Self-Driving, Autonomous Car for the 2025 American Control Conference QCar Student Competition

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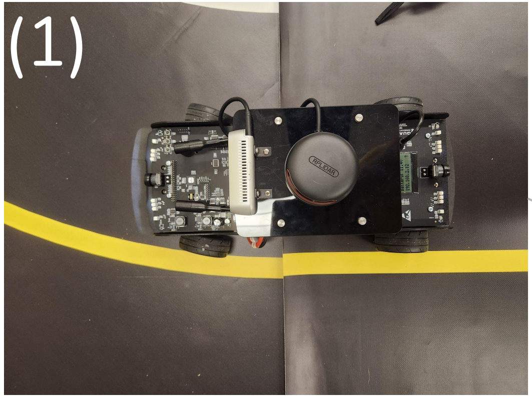
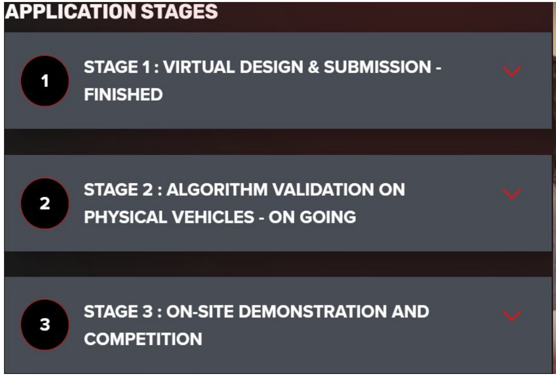
Goals/Project Outline

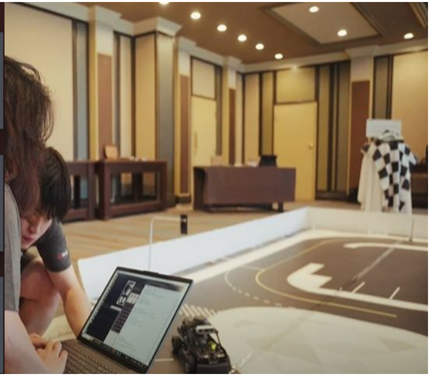
(1) QCar autonomous, self driving around track
(2) Completion of Quanser self driving car lab
(3) Compete in-person at the American Control Conference Self-Driving Quanser Car Student Competition



The American Control Conference and Quanser Overview

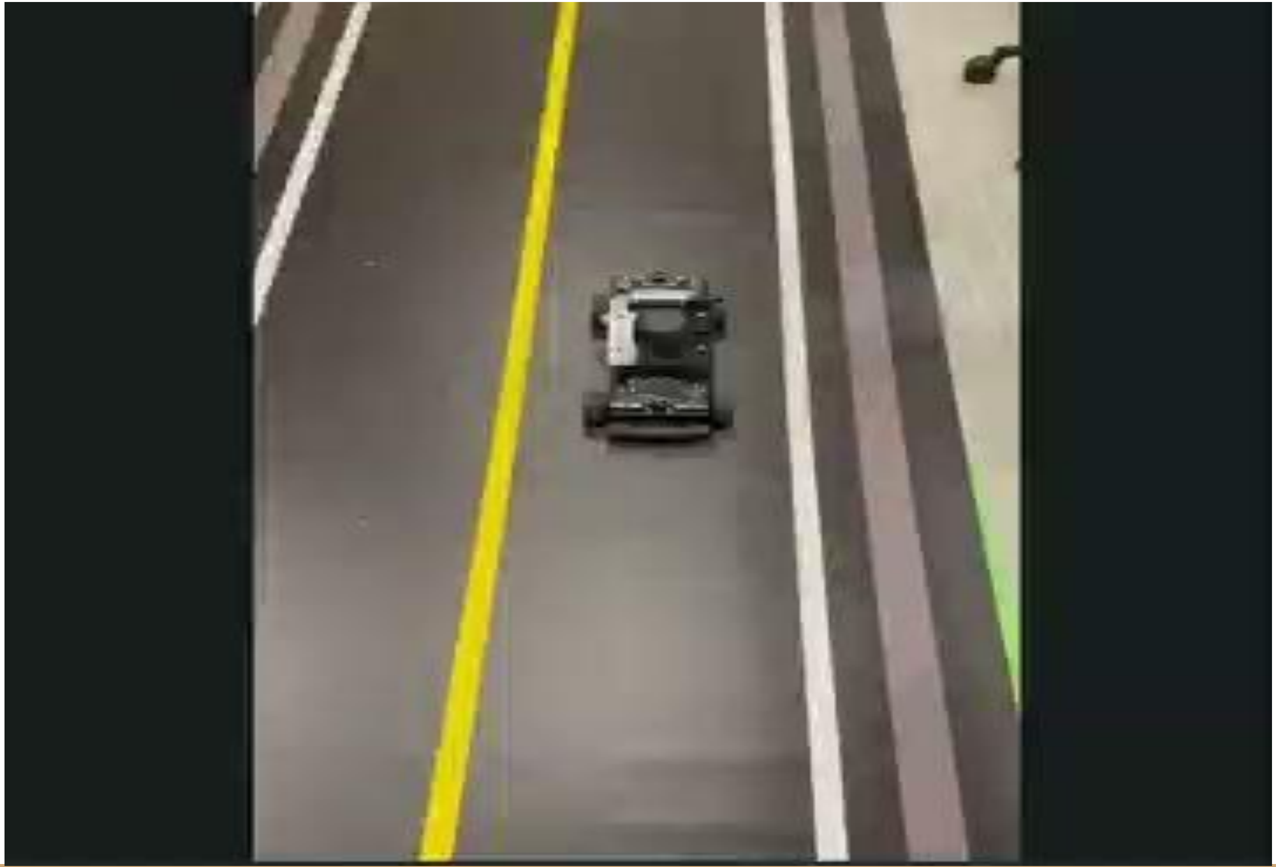
- **Quanser**
  - Educational product development company
  - Sponsor of student event and creator of QCar
  - Tiers focused event



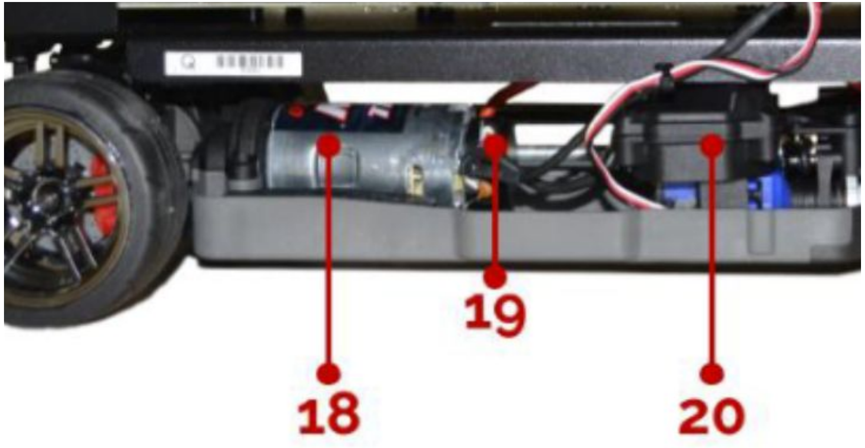


- **American Control Conference**
  - Annually held by Automatic Control Council and International Federation for Automatic Control
  - Professional and academic focused multi-day event

Fall Semester QCar Autonomous Loop



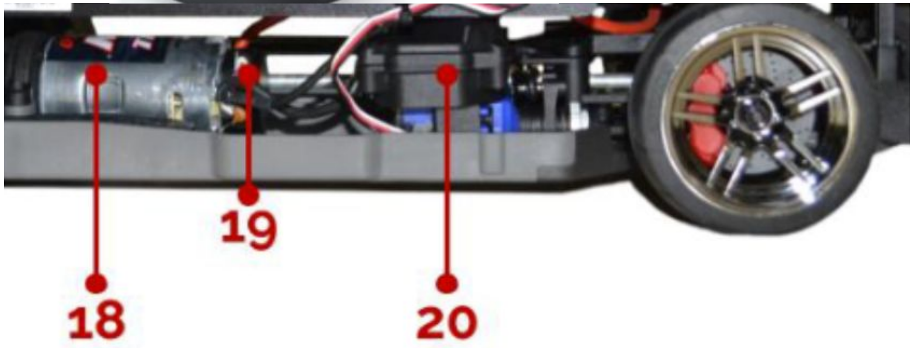
Controls - Motors



Point 18 - Drive Motor; Point 20 - Servo Motor

- Drive motor
  - Motor speed limits
- Servo steering motor
  - -0.5 to 0.5 radians (~28°)
  - $\tau = 0.16$ s
  - Bicycle model:
    - Global position (x, y) and turn angle (ψ)

Controls - Encoder



Point 19 - Optical encoder

- 720-count pre-gearing optical encoder
    - Uses hardware velocity to measure position and motor velocity
- Feedback speed controller
    - Time integration and motor modulation
    - Faster acceleration, precise positioning

Image Processing

- 2D CSI Cameras
  - Camera Serial Interface
  - Max 120 Hz Frame Rate
  - 160° Horizontal Field of View (FOV)
  - 4 Cameras for 360° Vision
  - 640 x 480
- OpenCV for Image Processing
  - Convert color from RBG to HSV or Binary
  - Draw boundary boxes around objects
  - Edge detection
  - Noise filtering

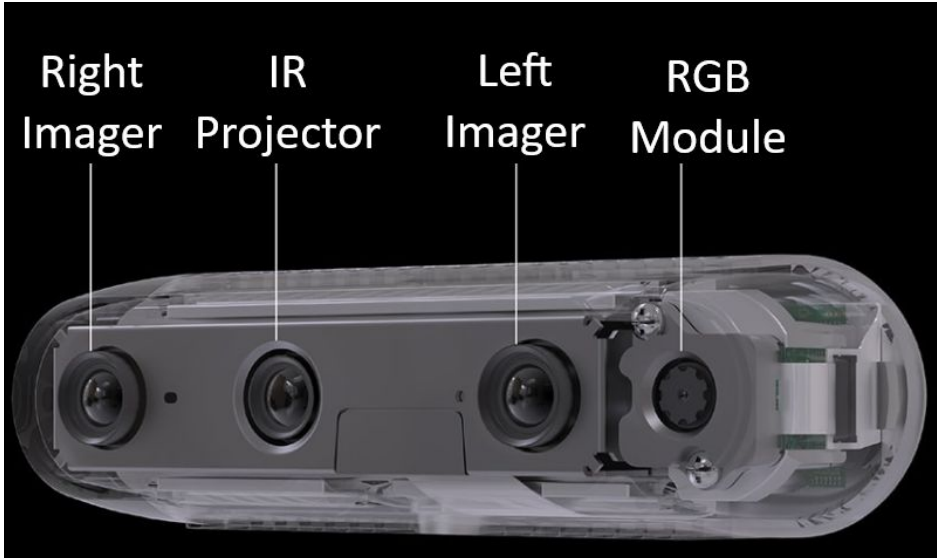

Red: CSI Camera positions. Pink: FOV of CSI

OpenCV


CSI Camera

RGBD Camera (Intel Realsense D435)

- Intel Realsense D435
  - 640 x 480 resolution
  - RGB 60 fps / Depth 90 fps
- Depth Detection
  - IR Projector and two IR Imagers used to calculate depth
  - Distance is tracked in meters



RGBD Camera Components

Driving Algorithm

- Autonomously complete a lap around loop
- Stays in the center of the lane
- Tracks the yellow and white lines
  - When in outer lane, track white line to the right
  - When in inner lane, track yellow line to the left
- Determines if the white pixels are within an acceptable range
  - If true, drive straight
  - If false, turn based on how far out of range white pixels are
- Adjust speed based on turn angle and road lines

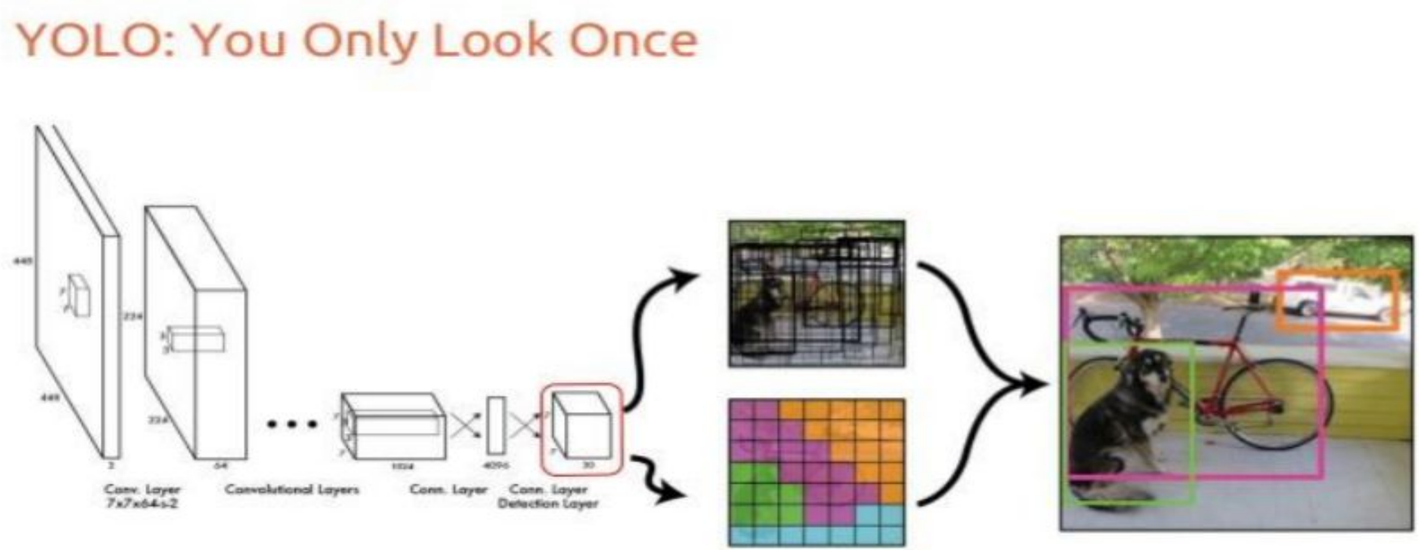
Camera Feed on Straight Road

Full Road Used for Testing

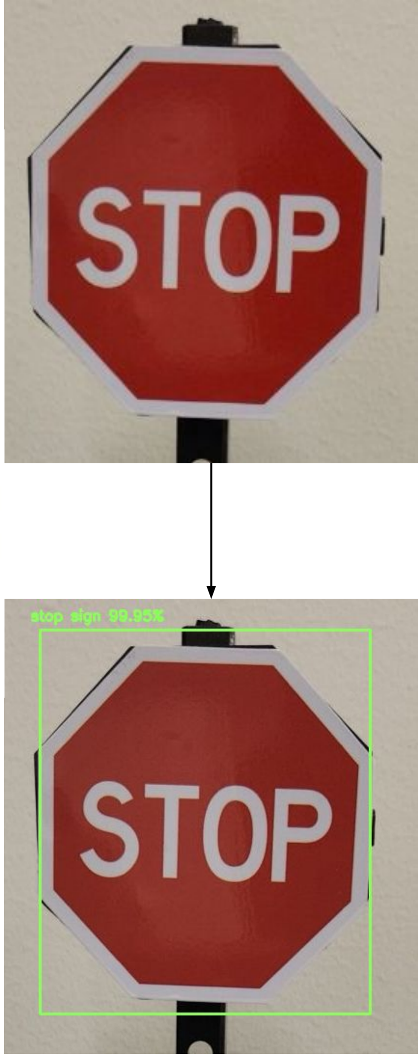
Camera Trade-off Analysis

Criteria / Camera	**Time Efficiency**	**Visibility**	**Complexity**	**Usefulness**
RGBD	Low (due to multiple cameras in use)	Medium (all colours RGB & grayscale depth)	High (two separate images of data)	High (depth capabilities)
CSI: HSV	High	High (all colors)	High (3 channels)	Medium
CSI: Binary	Medium (due to filtering out color)	Low (only black or white)	Low (only black or white)	High (more supported)

YOLO Algorithm

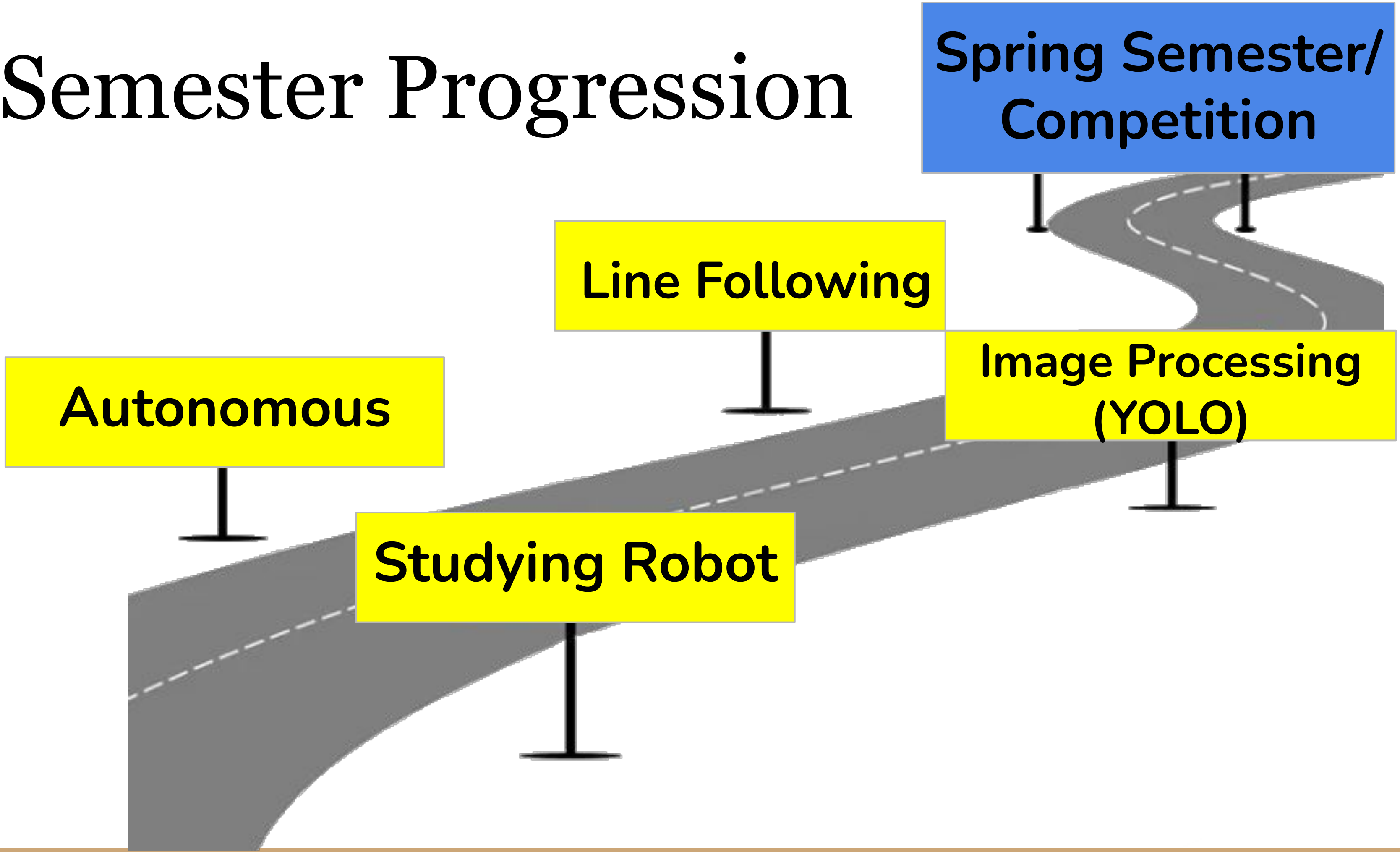


“You Only Look Once: Unified, Real-Time Object Detection”; Redmon, Girshick, Farhadi, and Divvala

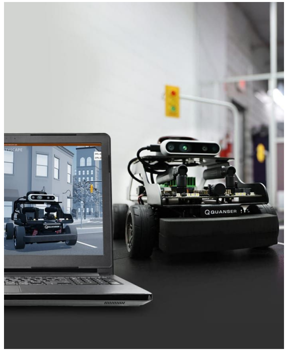


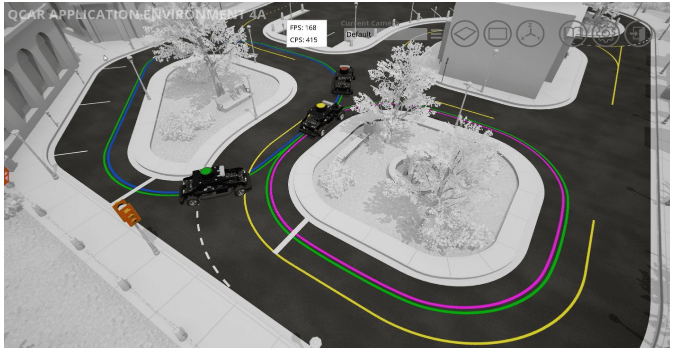
- OpenCV DNN module with a pre-trained YOLOv3 model
    - Trained using COCO (common objects in context from Microsoft) dataset
- Single-pass, multi-output layer filtered using confidence (0.7) and non-max suppression (0.55) thresholds

Semester Progression



Future Work





Quanser Simulation Images from Website

Algorithm Development	Improved YOLO with simultaneous localization introduction
Python Simulation	Quanser labs based python simulation of new arena
In-Person Competition	Compete in ACC Quanser 2025 student self driving competition