Deep Learning-Based Autonomous Navigation

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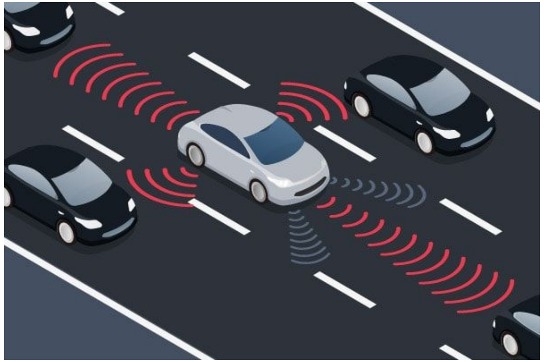
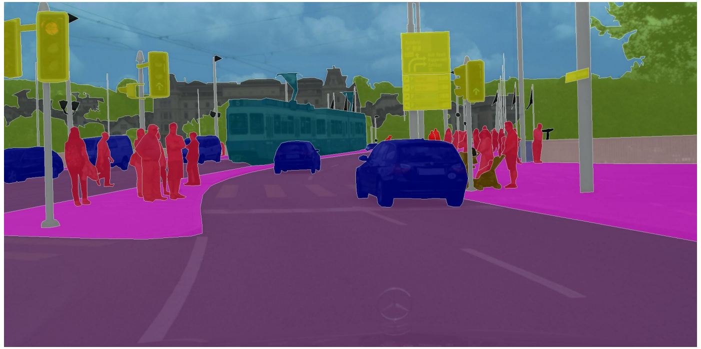
RSS 2019 Team 11

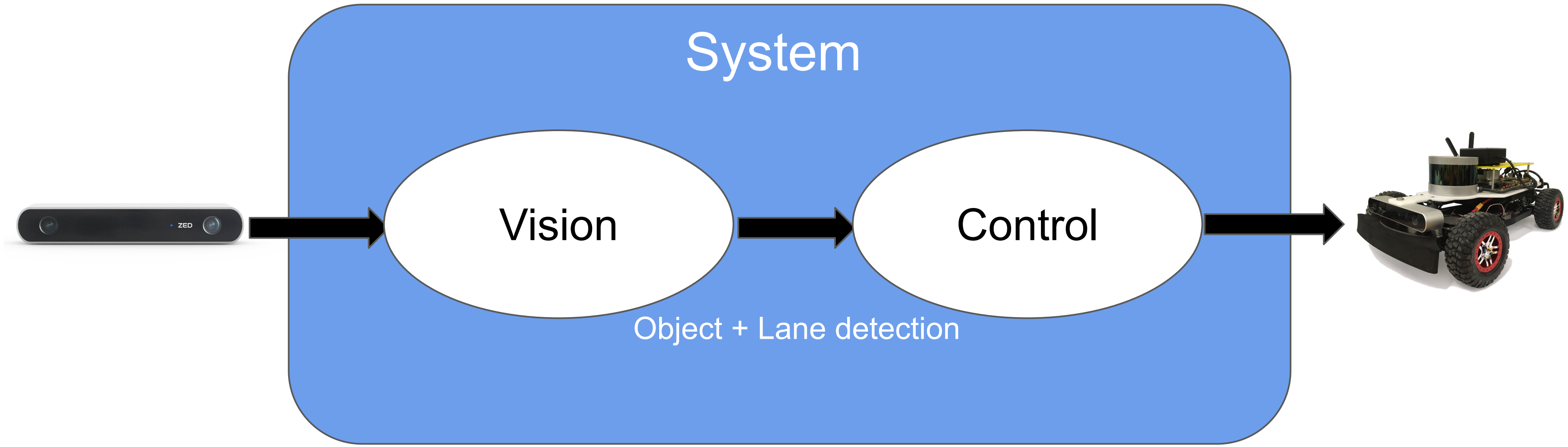
Motivation: Intelligent Autonomous Navigation



- Robust autonomous driving has massive societal implications:
  - Safer, more efficient transportation
  - Greater mobility
  - Increased productivity
- Autonomous driving requires robust ability to:
  - Understand the environment
  - Respond with well-developed controls



Our vision module informs our control module

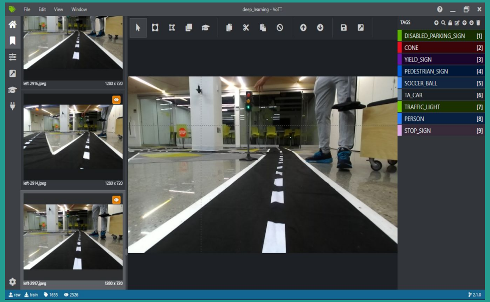


We trained object detection CNN on custom datasets

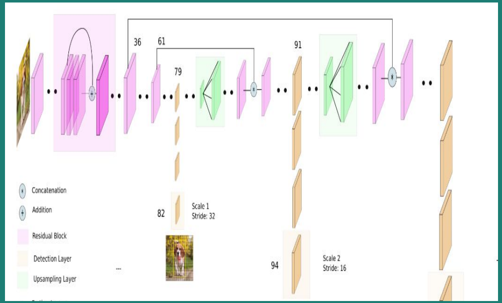
- **YOLOv3 Architecture**
  - Deep Convolutional Neural Network
  - Full Model: 252 layers
  - Tiny Model: 44 layers
- **Training**:
  - 1600 annotated custom images from Zed Camera
  - Keras + Tensorflow environment on Amazon EC2 Instance
  - 2-stage: first stage trains last 3 layers, second stage trains all layers
- **8 Custom Classes**
  - 4 signs: disabled parking, pedestrian, yield, and stop signs
  - car, person, traffic light, soccer ball (obstacle)

The YOLO Pipeline

[1] Labeling bbox via VoTT



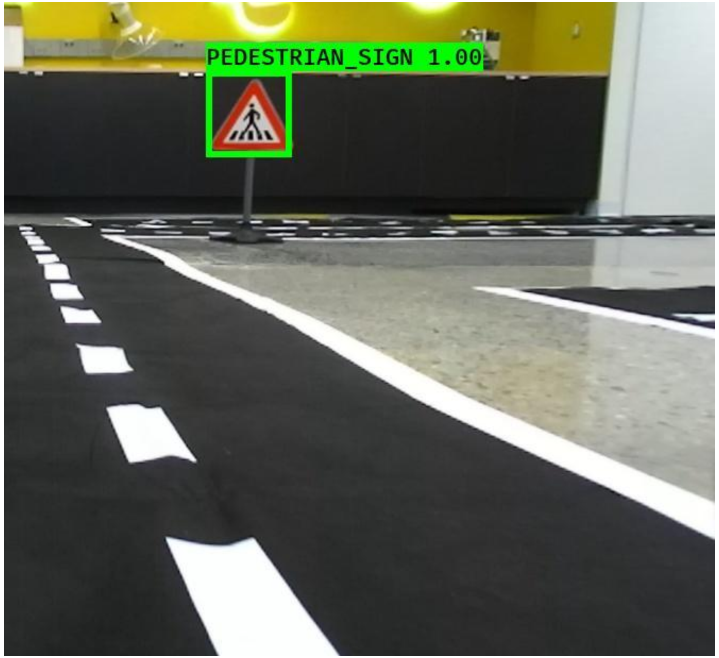
[2] Training YOLOv3



[3] Real Time Object Classification

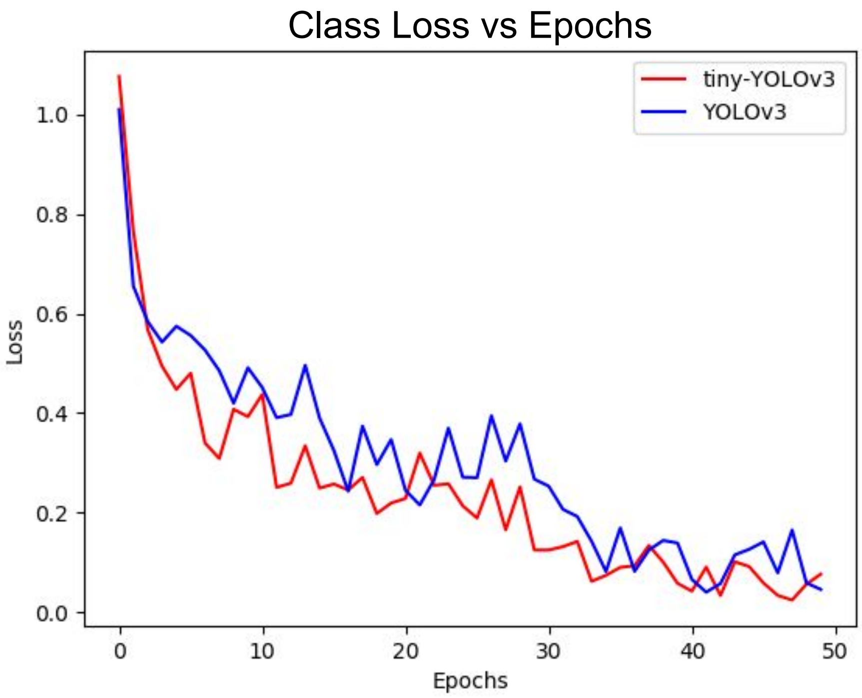
Real-time Object Detection

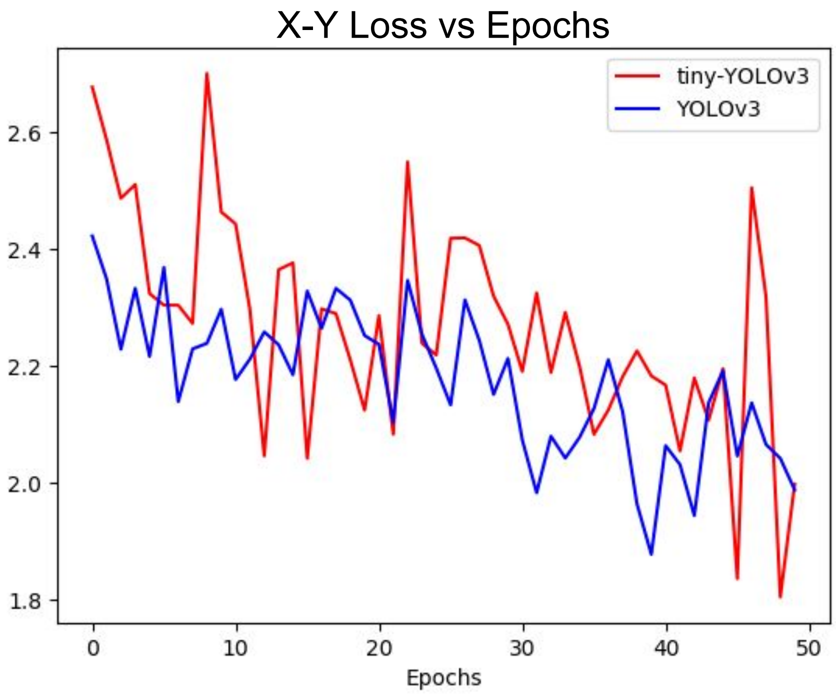
Detection of Disabled Parking Sign



Detection of Pedestrian Sign

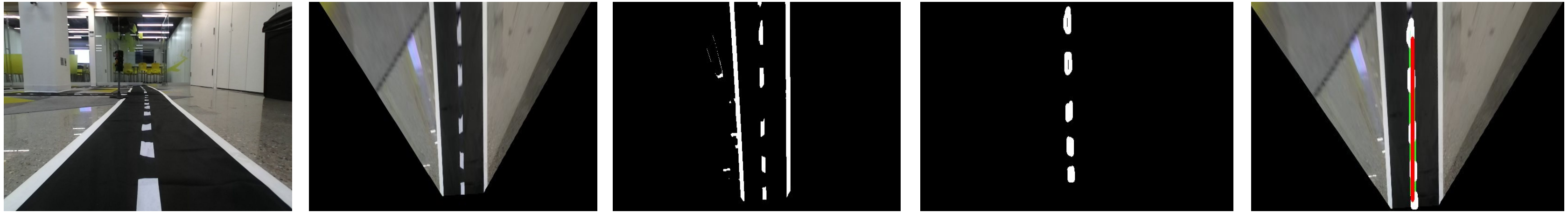
Tiny vs Full YOLOv3 Validation Error





Vision: Lane Segmentation

Original Image → Perspective Warping → White Segmentation → Contours Filtering → Hough Transform, Clustering



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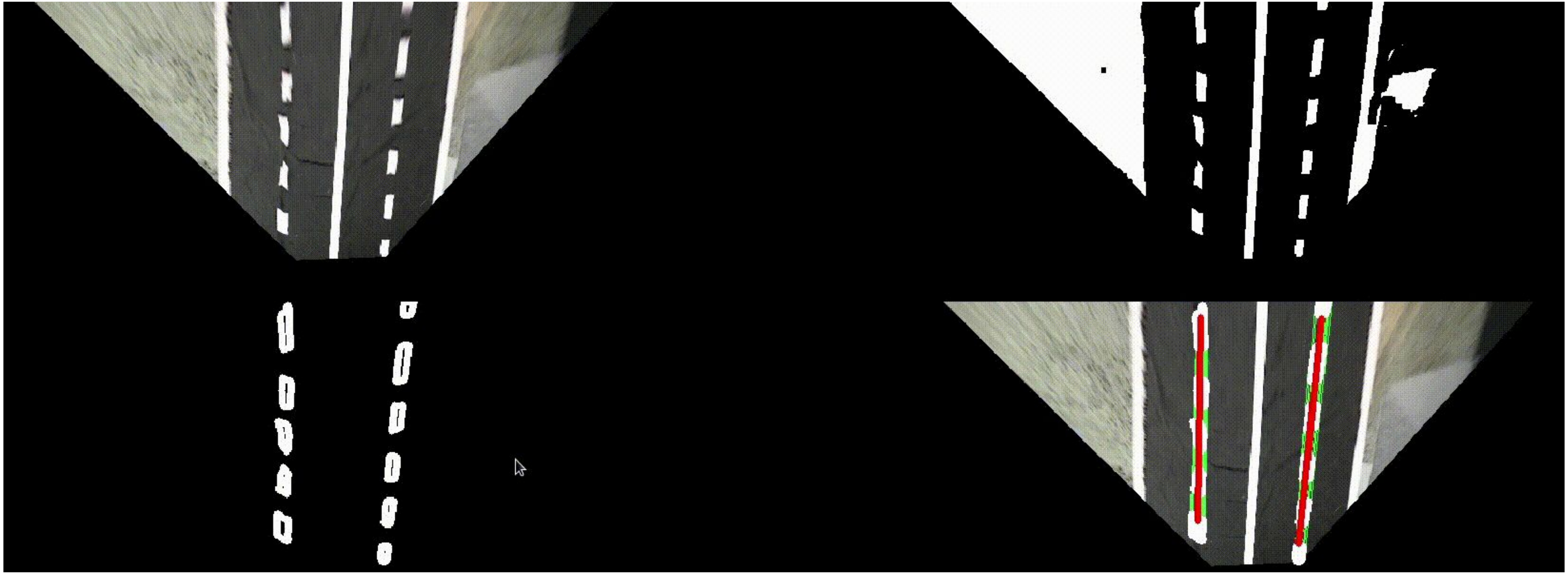
Lane Segmentation in Real Time



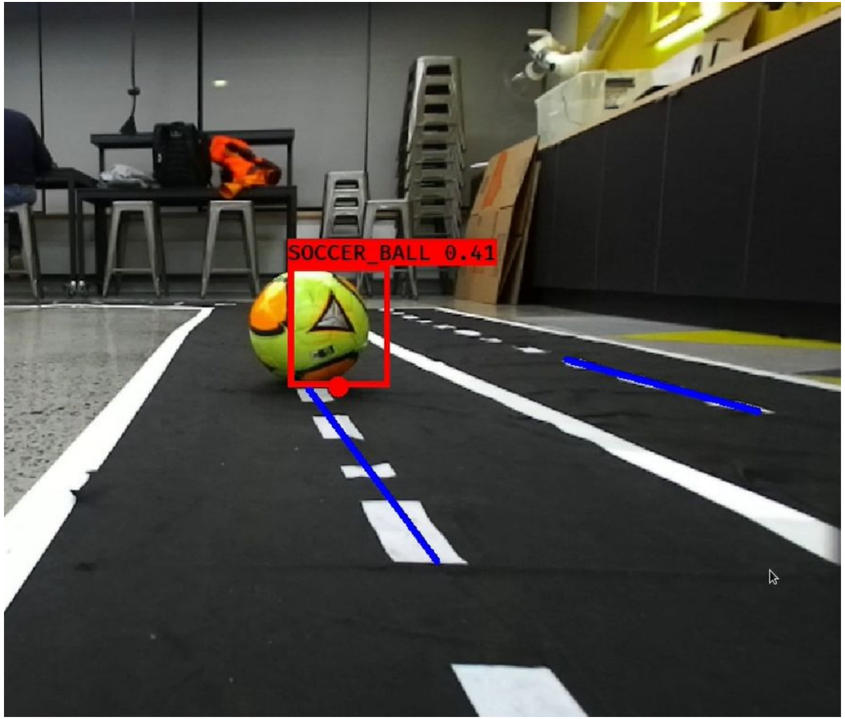
Controller: High Level

Object Detection + Lane Detection → Homography Transforms → $\boxed{\text{Controller Logic}}$ → Drive Commands (steering + speed)

Three states:

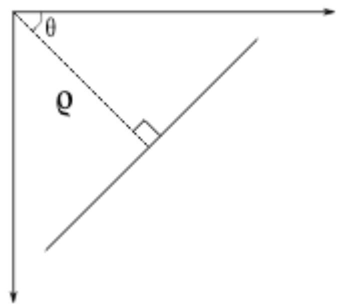
1) **Autonomous Driving**: lane changing/following, turning, stopping, traffic rules, etc.
2) **TA car following**: PD control based on relative distance/location from TA car
3) **Parking**: valid parking space detection + PD control

Steering controller finds the *best* unobstructed lane



1) Check for obstacles in current lane
2) *Best* lane: smallest difference to lane of previous timestep (in ρ, θ space)

$$\rho = x\cos\theta + y\sin\theta$$

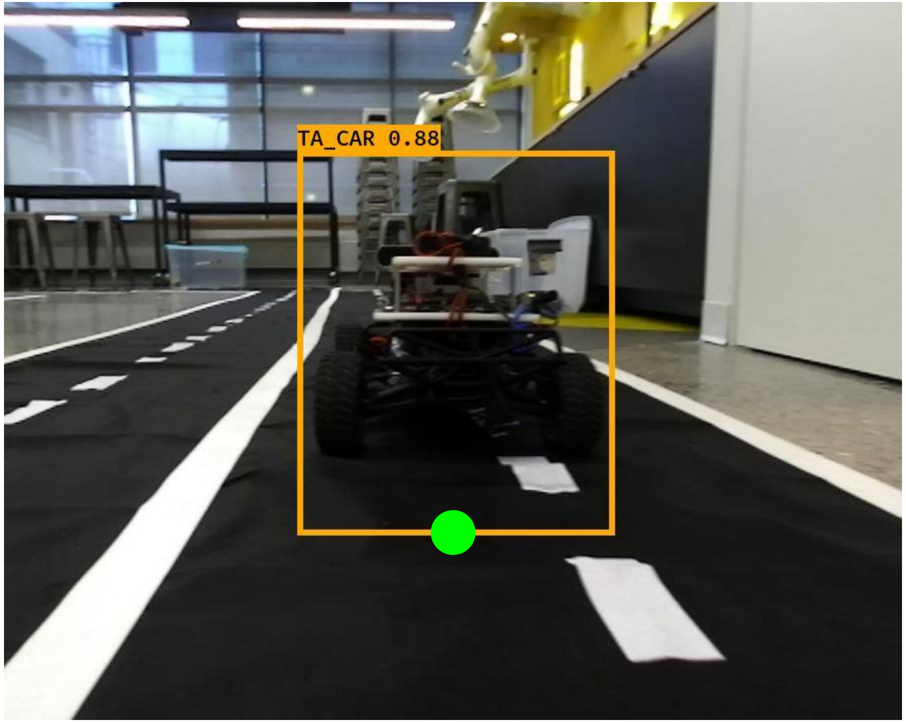


3) Angle calculation by Pure Pursuit

Limitations we faced, and our solutions

	Problems	Our solutions
1	Once at an intersection, robot can no longer see the intersection due to the camera’s limited field of view	● Plan out turns in advance ● Hardcode drive action ● (Ideally: more cameras)
2	Object detection does not recognize objects in every frame	● Rely on detected objects in the last frame(s)
3	YOLO often fails to load and crashes other nodes	● Wait… many hours ● Stressful hours ● (Ideally: explore options)

TA car following uses PD controller

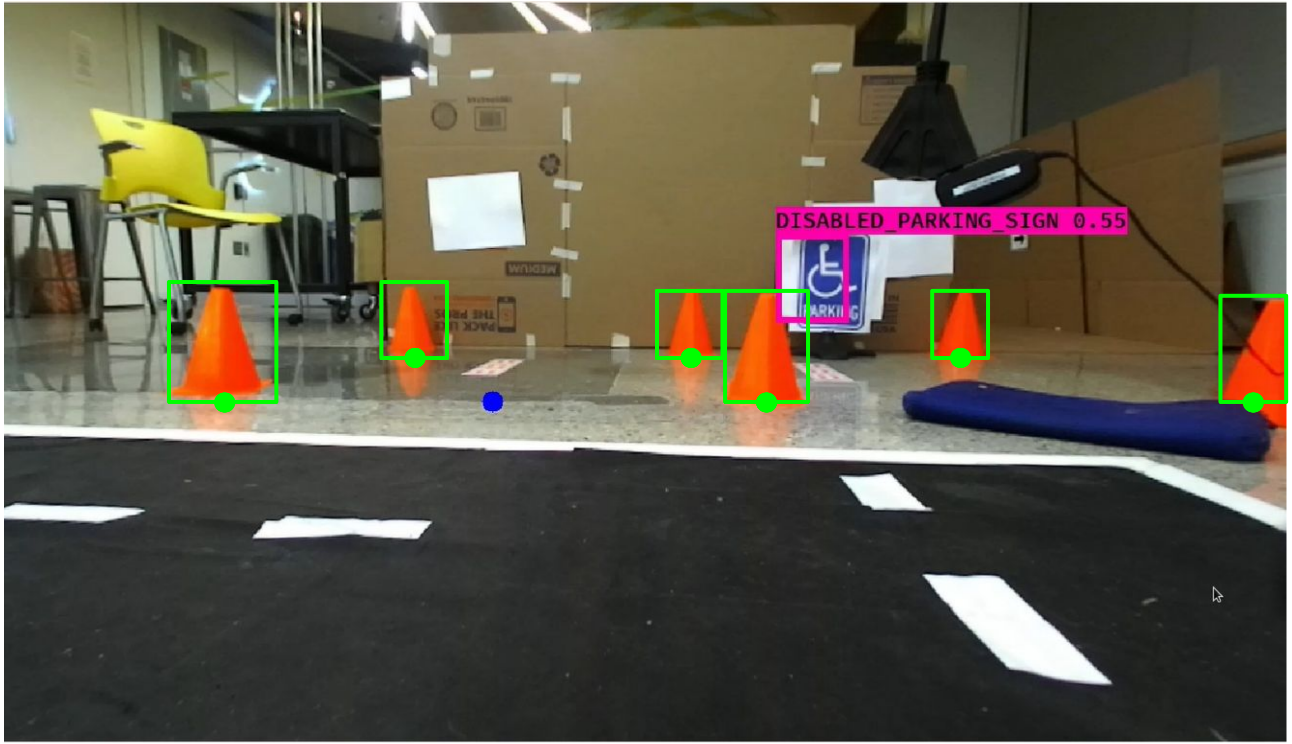


PD control on midpoint of bottom of bounding box

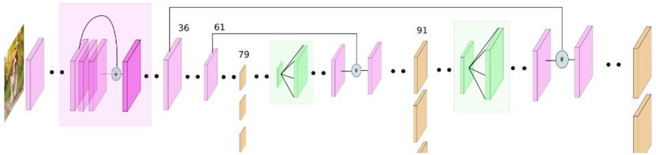
Desired distance: 1 meter

Parking controller uses color segmentation and YOLO

Color segment + bound orange cones → YOLO on disabled parking sign → Stage 1: Find spot with front 3 cones → Stage 2: Move to midpoint of back 2 cones → Stage 3: Stop when < 2 cones

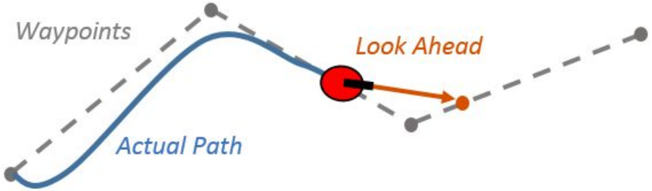


What We Learned

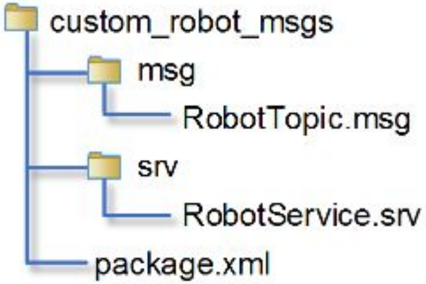


- **Object detection methods:**
  - YOLOv3 Deep Convolutional Neural Networks
  - Color segmentation

- **Lane detection methods:**
  - Hough Transform
  - Edge Detection
  - Clustering



- **Applications of pure pursuit control:**
  - Parking
  - Turning
  - Lane following
- **Developing our own ROS package**



What We Can Improve on

- **Object detection**
  - More data (e.g. lighting and placement variations) to decrease overfitting
  - Other network architecture for higher inference speed
- **Lane detection**
  - More robust algorithms, especially around the corners
- **Controller**
  - Higher driving speed for greater practicality

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