VISION-BASED NAVIGATION

TEAM A3

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PROJECT MISSION

Allow F1Tenth Car to Detect and React to Traffic Signs

Car detects:

- STOP and Yield Signs
  - Slow down and stop
- Speed Limits
  - Adjust driving speed
- U - Turn Sign
  - Turn around

Small set of sign detection and reactions
→ Proof of concept
→ More additions for future

PROPOSED SOLUTION

Perception

- Train YOLO11s model on RGB images
- Depth map fusion to compute average distance to sign

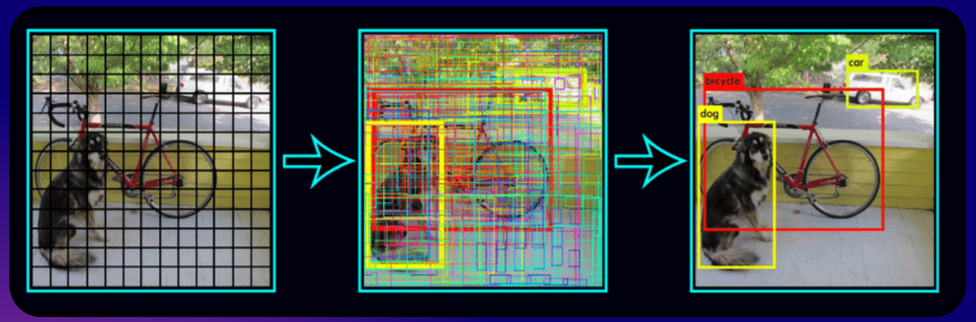
Decision

- Object timers: estimate time-to-reach
  = (distance – threshold) / avg_speed
- When timer expires → trigger sign action
- Cooldown periods for each action

Control

- LiDAR-based gap-following as default
- Sign detected → jump to U-Turn state machine, change speed, etc.

YOLO MODEL TRAINING



Architecture: custom-trained YOLO11s model

Data: ~500 labeled images per class (Stop, Yield, U-Turn, 20 kph, 100 kph)

Training: 100 epochs, batch = 16, lr = 1e-3

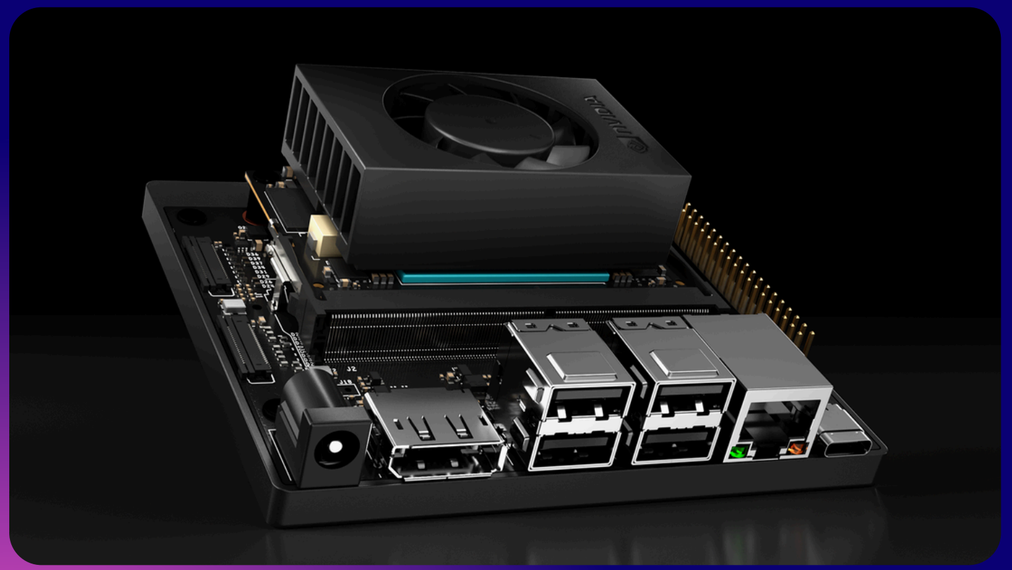
Inference pipeline:

- Acquire RGB frame via ROS Image topic
- Run model(rgb) on GPU (Jetson CUDA)
- Filter by confidence ≥ 0.7
  → get boxes & class IDs

Typical 70% to 90% confidence

Most confusion between 100 and 20 speed limit signs

NVIDIA ENVIRONMENT



Requirements and Set Up

In virtual environment, install:

- JetPack 5.1.4
- CUDA 11.4
- Python 3.8

Install correct version frameworks:

- PyTorch
- TorchVision
- Onnx

Finally, install the following:

- Ultralytics
- Onnx
- Onnxslim

MAKING CAR REACTIVE

LiDAR gap-following

- Truncate → filter → smooth ranges
- Safety bubble around nearest obstacle
- PID-steer toward largest gap center

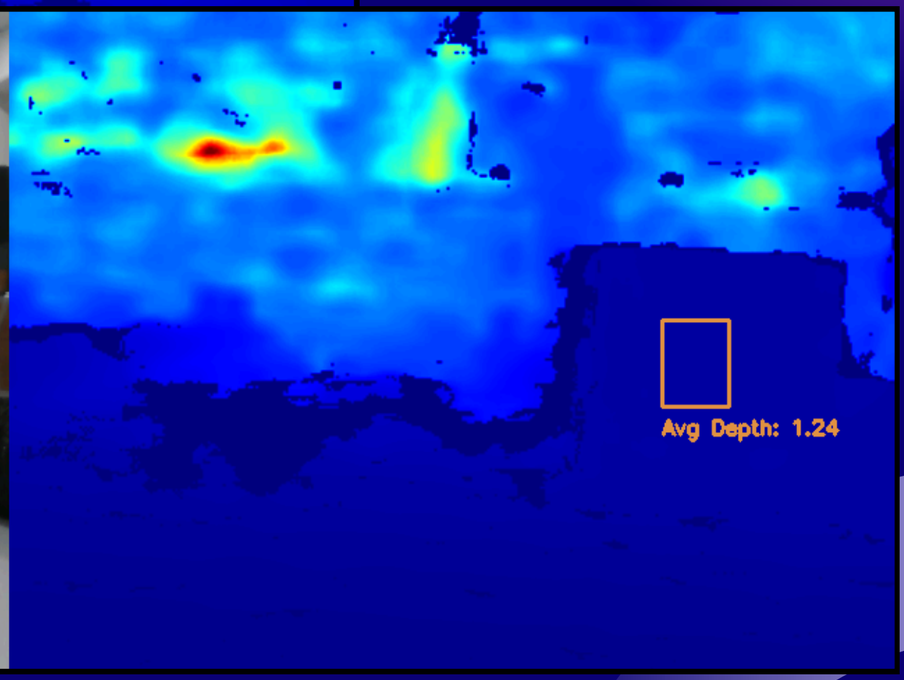
Sign-to-action bridge

- On detection: compute time-to-reach, store in object_timer_end[label]
- Periodic check → when expired, call trigger_object_action(label)

Actions implemented

- Stop: full brake + 3 second pause
- Yield: placeholder / slow-down behavior
- Limit-20/100: adjust relative speed
- U-Turn: launch U-Turn state machine

What does the car see?



Traffic sign type and average distance from sign

DEMO

https://drive.google.com/file/d/164ozK4v_fZUlWy7NwilK1Sc-7xdN4c9e/view?usp=sharing

FUTURE REVISIONS

Detection System

- Expand dataset (rain/low-light), add semantic segmentation
- Temporal smoothing of detections

Navigation Control

- Adaptive speed via MPC (model predictive control)
- Adaptive cooldown periods based on car speed and other factors
- Fuse IMU for more robust yaw estimation

Software

- ROS-nav stack integration for global path planning
- Real-time logging & playback (ROS bags + metrics dashboard)

THANKS FOR LISTENING!

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