RSS LAB 4

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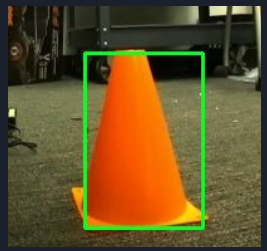
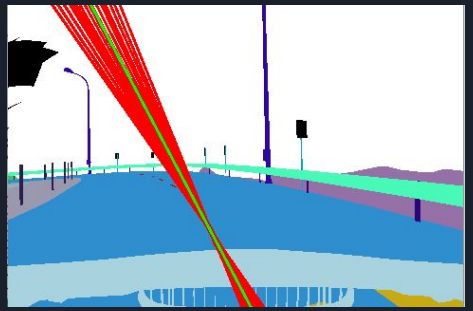
Four modules focused on computer vision and controls.

1. Cone Detection via Color Segmentation
2. Homography Transformation
3. Cone Detection and Parking In Tesse
4. Line Detection via Hough Transforms





$$s \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix}$$

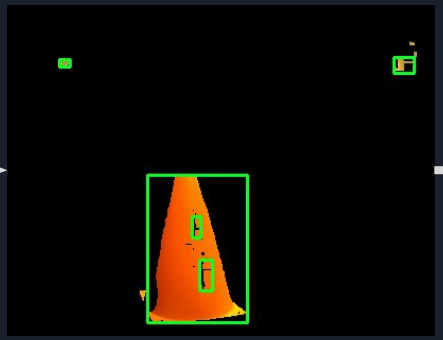
Module 1:
Cone Detection via Color Segmentation

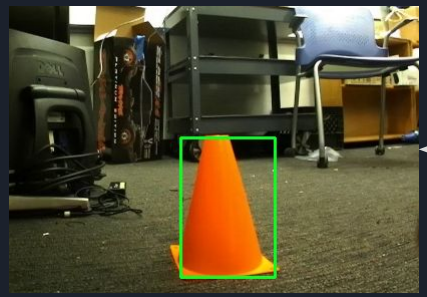
Using OpenCV to Conduct Color Segmentation

Erode Input File

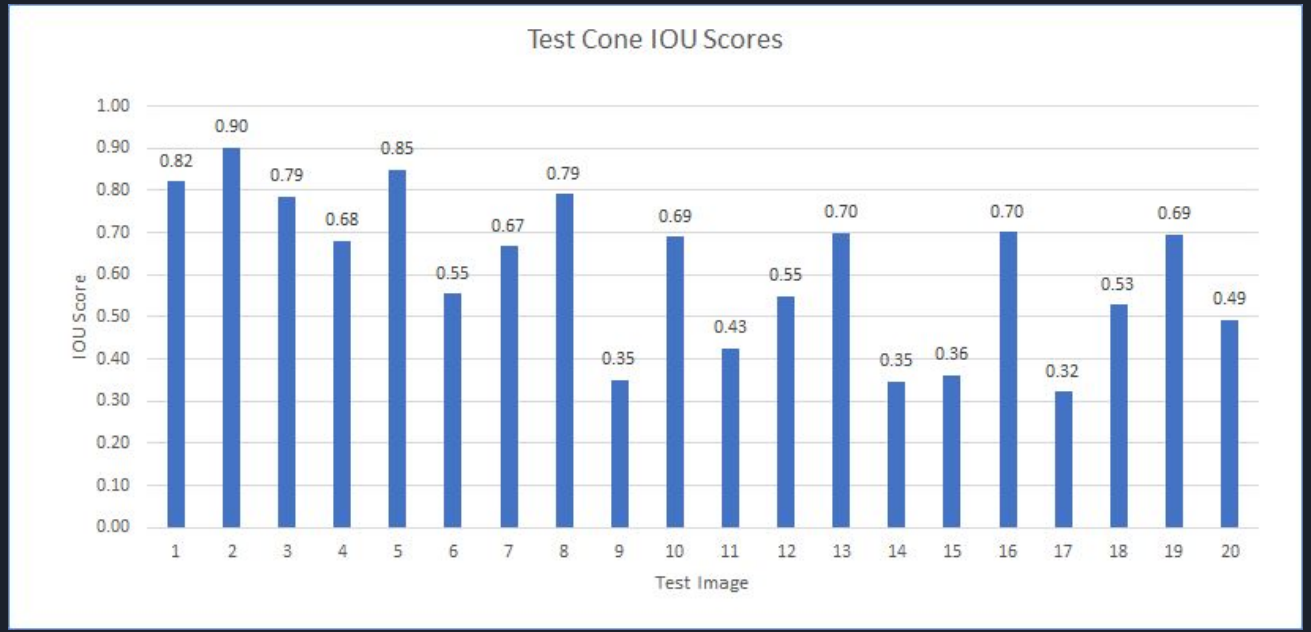
Create Mask Based on HSV Color Range

Use Blob Detection to Find Blobs

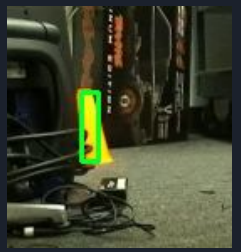




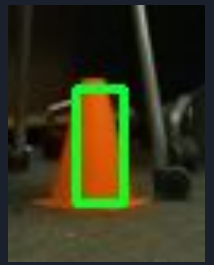
IOU Score Validation of Color Segmentation Bounding Boxes



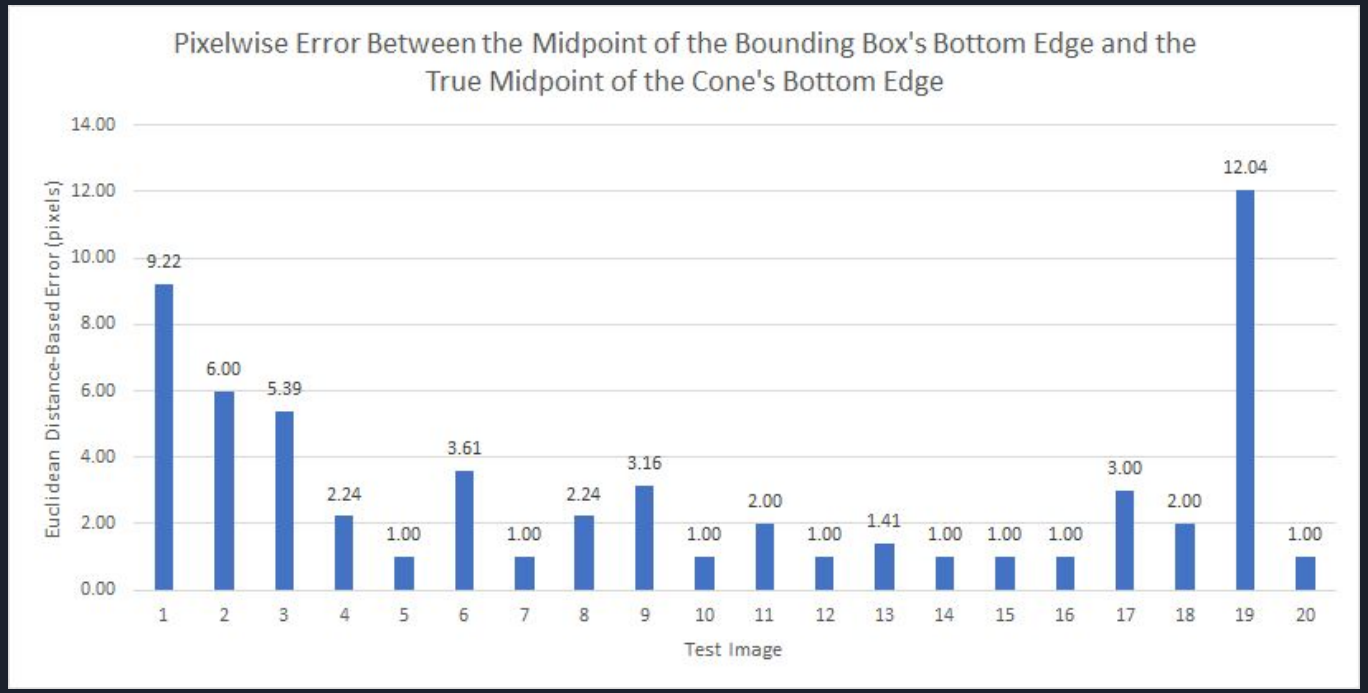
test9.img



test17.img

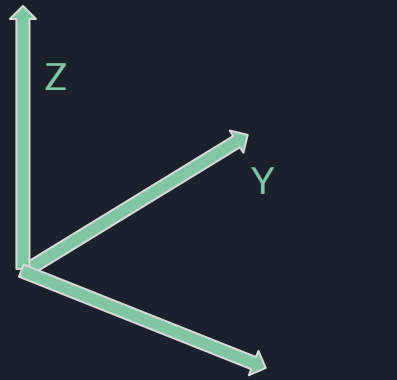


Determining Pixel-wise Error Between Bounding Box and Cone With Respect to the Midpoint of the Bottom Edge

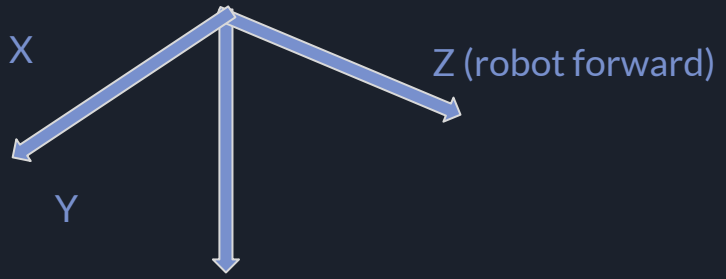


Module 2: Homography Transformation

Homography Transformation computes reverse projection from pixel coordinates into ground plane coordinates.



Base Link Frame

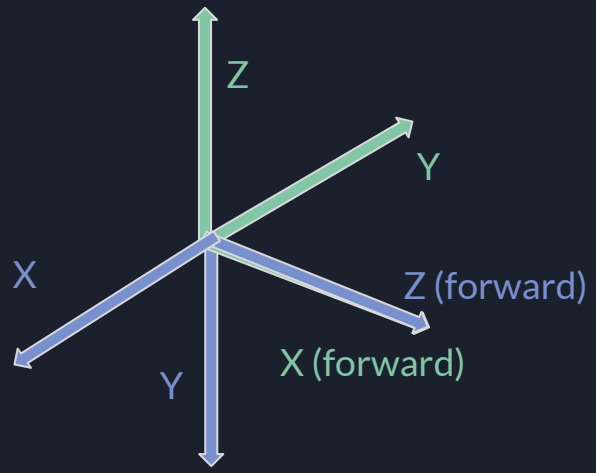


Camera Frame

Calculating the homography matrix

$$s \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad (1)$$

2D Image Coordinates | Intrinsic Properties | Extrinsic Properties | 3D World Coordinates



$$s \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} \quad (2)$$

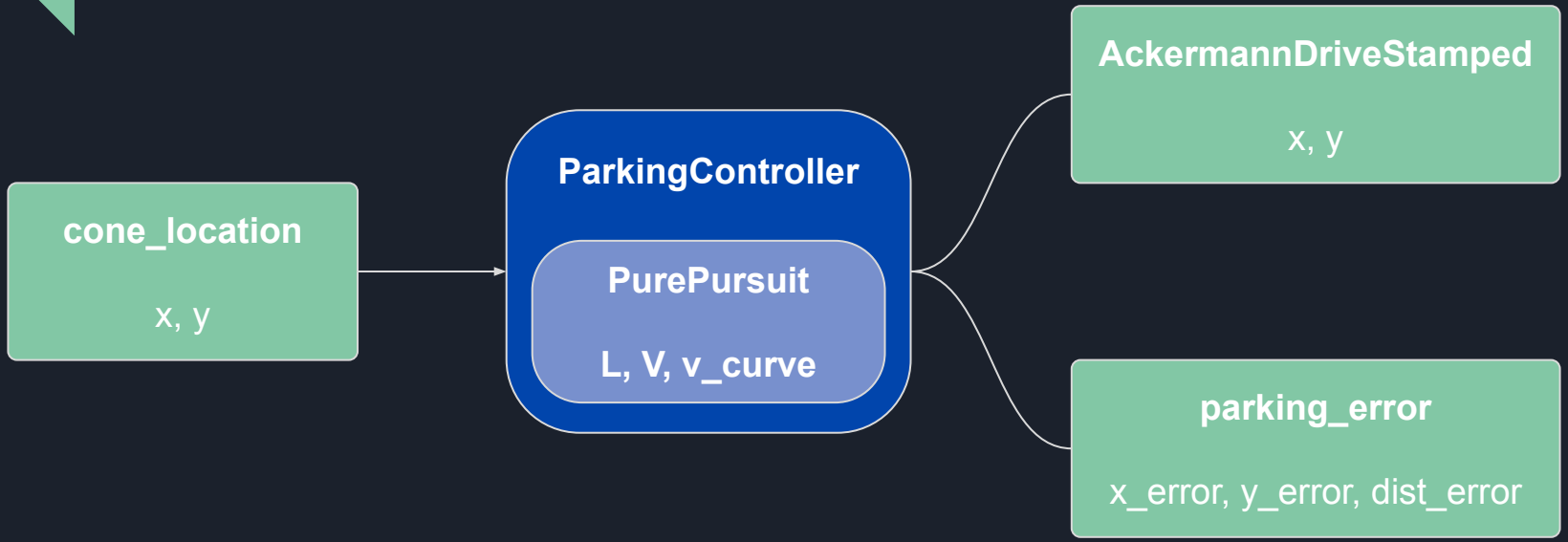
3D World Coordinates | Homography Matrix | 2D Image Coordinates

$$Exrinsic\ matrix = \begin{bmatrix} 0 & -1 & 0 & 0.05 \\ 0 & 0 & -1 & 1.03 \\ 1 & 0 & 0 & -1.5 \end{bmatrix} \quad (3)$$

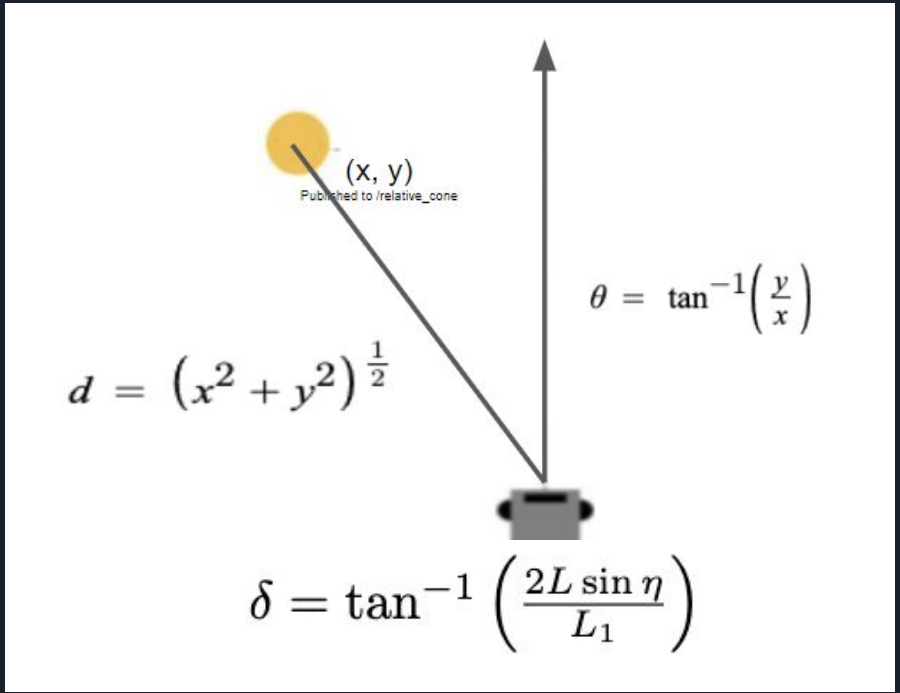
Rotation | Translation

Module 3:
Parking Controller

Parking Controller subscribes to Cone Location, and publishes Ackermann Drive



Pure Pursuit Controller gets steering angle from cone location

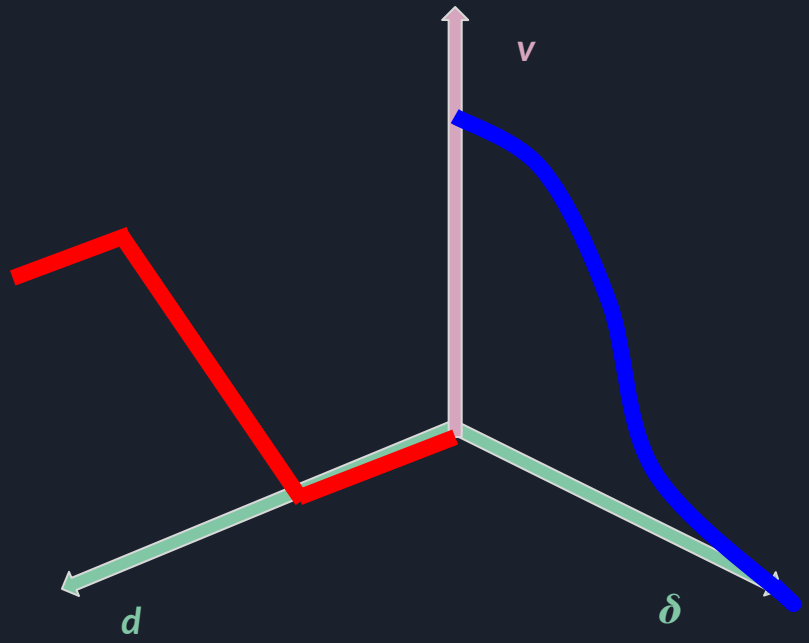


Velocity Curve **increases** with Distance and **decreases** with Steering Angle

$$v_d = \frac{1}{D_{park}}(d - D_{bumper})$$

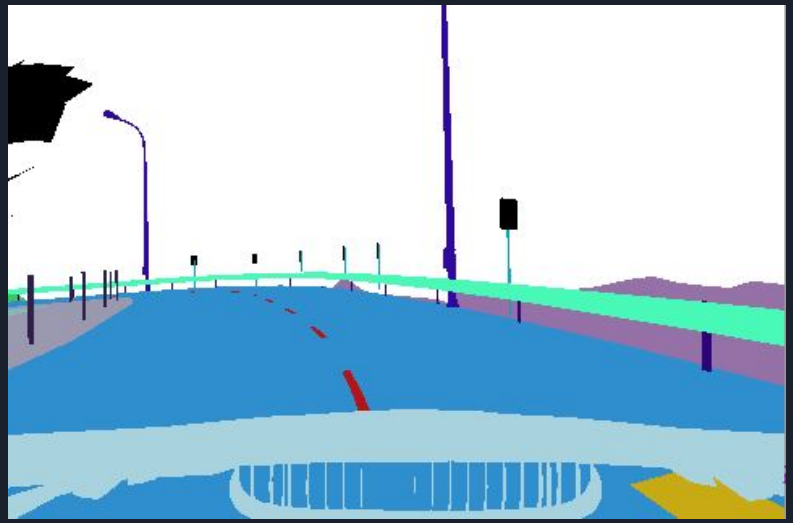
$$v_\delta = sech(\frac{\delta}{\frac{\pi}{4}})$$

$$v(d, \delta) = |V_{max}| v_d(d) v_\delta(\delta)$$



Module 4:
Line Follower

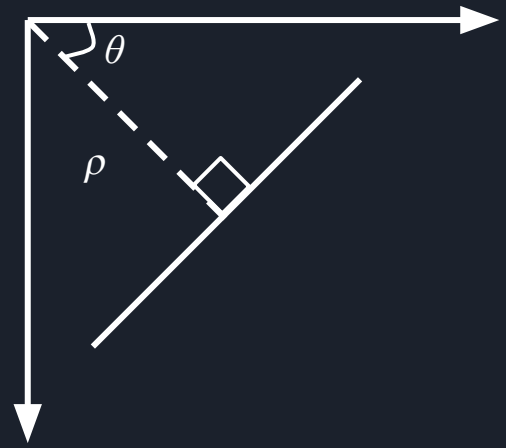
Color Segmentation Mask



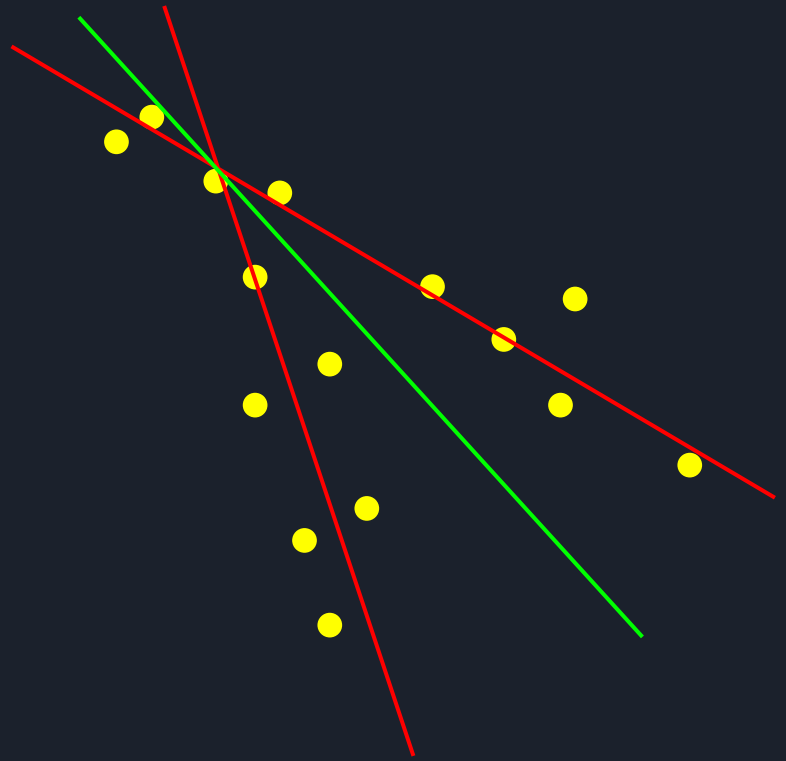
Original

Mask

Hough Line Transform



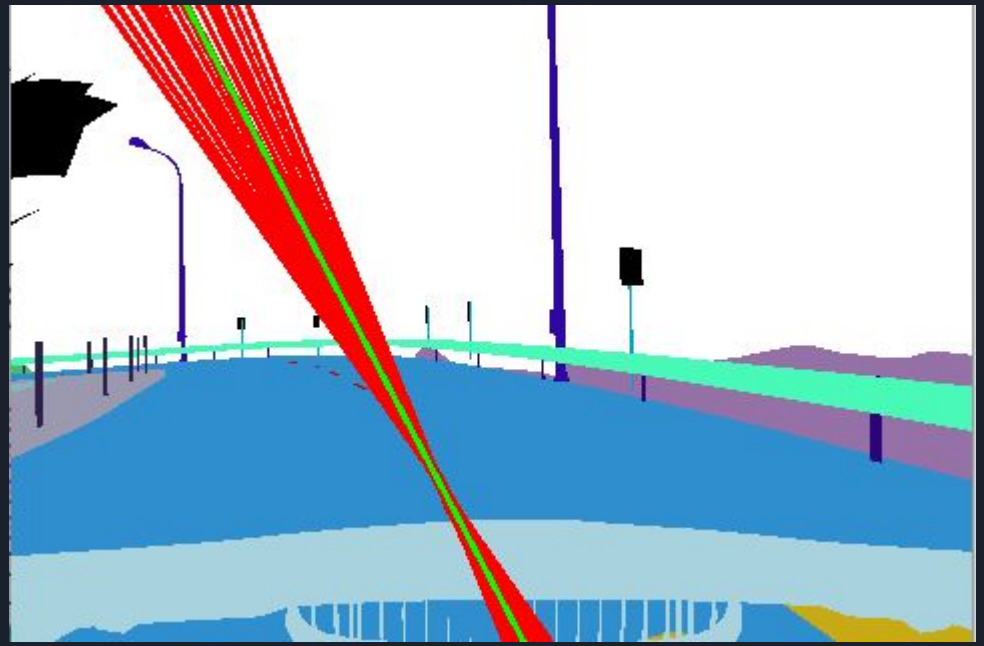
$$\rho = x \cos\theta + y \sin\theta$$



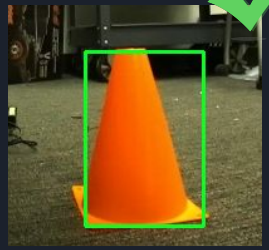
Average Line

Hough Lines —

Average Line —



Summary of takeaways / future work on computer vision and controls modules



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