Research and Adaption of Efficient Autonomous Driving methods in Duckietown

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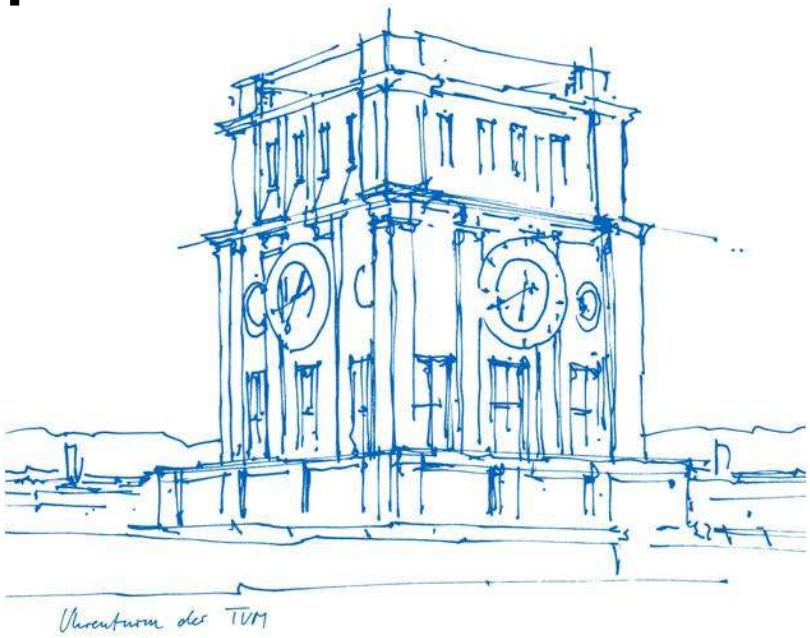

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Heilbronn, 14th March 2024

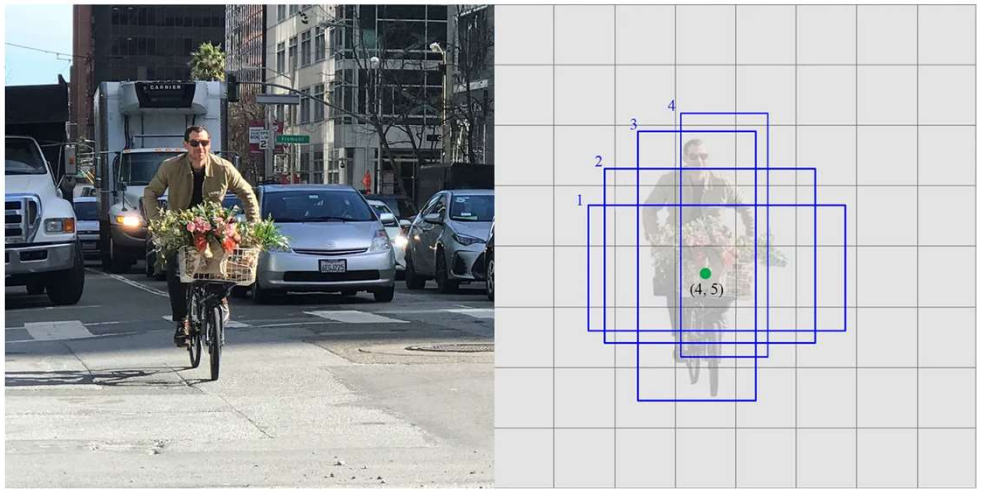
Overview

- Mid-term progress
- Demo Video
- Autonomous Navigation in Duckie-town
  - Lane Following
  - Stop Line Detection
  - April-Tags
  - Intersection Navigation
- Observations

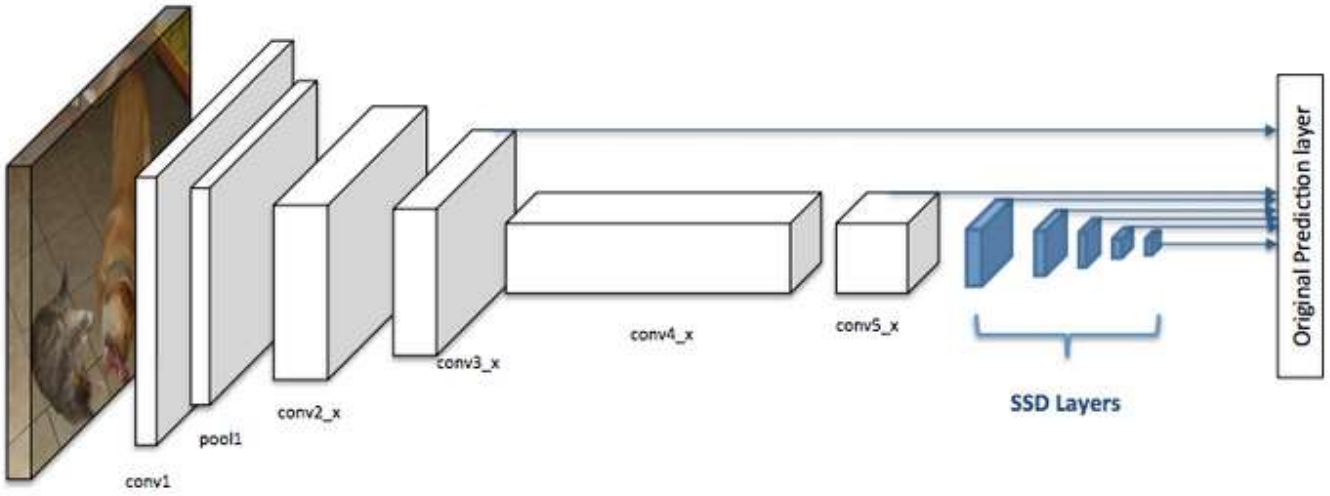
Mid-Term Progress

SSD - Single Shot MultiBox Detector

- Single Shot Detection Approach
- Use of Multi-Scale Feature Maps
- Default Boxes and Aspect Ratios



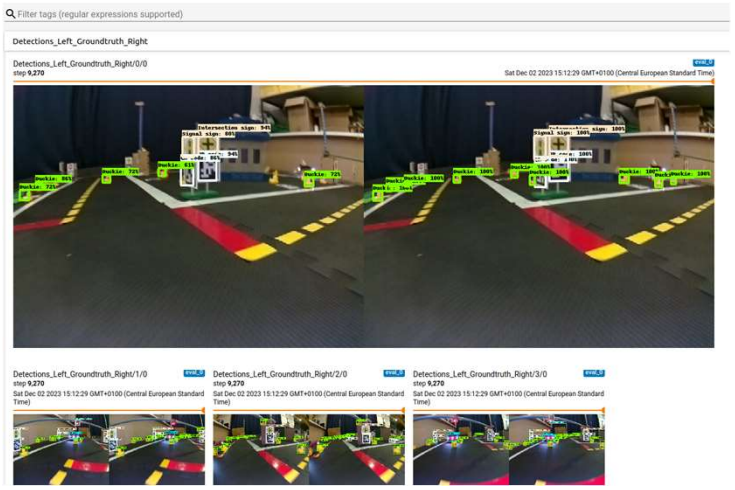
SSD - Single Shot MultiBox Detector



SSD - Single Shot MultiBox Detector

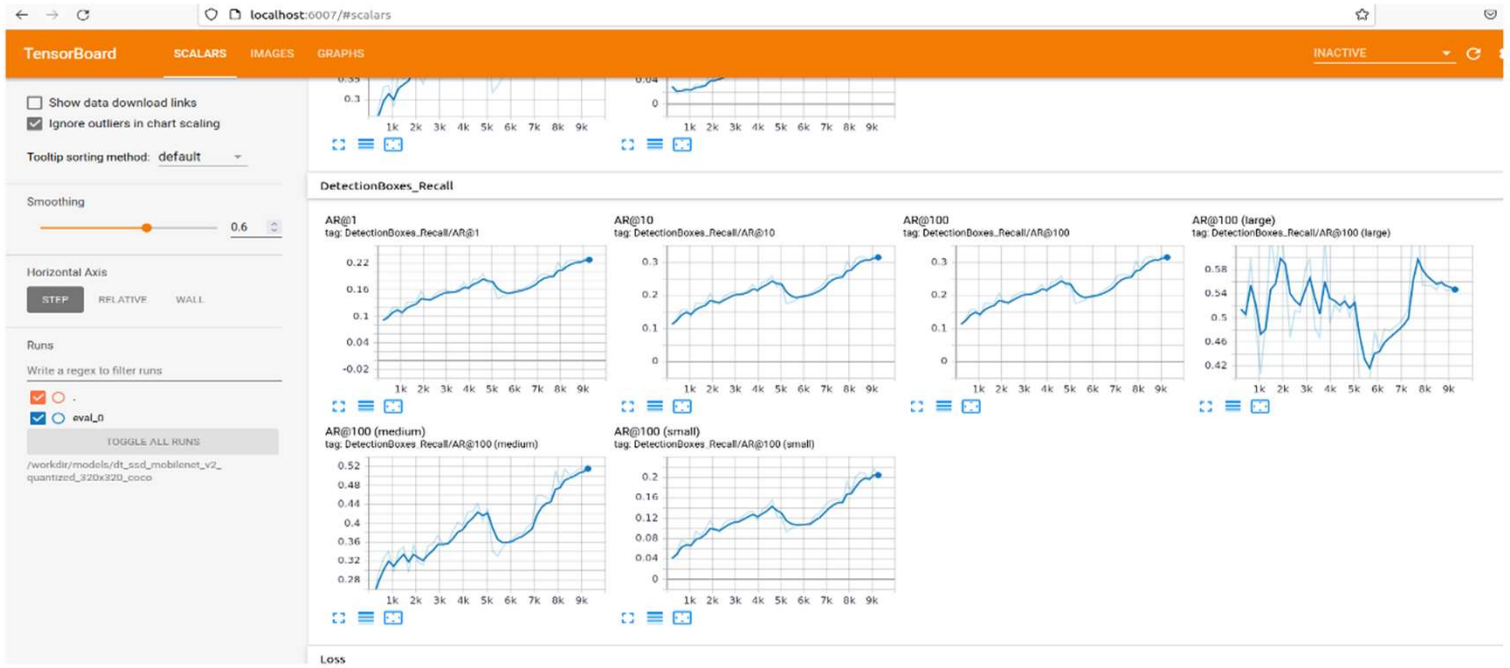
We failed:

- 4 years old repo – was running Google Coral TPU.
- Succeed to trained the model – No inference – unable to communicate with ROS camera node
- Tried re-writing entire camera node Pub-Sub code – in progress

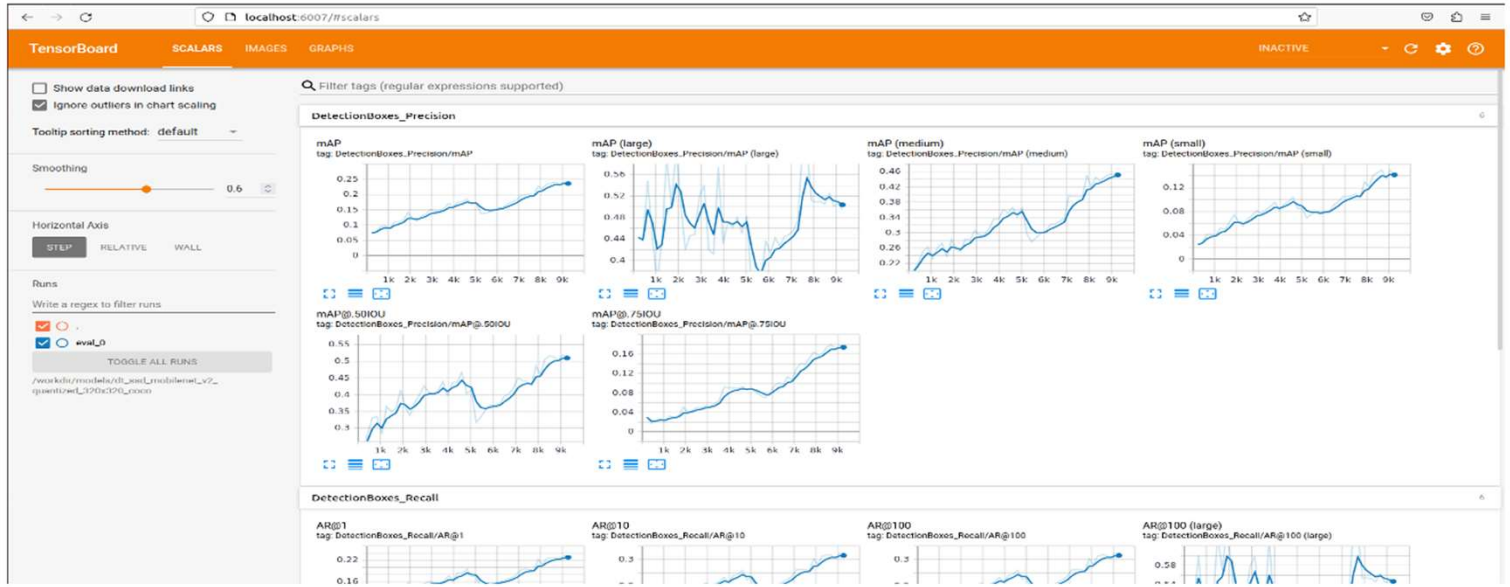


https://github.com/duckietown-ethz/proj-lfivop-ml

SSD Results: Recall



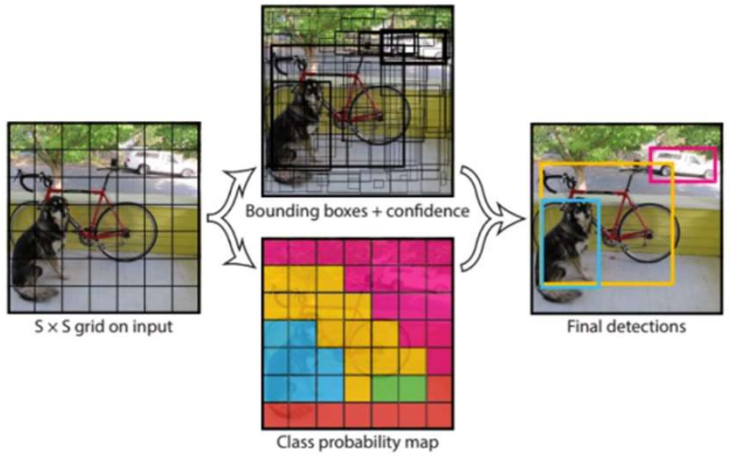
SSD Results: Precision

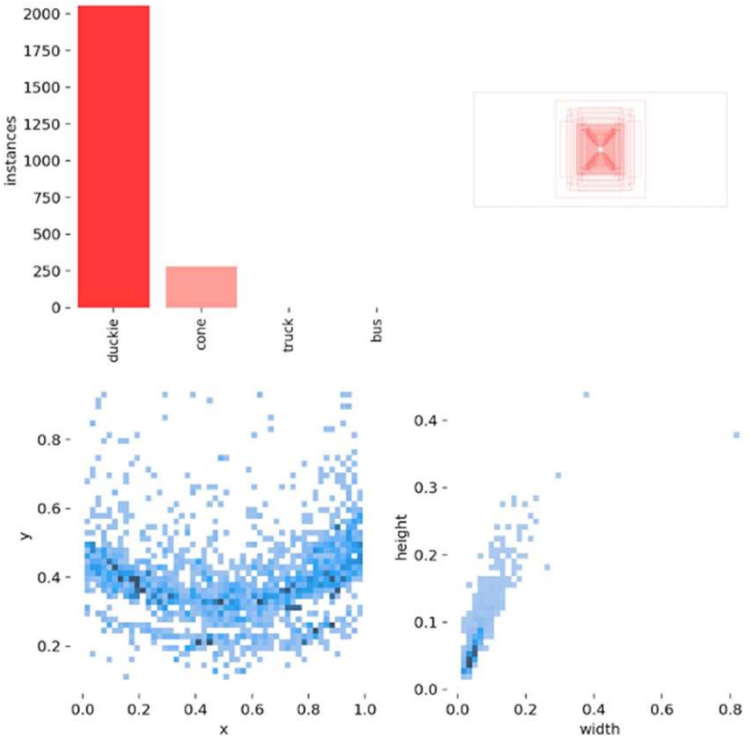


SSD Results: Loss

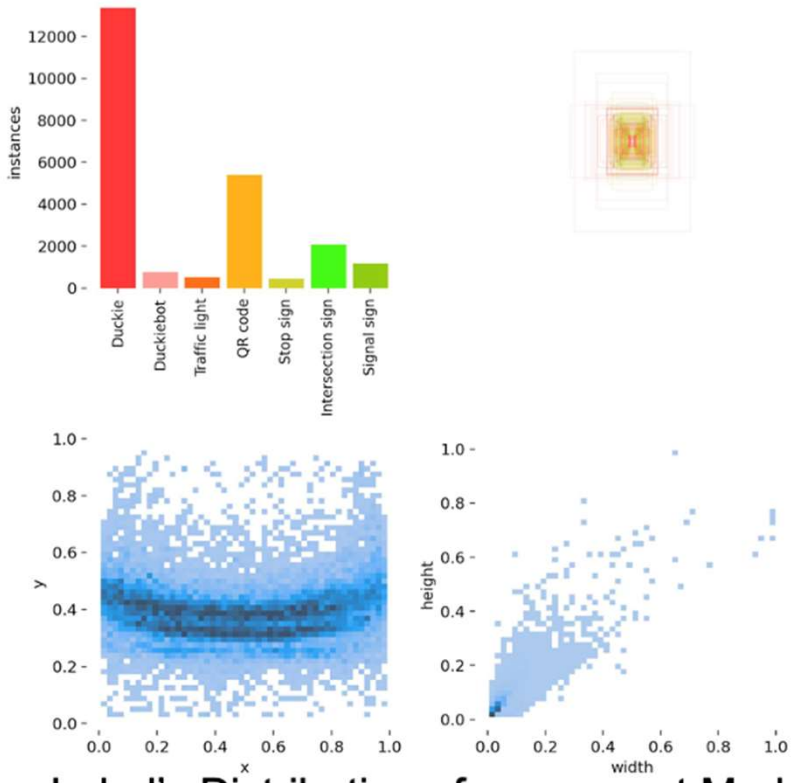
Yolo - You Only Look Once

- Started from scratch again but now using different algorithm
- Our target was to implement end to end feature
- Starting with a Baseline Model
- Transition to an Advanced Model

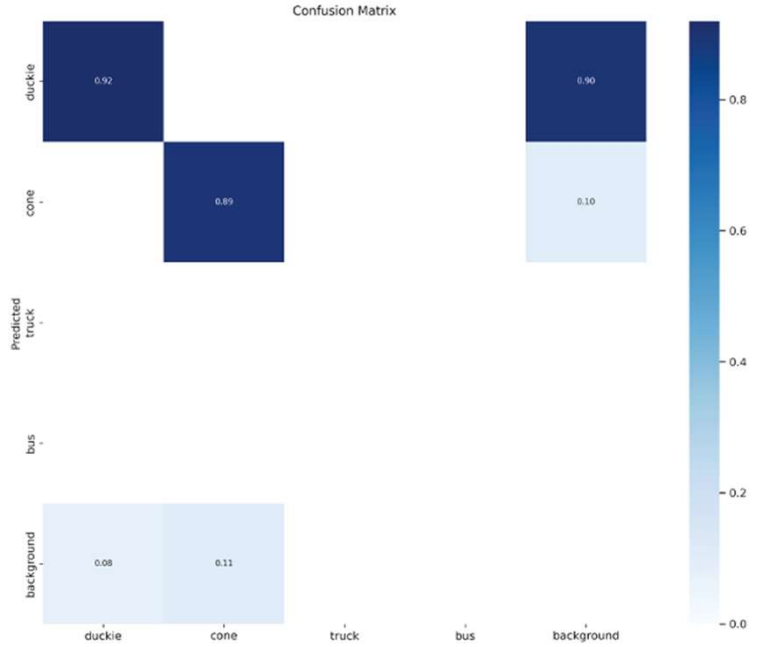




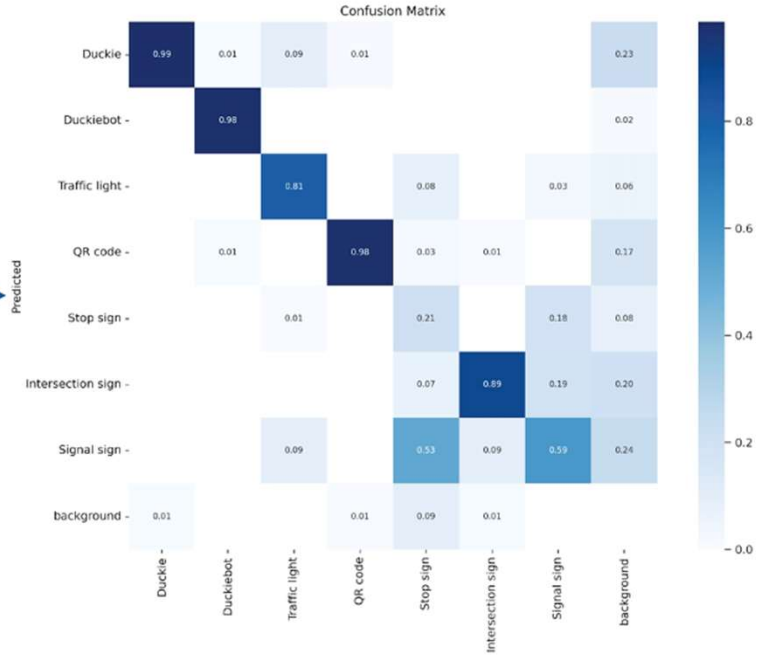
Labels' Distribution of the baseline Model



Label's Distribution of our current Model

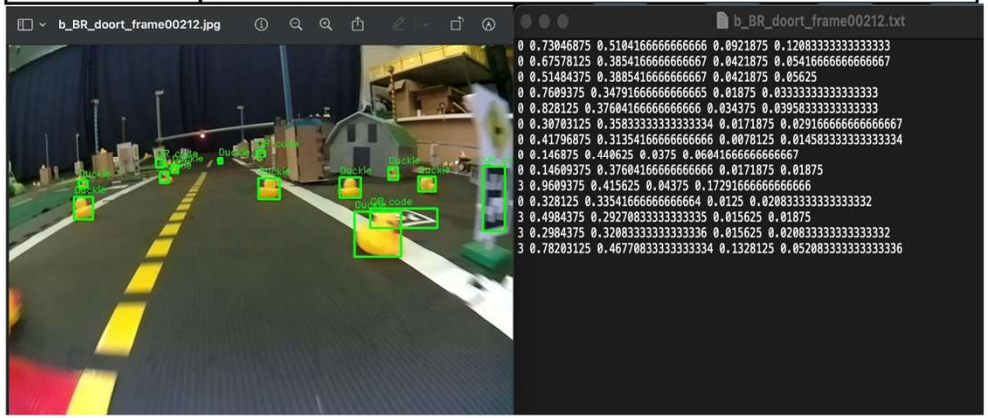


Confusion Matrix of the baseline Model



Confusion Matrix of our current Model

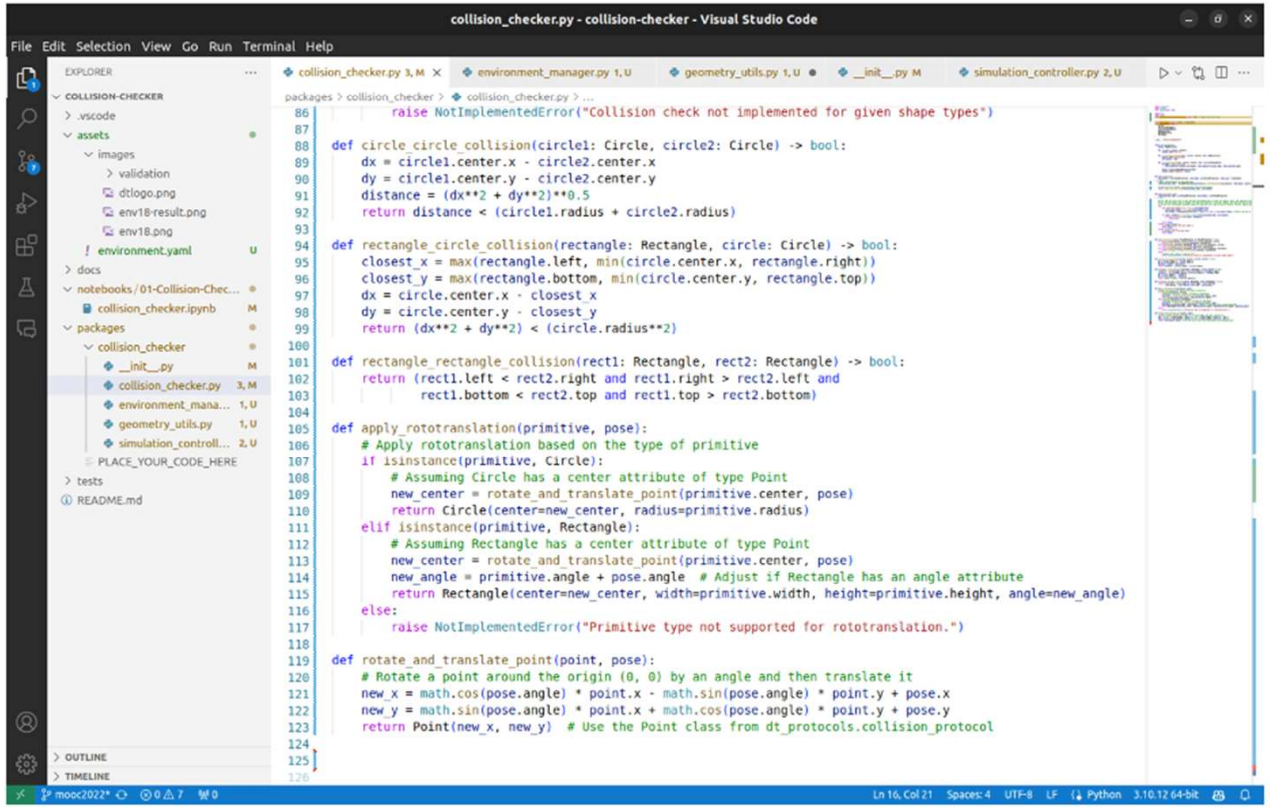
New and improved annotations



Results of our current Model

Collision-Checker

- tried to Implement Collision checker
- No map Definition
- Therefore shifted to ToF Approach



Collision-Checker

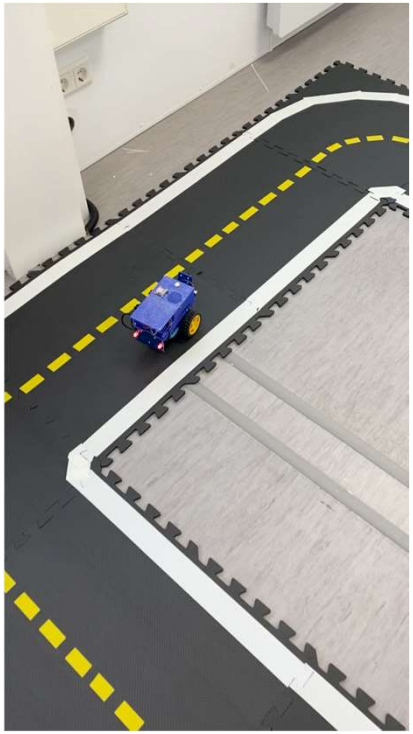
- Implemented the **publish-subscribe** pattern using **ROS Publishers** and **ROS Subscribers**
- Succeeded but sometimes not receiving incorrect data

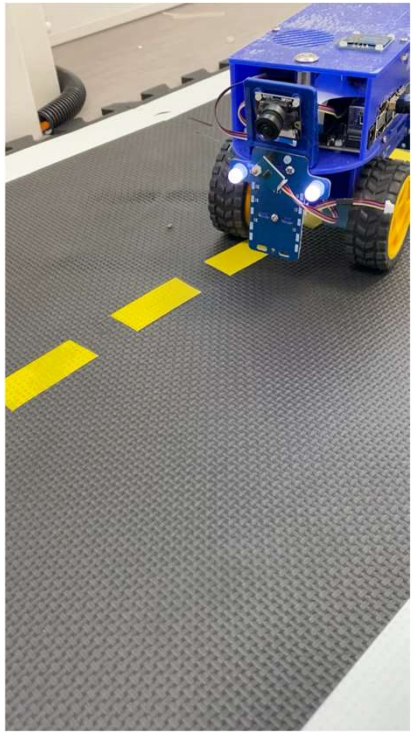
Demo video

Demo Video

Previously in

Duckietown…





Demo Video

And now in Duckietown…

Demo Video

And **now** in Duckietown…

/sapduckie/apriltag_detector_node/detections/image/compressed
/sapduckie/camera_node/image/compressed
/sapduckie/camera_node/image/raw
/sapduckie/ground_projection_node/debug/ground_projection_image/compressed
/sapduckie/lane_filter_node/belief_img
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/sapduckie/line_detector_node/debug/maps/compressed
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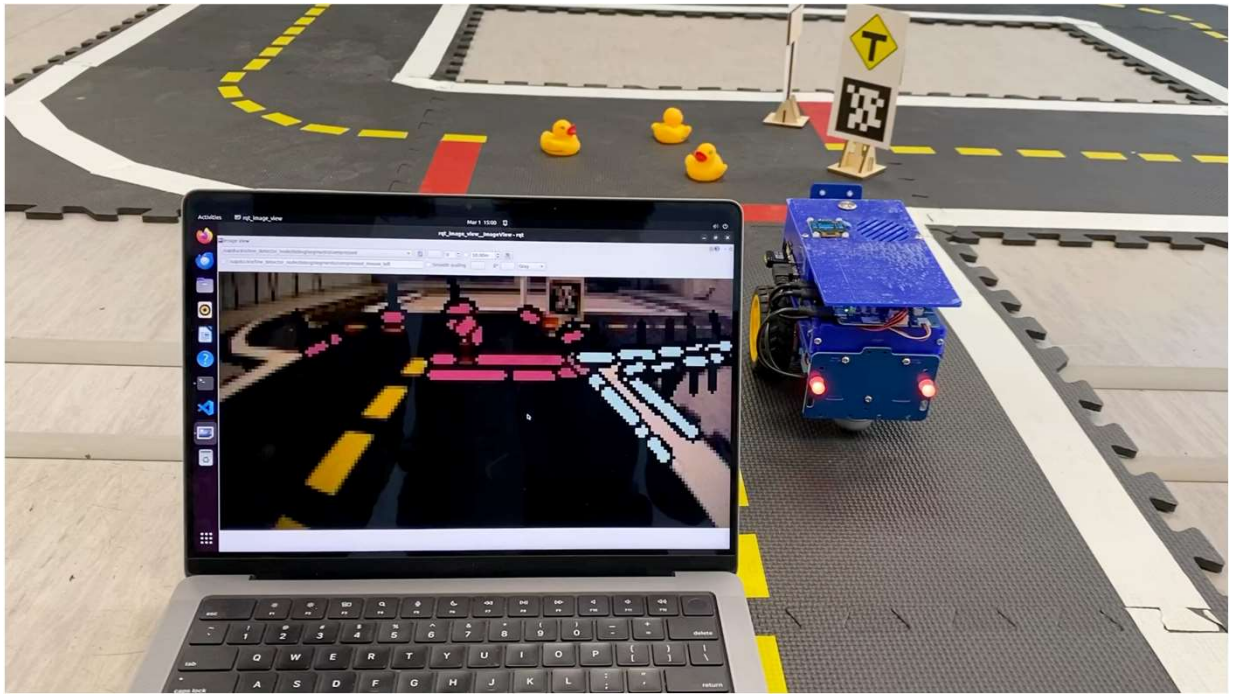
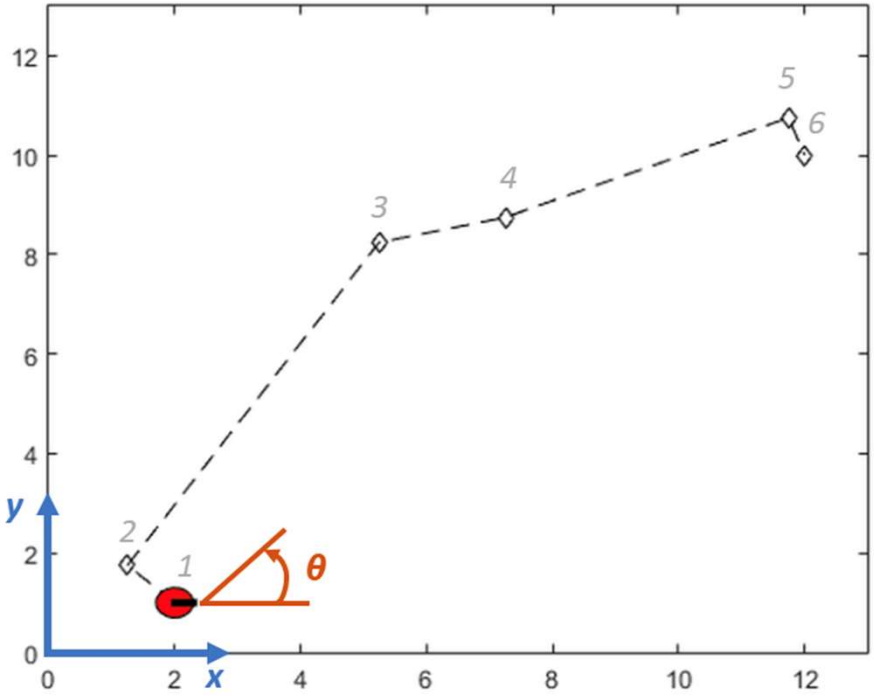


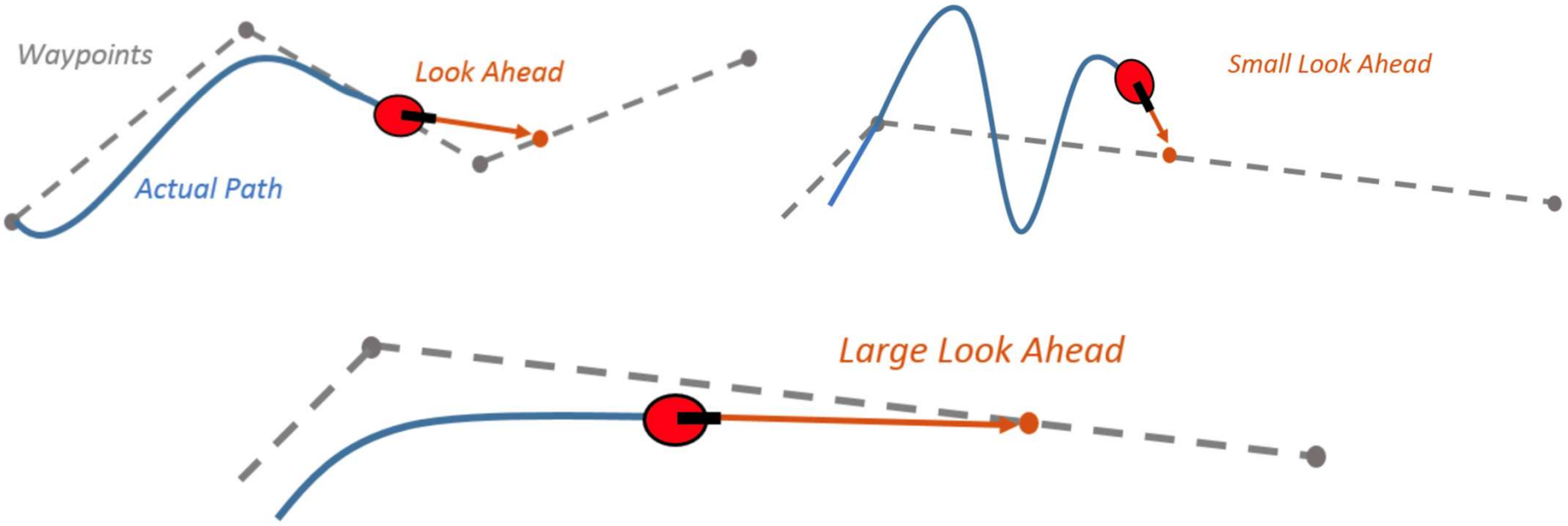
Lane Following

Lane Following

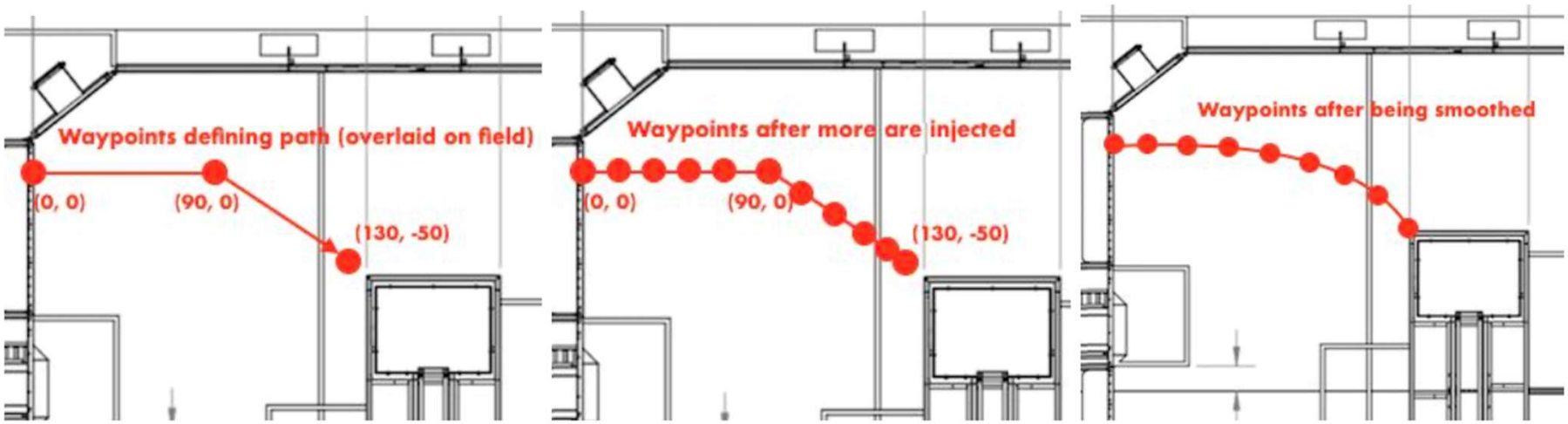
- Pure Pursuit Algorithm
- General purpose tracking algorithm



Lane Following



Lane Following



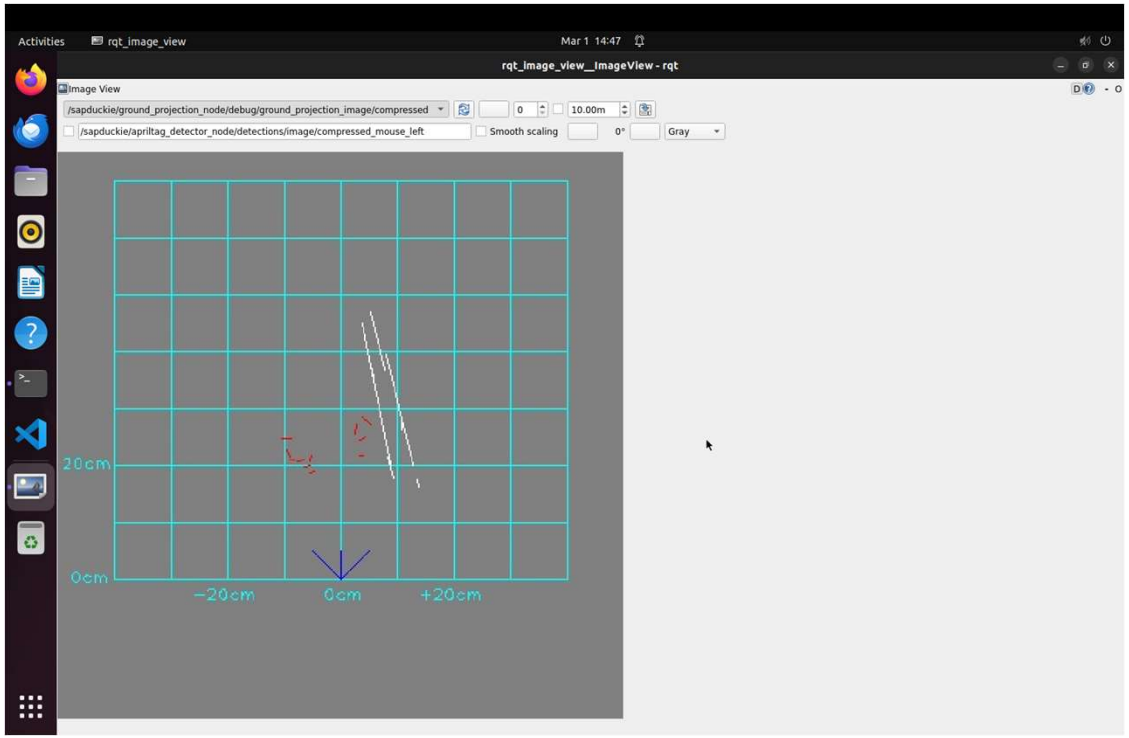
Lane Following

Modification in Pure Pursuit Algorithm:

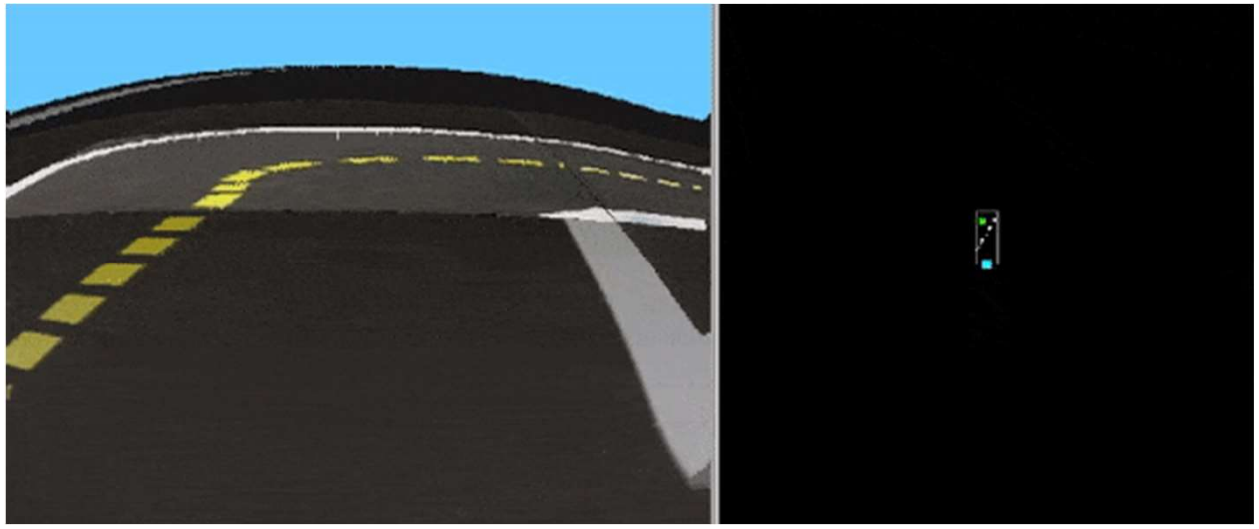
- Yellow lane points to the right
- If yellow lane not visible then offset ground-projected white lane to the left
- We than take average of this offset

Lane Edge Detection

Ground Projection



Lane Following



Lane Following

Modification in Pure Pursuit Algorithm:

- Varying speeds and Omega gains
- Gradual speed-up occurs on straight paths
- Slows down at turns for smoother turns

Lane Following

Modification in Pure Pursuit Algorithm:

- Modified Lane Filter
  - At each update step, we calculate the time elapsed since the last update.
  - Dynamically scale the variance of the Gaussian used for smoothing
  - Adaptive Scaling

Lane Following

Limitation:

- The controller cannot exactly follow direct paths between waypoints
- Parameters must be tuned to optimize the performance and to converge to the path over time.
- This pure pursuit algorithm does not stabilize the robot at a point.
- In our application, a distance threshold for a goal location should be applied to stop the robot near the desired goal.

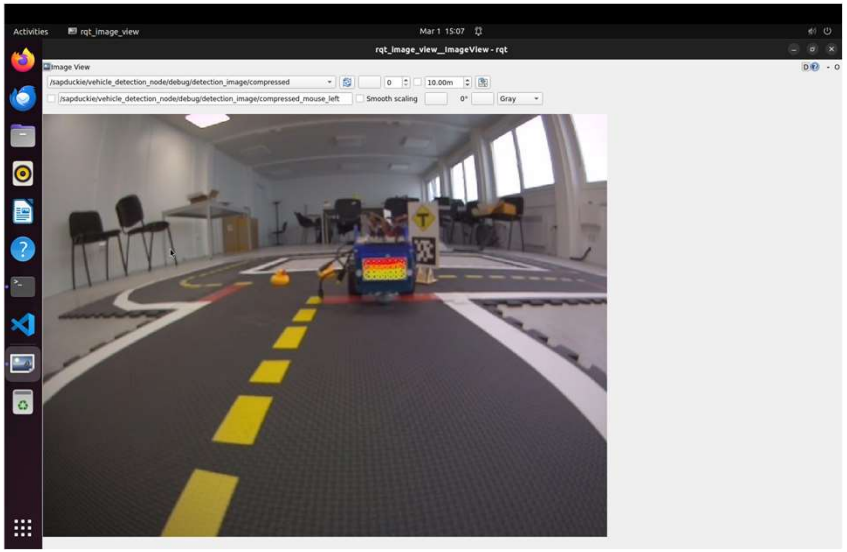
Stop Line Detection

Stop Line Detection

- Identifying the colour coordinates of the line ahead of the camera,
- If we see red line, then we should stop at the safe distance.
- Stop is really import for car to take time to determine turns.

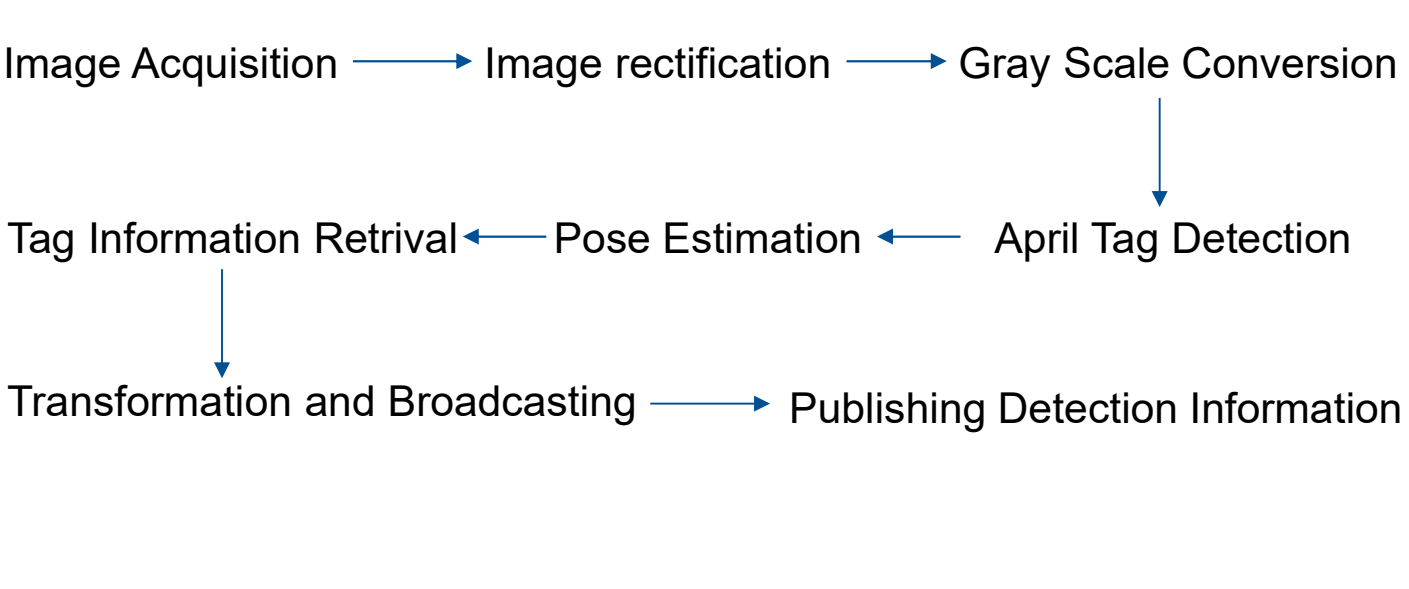
Obstacle-Vehicle Detection

- Similarly, we need to stop when we have a bot Infront of us to avoid colliding with that, so bot detection is also very crucial for that.

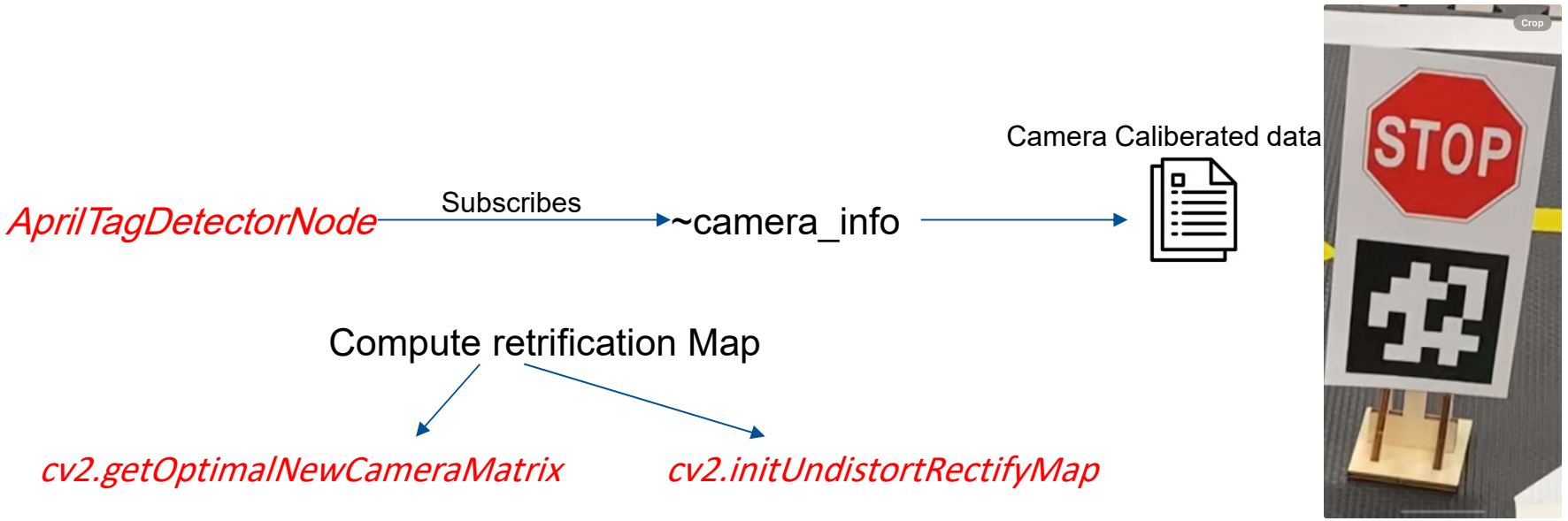


April - Tags

How April Tag works?



How April Tag works?



How April Tag works?

Image Acquisition → Image rectification → Gray Scale Conversion

↓

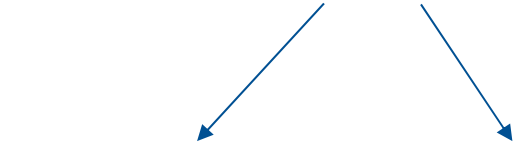
April Tag Detection → Pose Estimation → Tag Information Retrival

↓

Transformation and Broadcasting → Publishing Detection Information

How April Tag works?

April Tag Detection Algorithm



Edge detection Quad Extraction

How April Tag works?

Image Acquisition → Image rectification → Gray Scale Conversion

↓

April Tag Detection → Pose Estimation → Tag Information Retrival

↓

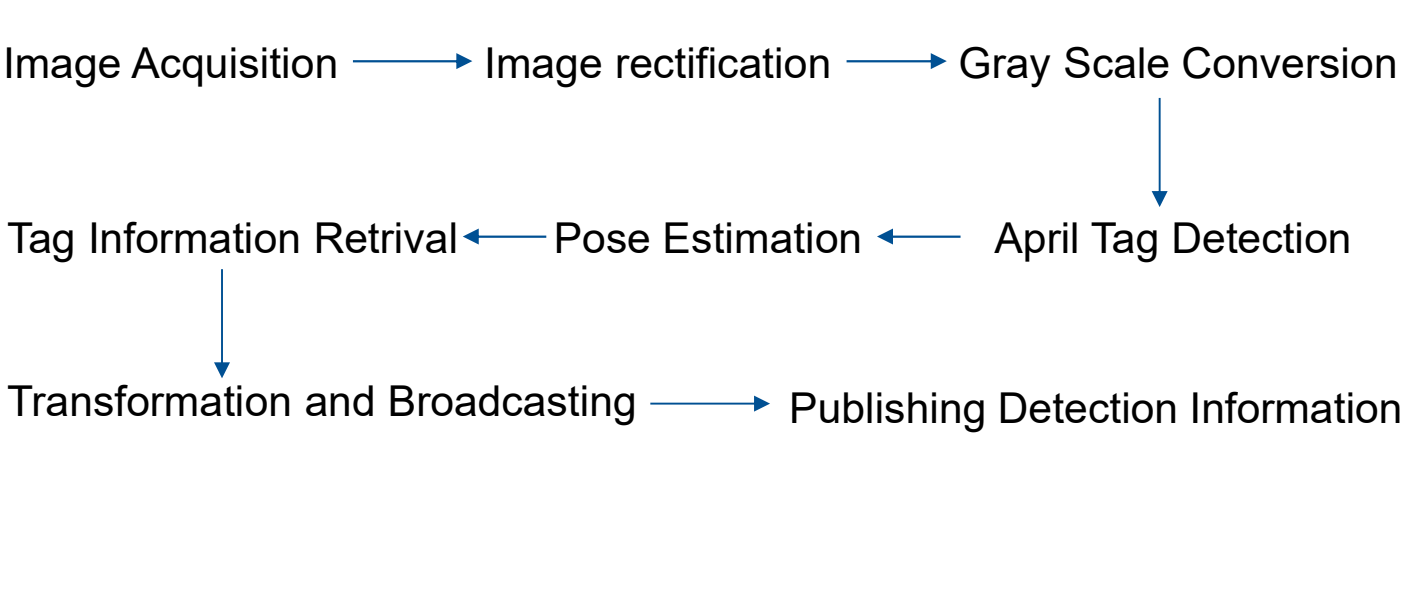
Transformation and Broadcasting → Publishing Detection Information

How April Tag works?

AprilPostPros matches 

Metadata about each tag

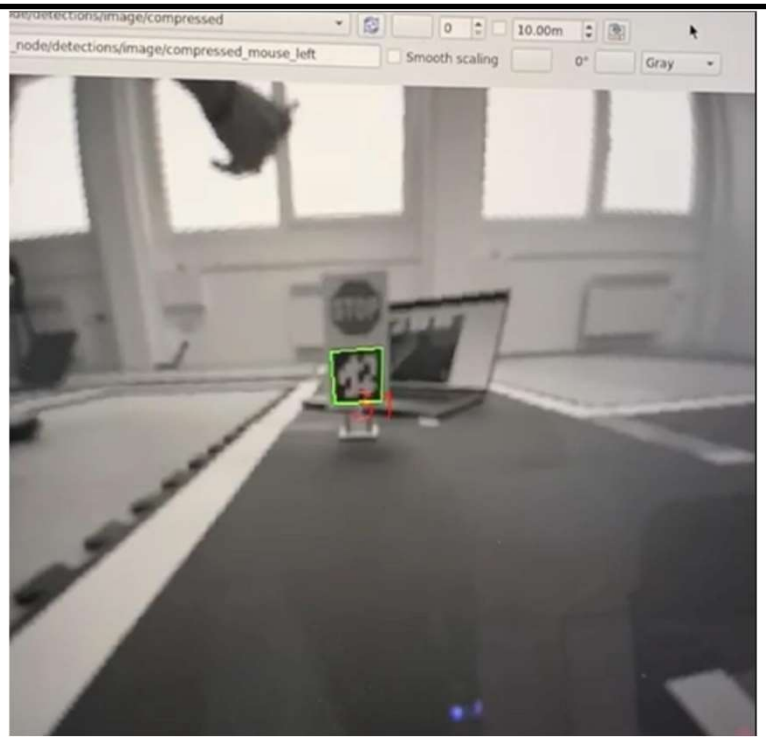
How April Tag works?



Intersection Navigation

Intersection Detection

- April Tags
- April Tags IDs
  - 0 for Left
  - 1 for Straight
  - 2 for Right

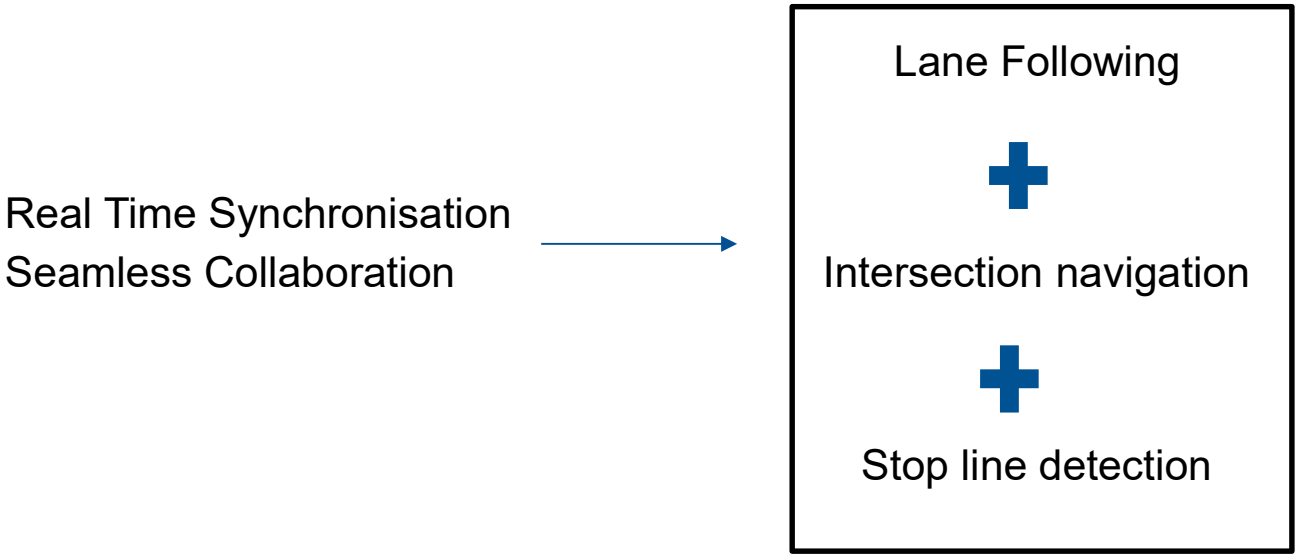


Intersection Detection

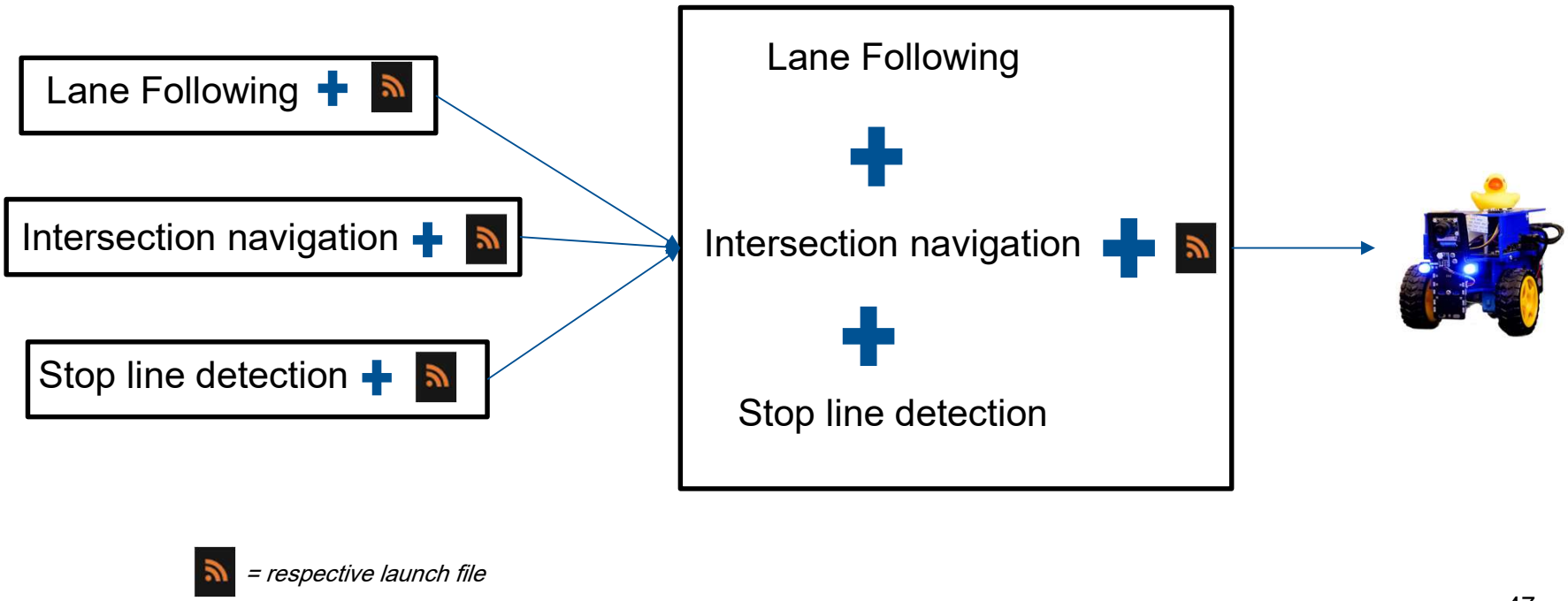
Harmonizing all the modules

Harmonizing all the modules

Real Time Synchronisation
Seamless Collaboration



Harmonizing all the modules



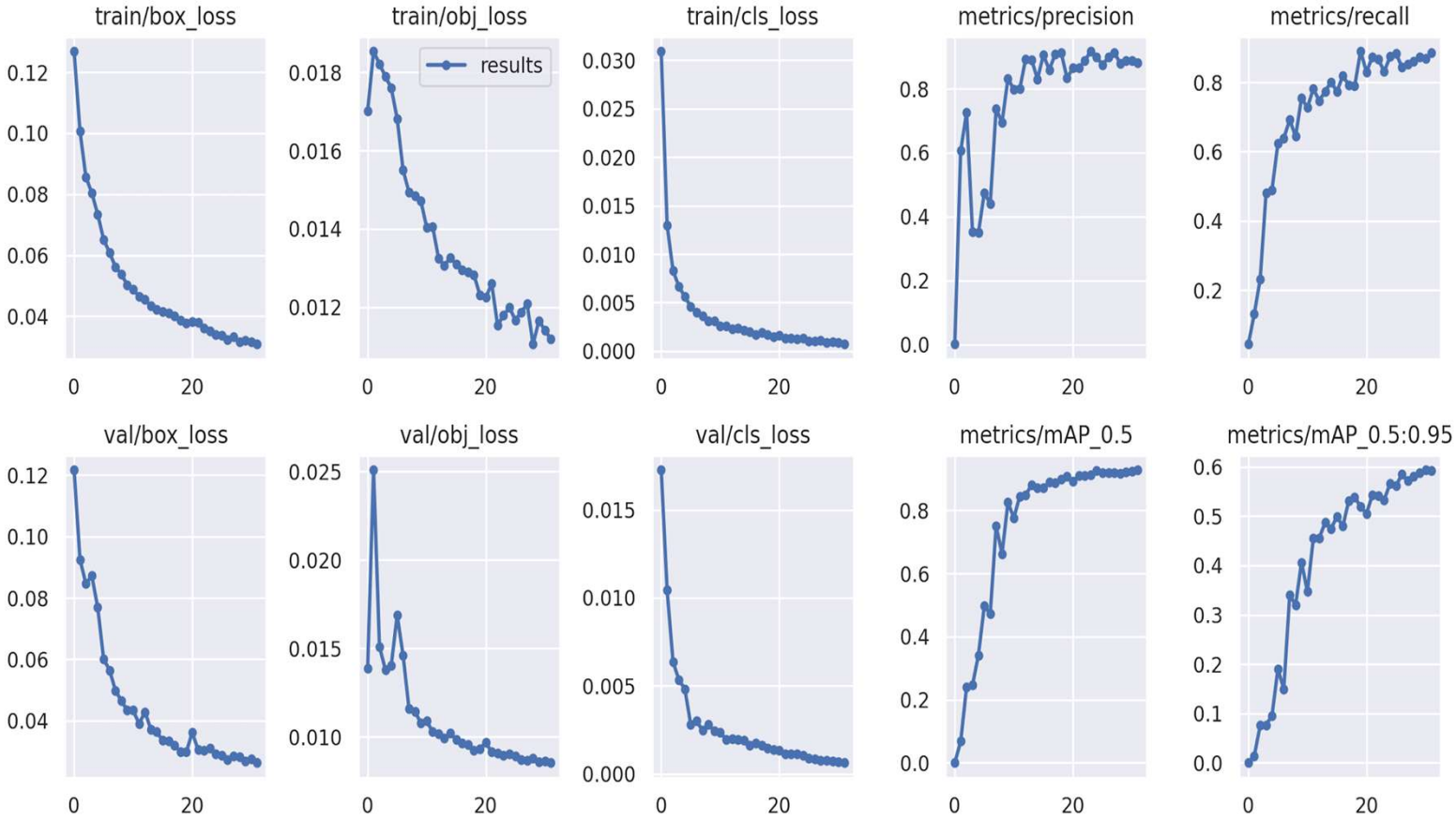
Observations

Observation

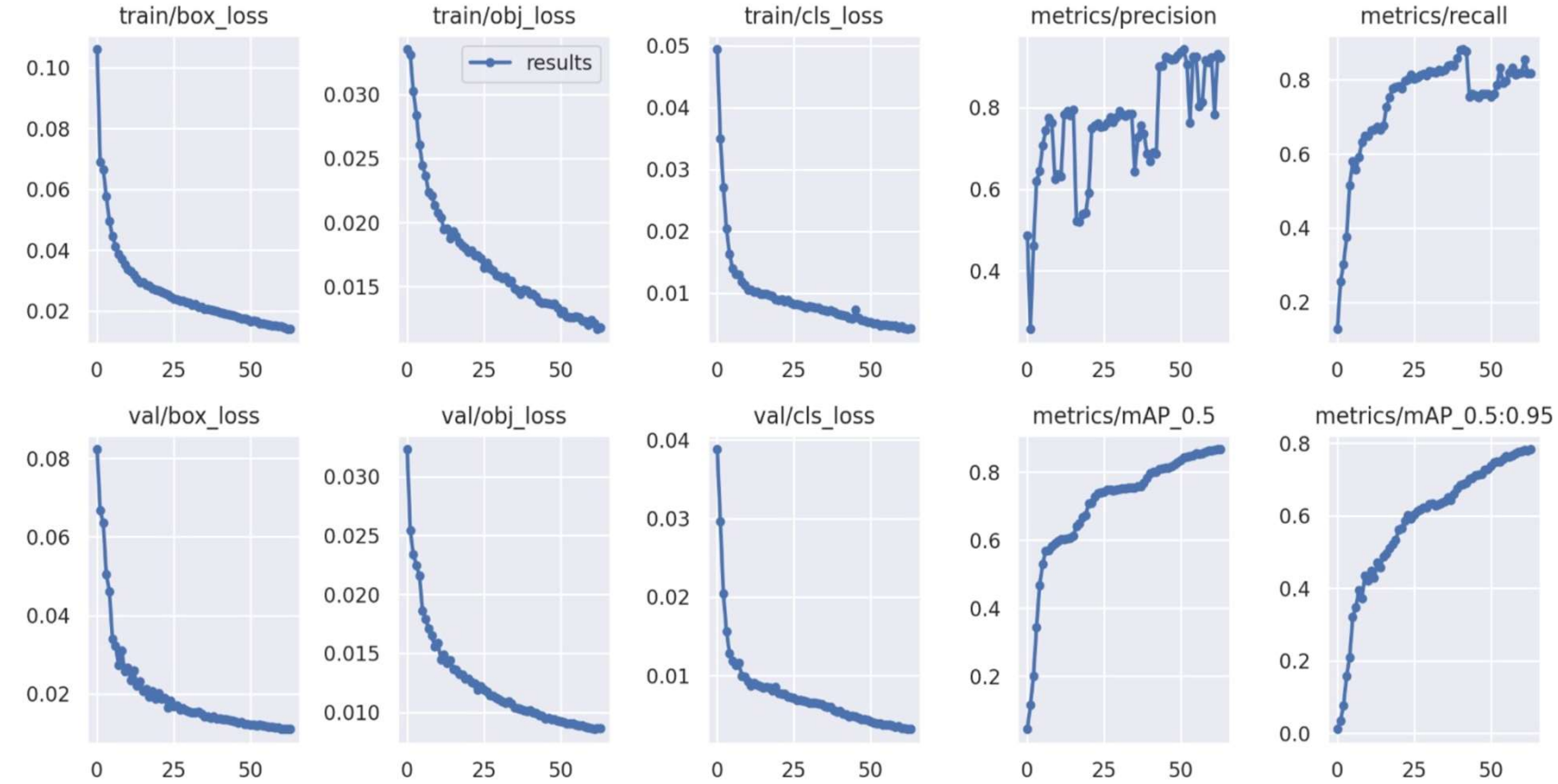
- When running all the modules togather, we hit the maximum CPU usage.
- After we tried a lot of things, memory usage of the bot was over 90%.
- We could not utilize GPU capacity of the Jetson.
- Lidar sensor we wanted to use didn’t had proper port to connect.

Thank You

Back-up Slides



Results of our baseline Model



Results of our current Model

```
Validating runs/train/exp/weights/best.pt...
Fusing layers...
YOLOv5n summary: 157 layers, 1768636 parameters, 0 gradients, 4.2 GFLOPs
                 Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 11/11
                   all        641       5912      0.924      0.818      0.867      0.783
                Duckie        641       3318      0.971      0.978      0.993      0.885
             Duckiebot        641        193      0.979      0.995      0.995       0.96
         Traffic light        641        140      0.953      0.957      0.983      0.831
               QR code        641       1353      0.975      0.988      0.993      0.897
             Stop sign        641        112      0.975     0.0357      0.303      0.275
     Intersection sign        641        503      0.886      0.974      0.981       0.89
           Signal sign        641        293      0.726      0.797      0.819      0.743
Results saved to runs/train/exp
```

Collision-Checker

- Implemented the publish-subscribe pattern using **ROS Publishers** and **ROS Subscribers**
- Succeeded but sometimes not receiving incorrect data

Future Plans

- Quickly finish basic functionalities such as:
- State Estimation and localization
- Planning and Control
- Agent
- Research and implementation of our final goal from next year.

References

- https://www.mathworks.com/help/nav/ug/pure-pursuit-controller.html