JETRACER SOCCER LEAGUE

LOCKHEED MARTIN

Objectives

- Design and construct JetRacer cars to compete in autonomous 2v2 soccer.
- Incorporate a new sensor suite to enhance car capabilities and situational awareness.
- Demonstrate the ability to score goals by dribbling and striking the ball in a controlled trajectory.
- Enable cooperation with allies to score goals and oppose foes trying to score.

JetRacer Hardware

- Jetson Orin Nano Developer Kit
  - 8 GB DDR5
  - 40 TOPS
  - 1.5GHz
- ZED2 Stereo AI Camera
  - 120° Wide-Angle FOV
  - Neural Depth/Spatial Object Sensing
  - Built-in IMU
- Tamiya TT-02 RC Chassis Kit
  - Mabuchi RS-540 Brushed Motor
  - Futaba S3004 Servo
  - 7V 3000mAh NiCd Battery Pack
  - RS304 Receiver
  - T3PV FM Controller
- PCA9685 Adafruit 16-Channel I2C Servo Driver
- Pololu 4-Channel RC Servo Multiplexer
- Miuzei 25kg High Torque Servo
- Anker Nano 10,000mAh Portable Charger

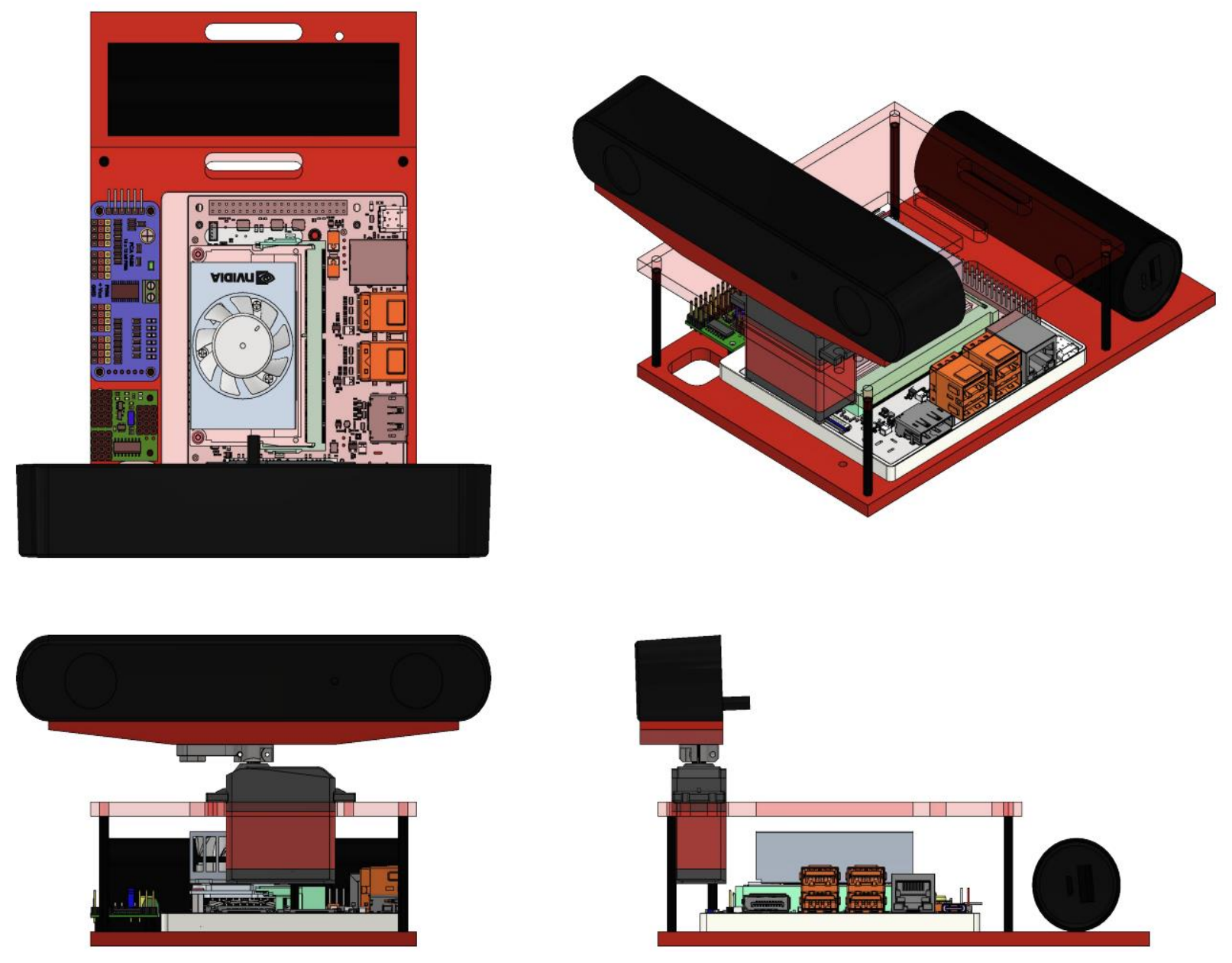

Fig 1. Hardware CAD

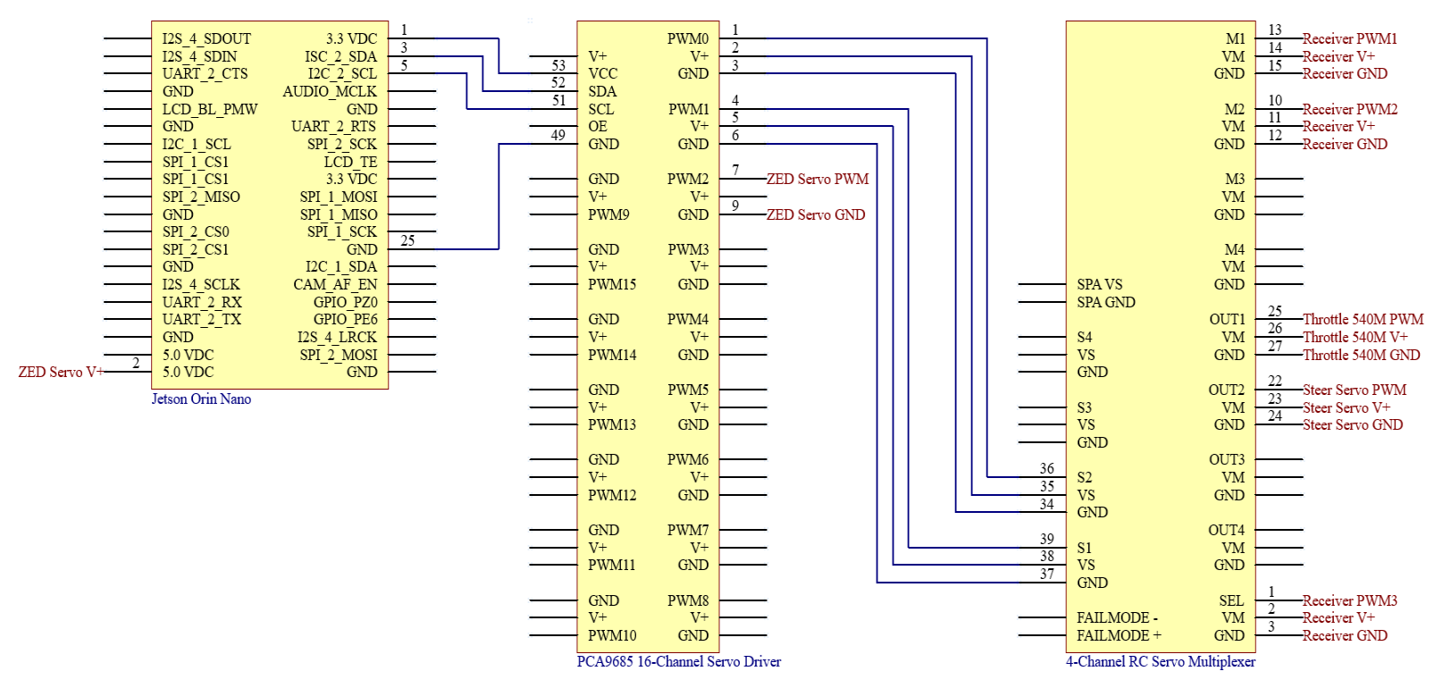

Fig 2. Wiring Diagram

ROS Integration

- Streamlined communication between distinct hardware and software processes using a ROS Noetic environment.
- The top-level JetRacer package uses the ZED2 ROS wrapper for object detection to determine strategy.

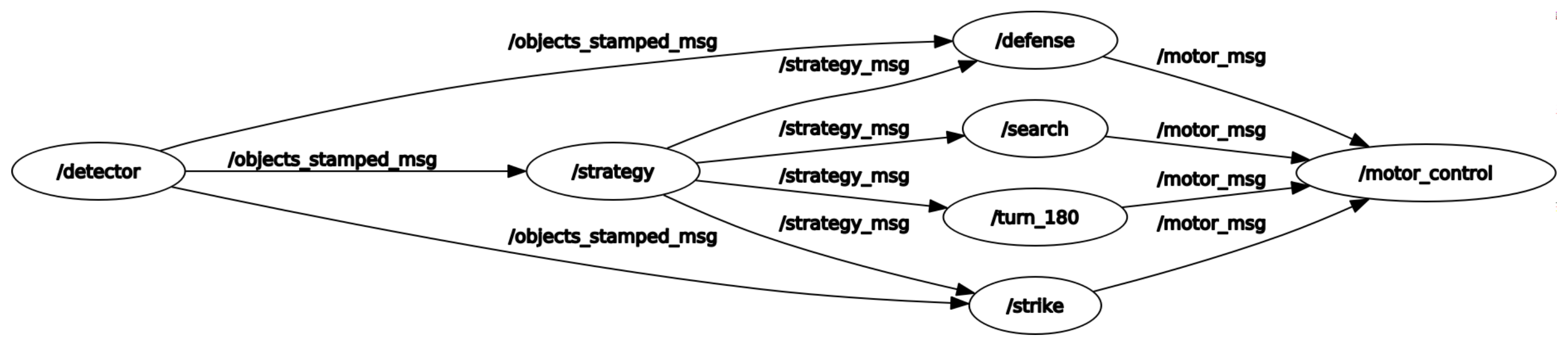

Fig 3. JetRacer Package RQT Visualization

Object Detection

- Roboflow computer vision software used to create image dataset.
  - Annotated over 1000 images of cars, ball, goals, and crosses for dataset.
- YOLO object detection algorithm allows for smooth integration with ZED2 and ROS.
  - Utilized YOLOv8 model to improve both detection accuracy and inference speed.
- Increased confidence rates of object detection by +20% compared to last year.
- Achieves 30 FPS detection for 720p HD video stream.

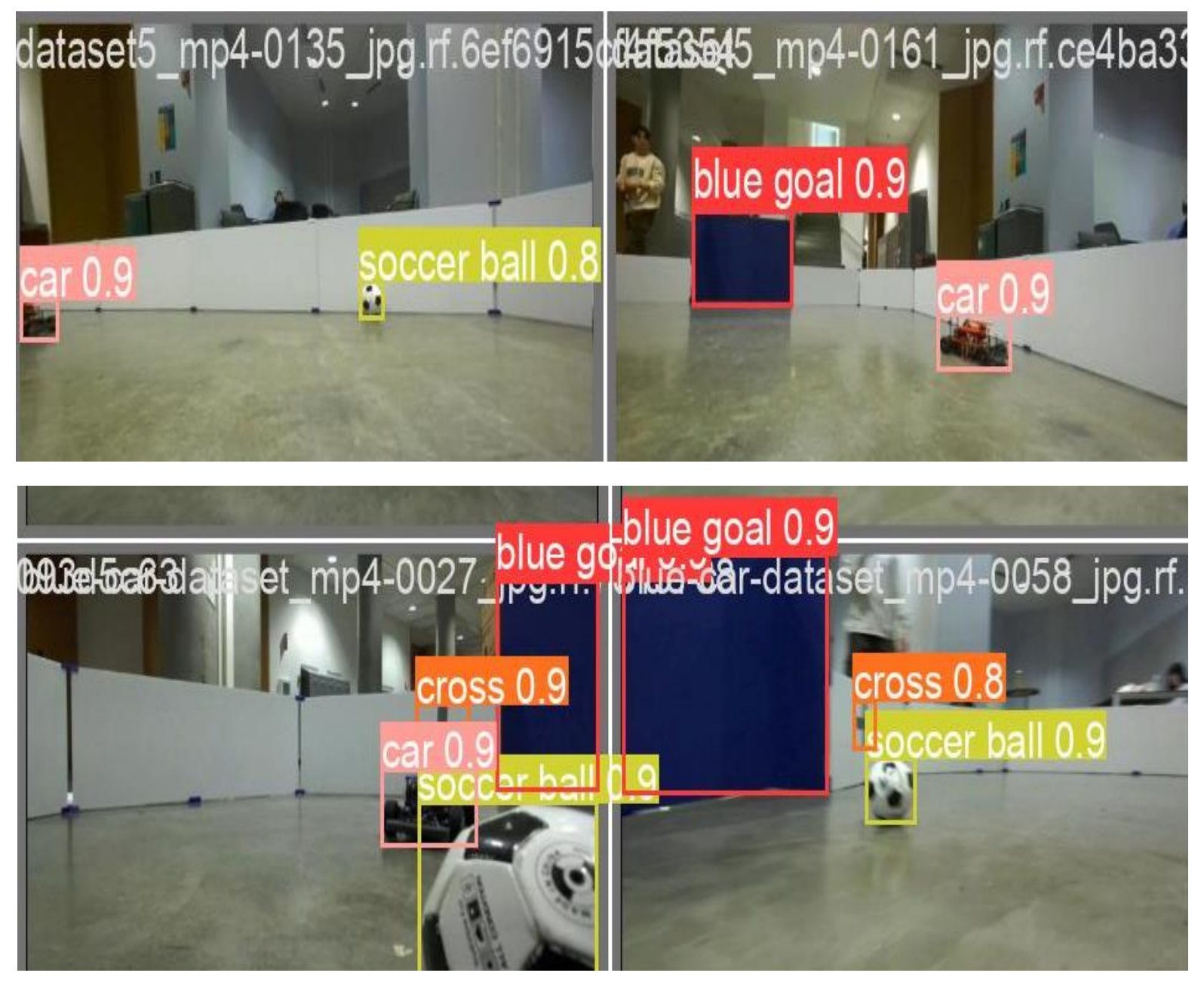

Fig 4. Object Detection Validation Dataset

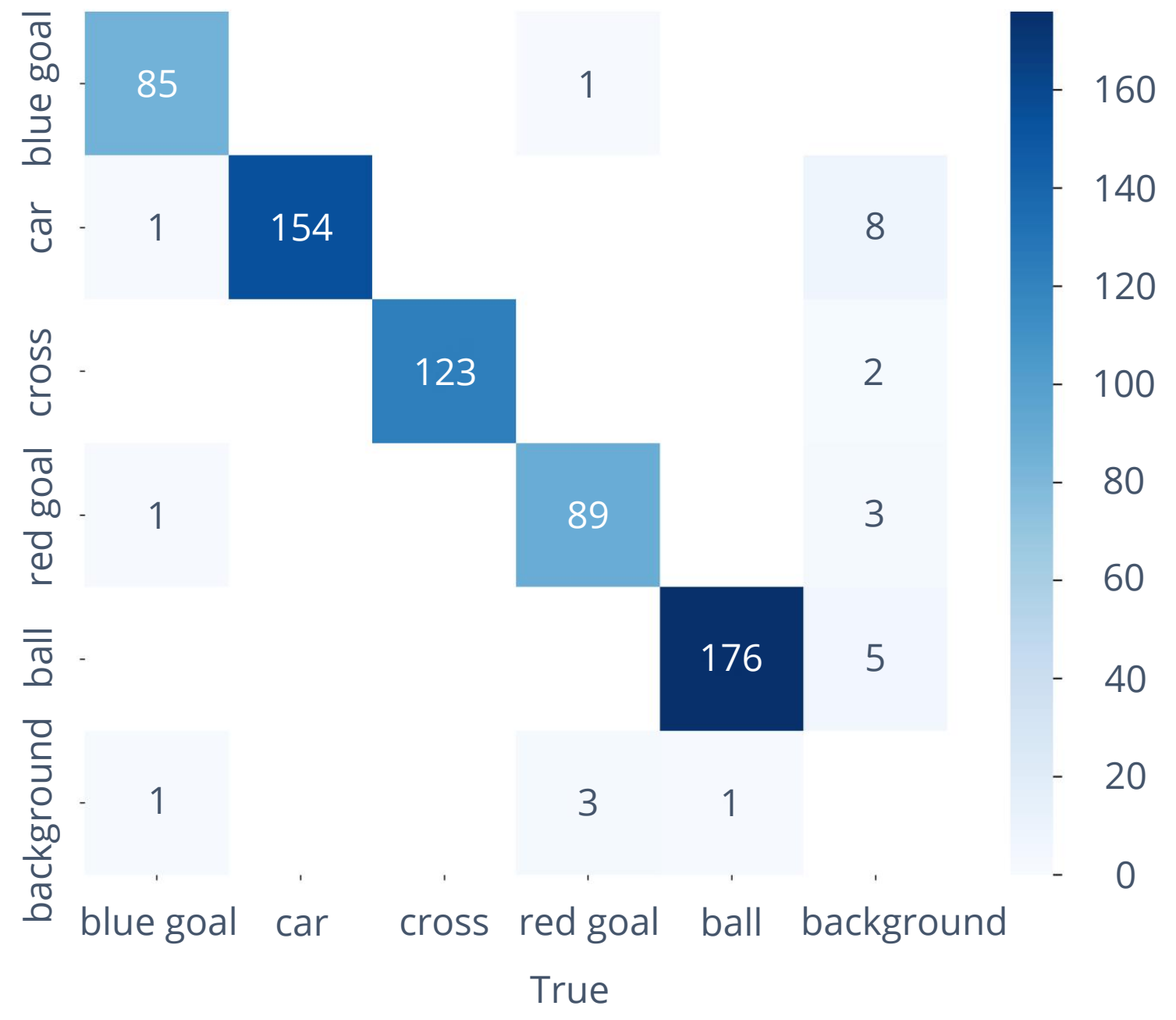

Fig 5. Confusion Matrix of Test Data

Depth Sensing & Positional Tracking

- Overlays detected objects bounding boxes over 3D point cloud for accurate object depth estimation and positional tracking.
- Achieves a median error of 0.914% for depth measurements less than 5m.

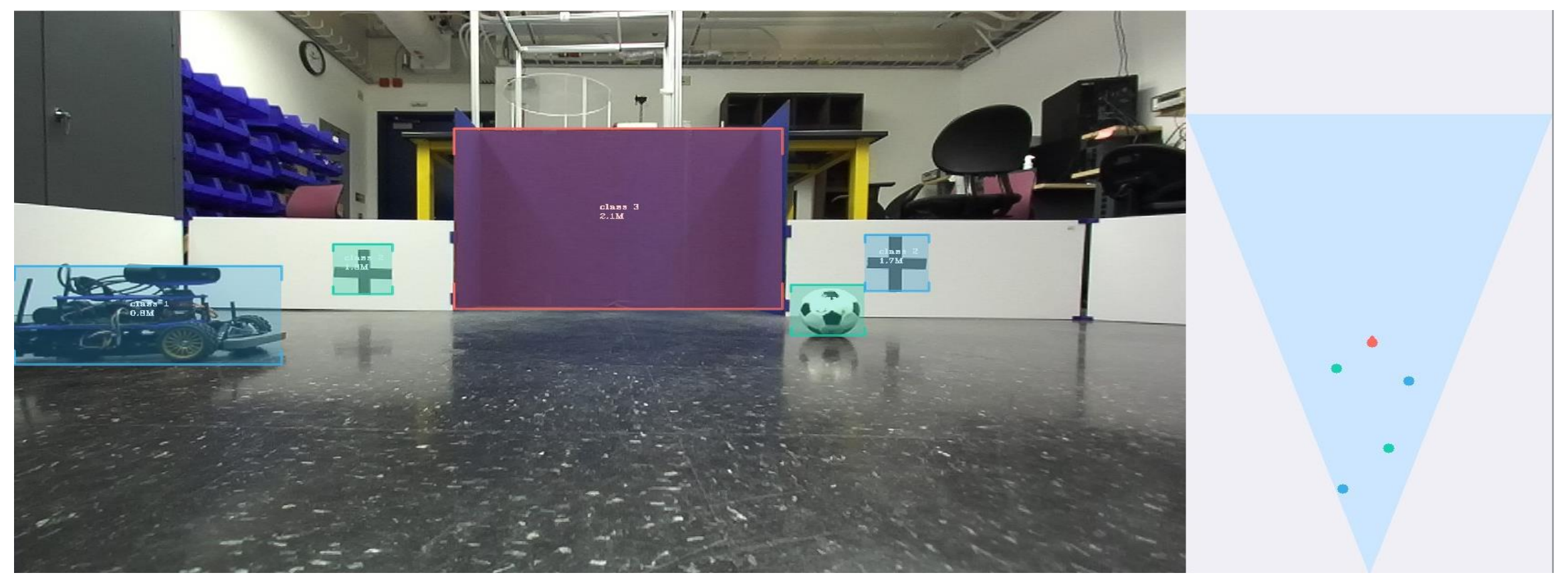

Fig 6. Positional Tracking

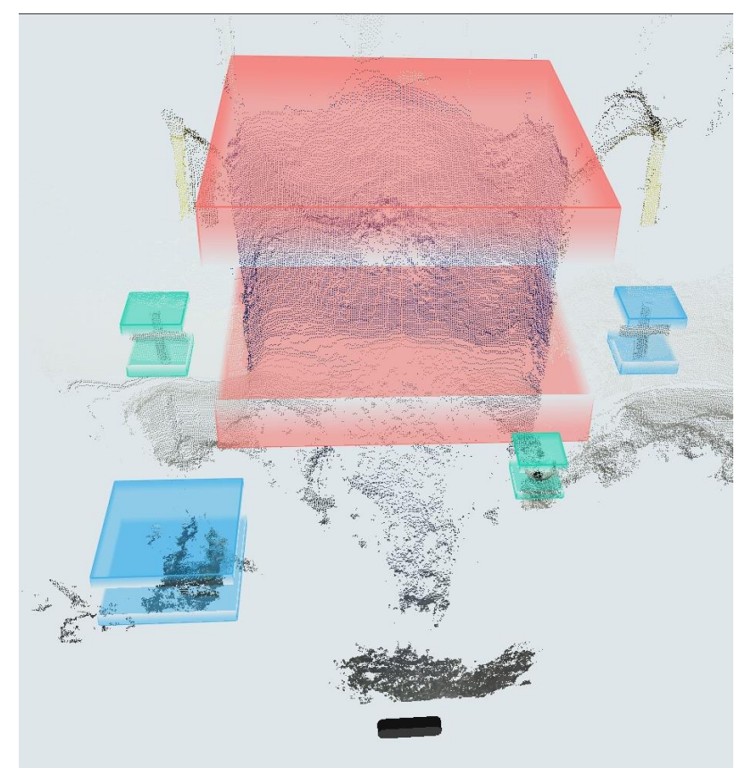

Fig 7. 3D Point Cloud of Detected Objects

Field Design

- Constructed a brand new 20' x 15' soccer arena.
- Red and blue colored goals for object detection.
- Assembled using 3D printed brackets and foam board.
- Included cross symbols on the walls to assist with offensive and defensive soccer strategy.
- Match played with a size 1.5 black and white soccer ball.

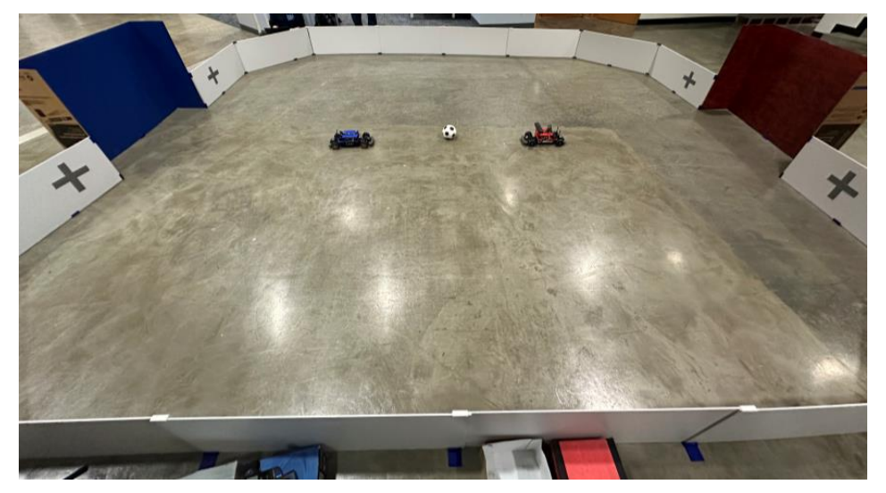

Fig 8. JetRacer Soccer Field

Soccer Strategy

- The Strategy node allows for simple node switching based on the environmental situation.
- The FSM within the Strategy node transitions states based on detected objects and position, triggering or stopping individual movement nodes.
- Each movement node uses CV information to determine proper trajectory and speed.

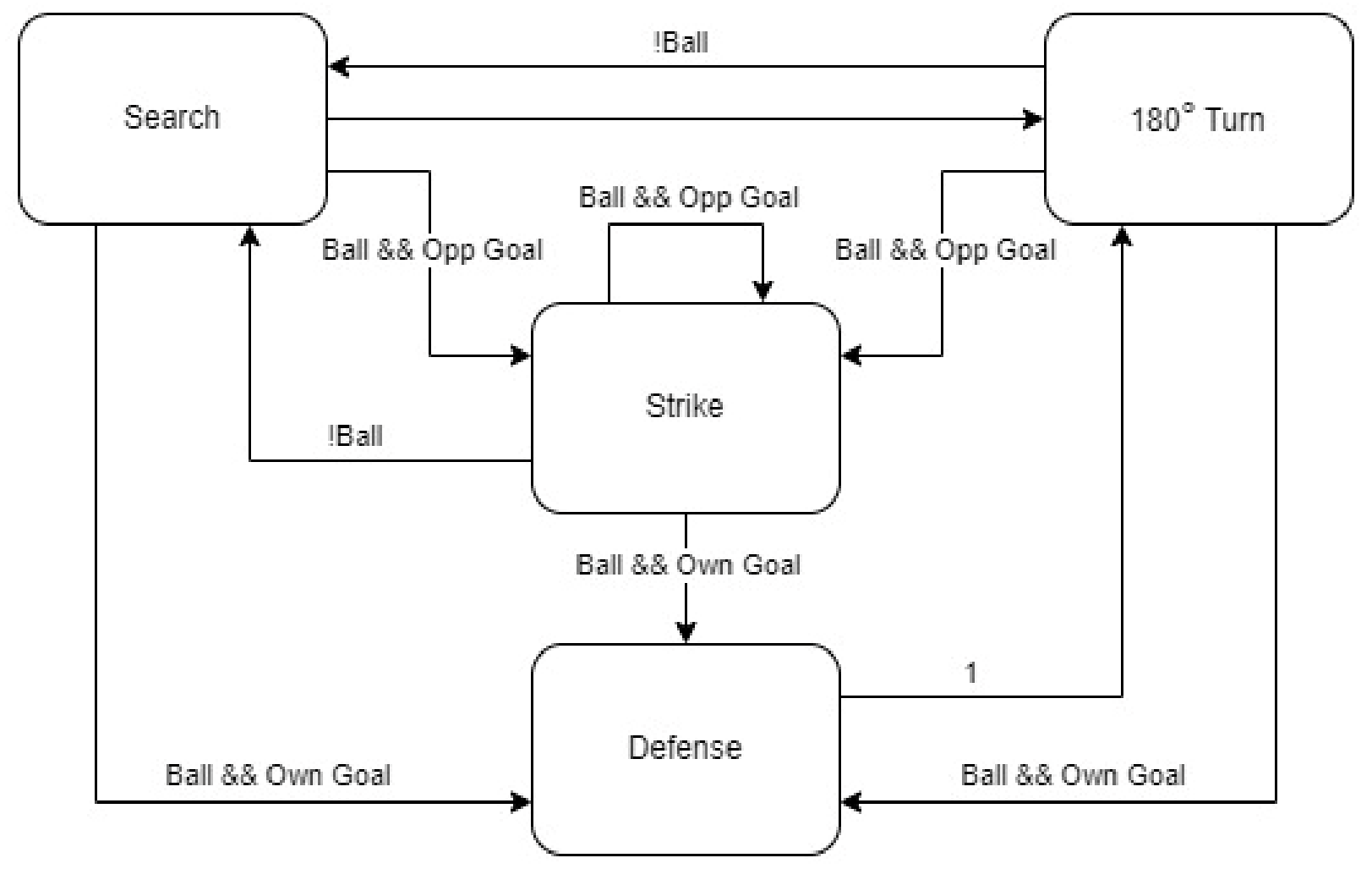

Fig 9. Strategy Finite State Machine

Results

- Demonstrated working 1v1 soccer with autonomous JetRacer agents.
- Improved sensor suite with ZED2 AI stereo camera.
  - Enhanced object detection confidence using a new dataset.
  - Implemented depth sensing and positional tracking.
  - Increased perception capabilities using a swiveling servo camera mount.
- Created a more robust control strategy using a custom ROS Noetic package.
  - Strategy FSM for offense and defense node switching.
  - Flexible structure optimized for smooth future integrations.
- Upgraded JetRacer car hardware and mounts.
- Constructed a new soccer field.
- Provided detailed documentation for future years.

Github Repository:

Future Work & References

Future Work:

- Purchase hardware to construct additional cars.
- Utilize more ZED2 built-in capabilities.
- Improve strategy to include more environmental scenarios.
- Decrease object detection latency.
- Implement additional sensors, such as motor encoders, to supplement ZED2 IMU.
- Develop reinforcement learning in a simulation environment to train agents.

References:

[1] "NVIDIA-AI-IOT/jetracer," GitHub, Apr. 23, 2021. https://github.com/NVIDIA-AI-IOT/jetracer (accessed May 17, 2024).

[2] B. L. M. de Oliveira, "bryanoliveira/soccer-twos-env," GitHub, Apr. 12, 2024. https://github.com/bryanoliveira/soccer-twos-env (accessed May 17, 2024).

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

ADVISERS: Dalton Smith, Pete Sulcs, James Waltner, Prof. John Raiti, Amisha Somaiya