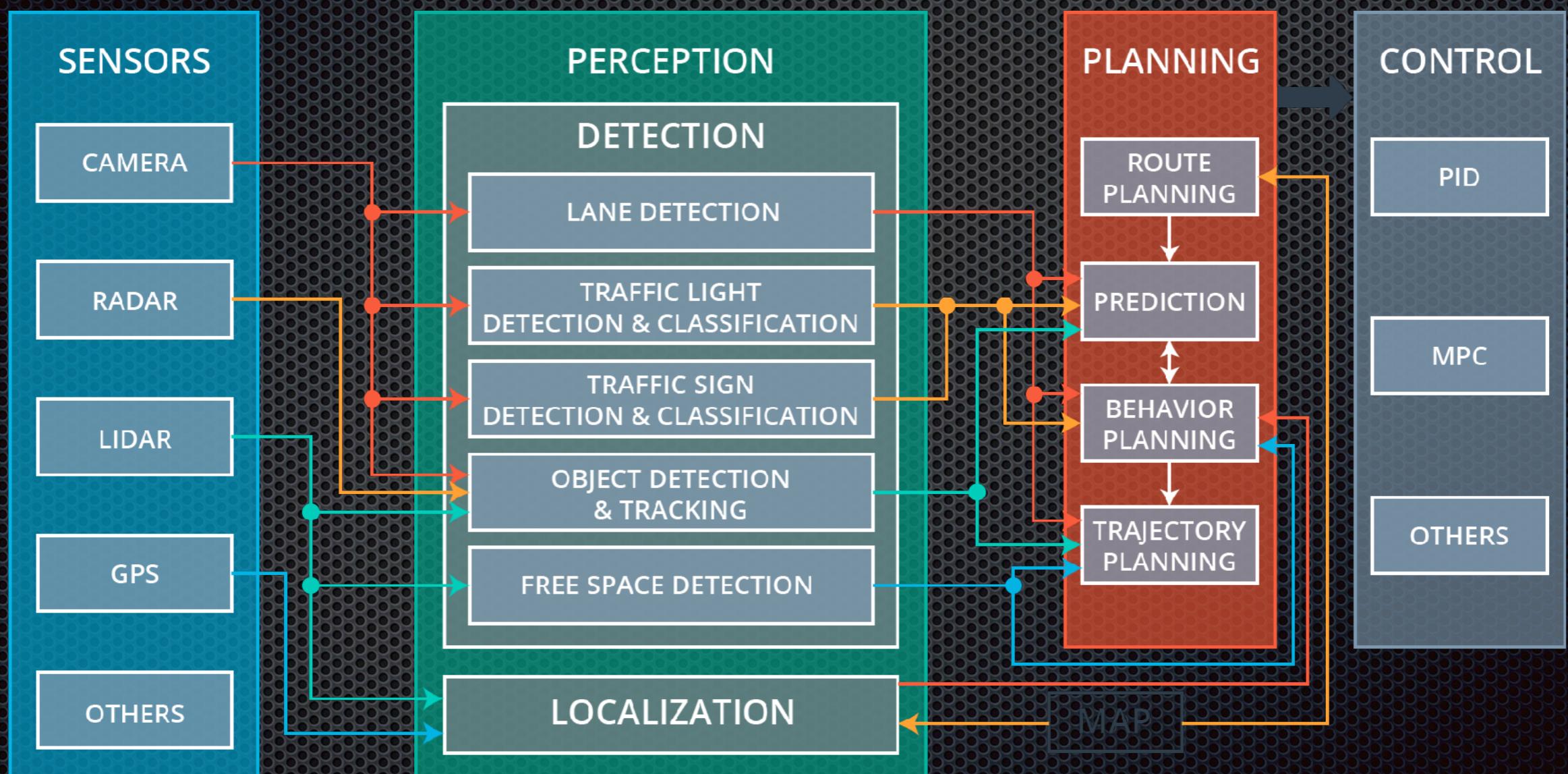
- * Use a series of measurements over time to produce estimates that are more accurate than those based on a single measurement.
- * 2 steps
 - * prediction
 - * update
- * Extensions
 - * Extended Kalman Filters (EKF)
 - * Unscented Kalman Filters (UKF)



Meet Carla

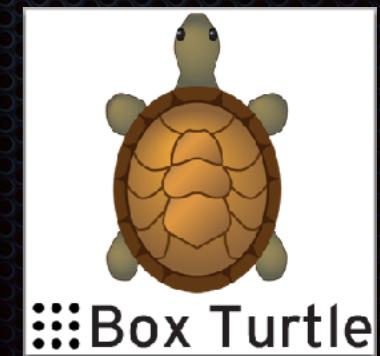
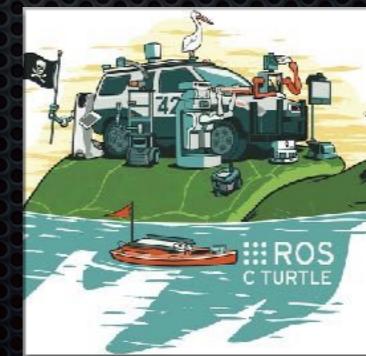
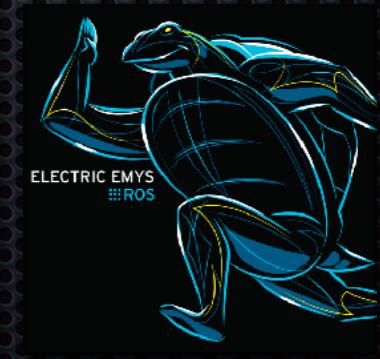
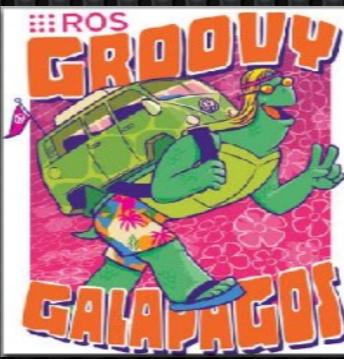
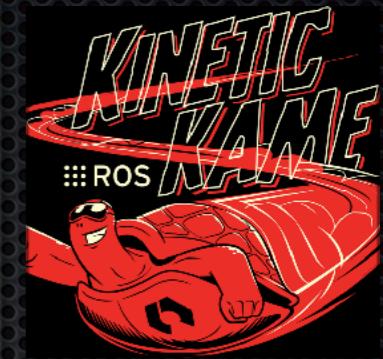


Carla's Subsystems

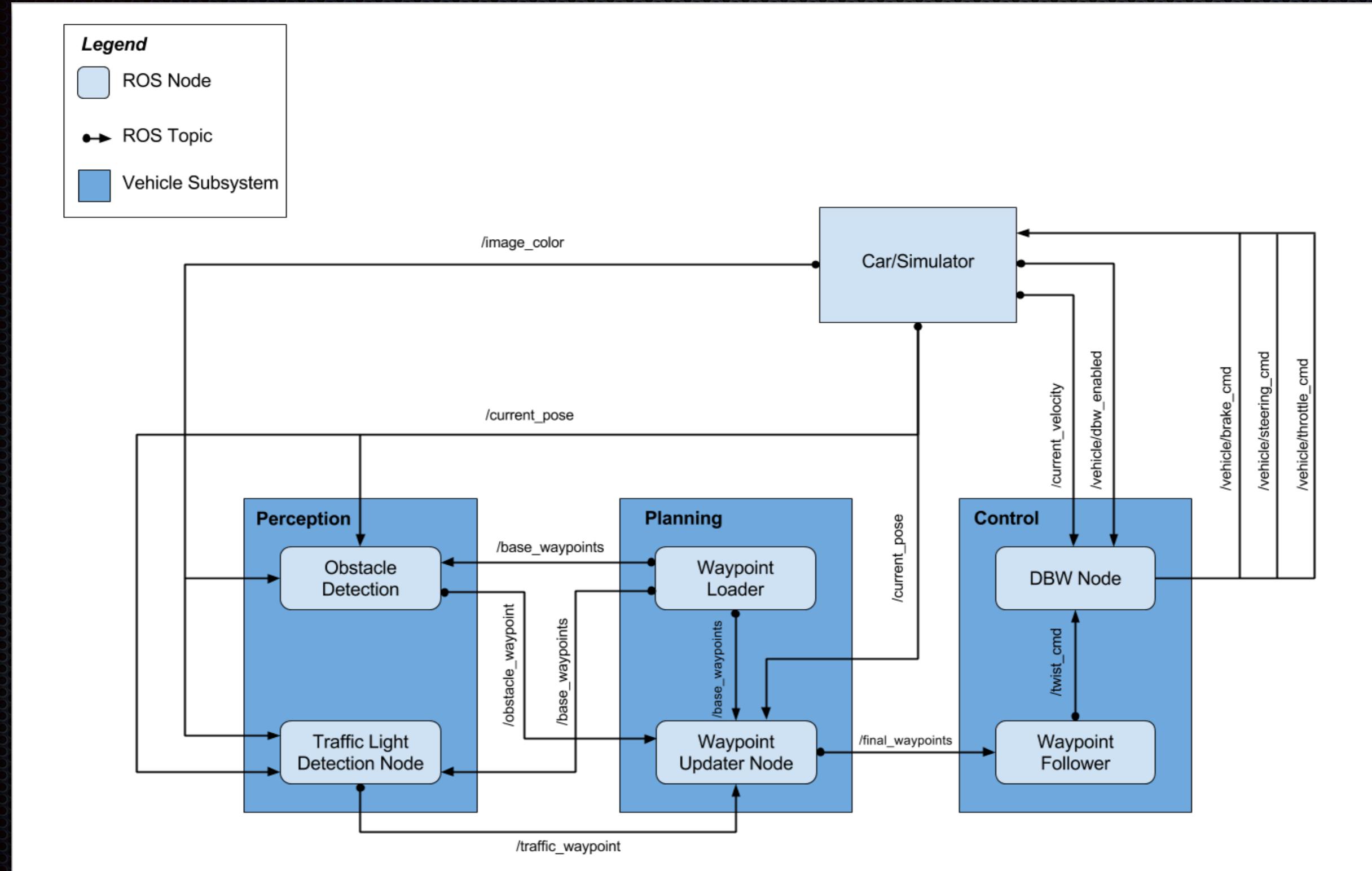


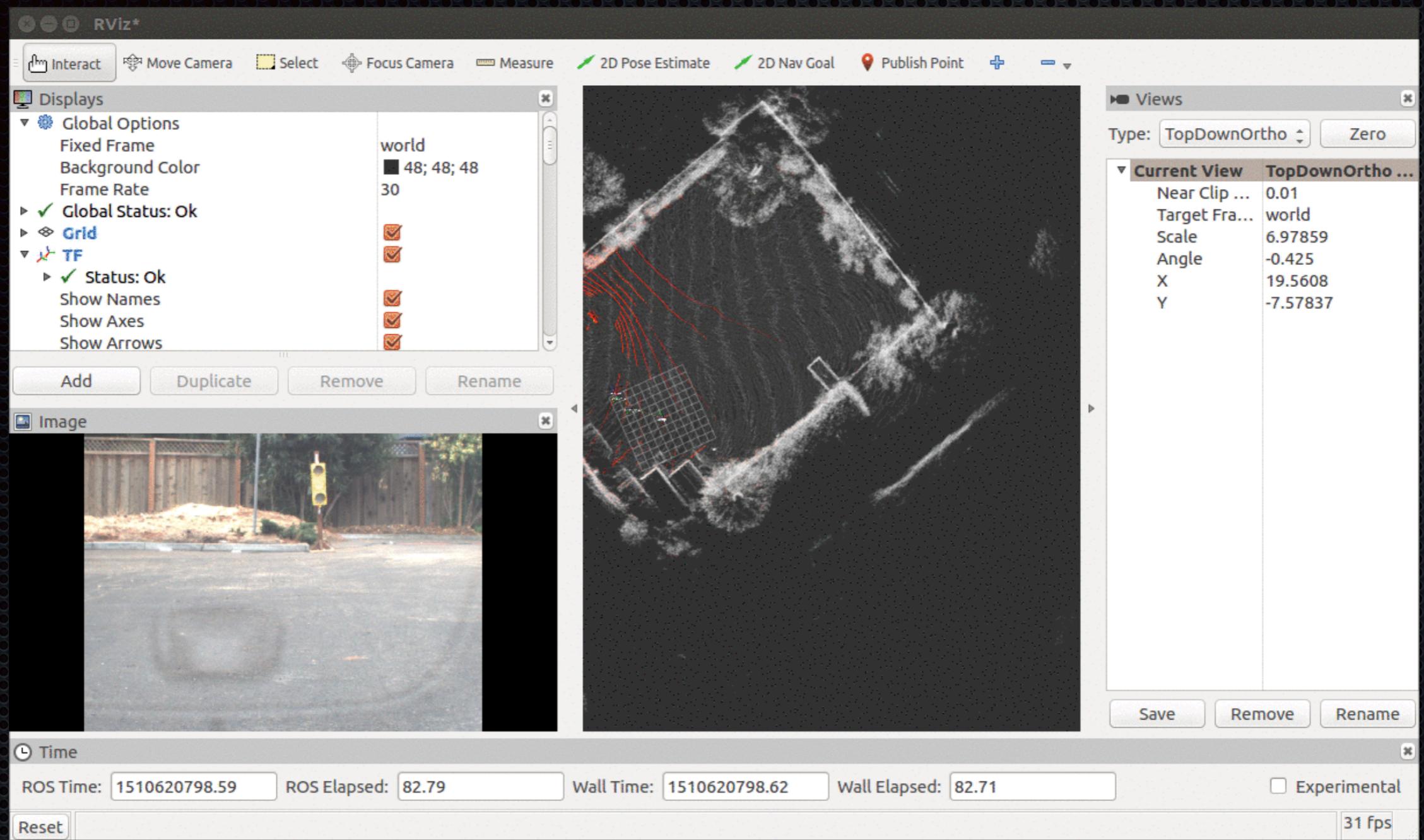
ROS

- * 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

