Micro-controller Image Classification

Tools and skills: C/C++, Python, TensorFlow, STM32 Micro-controller, Data analysis

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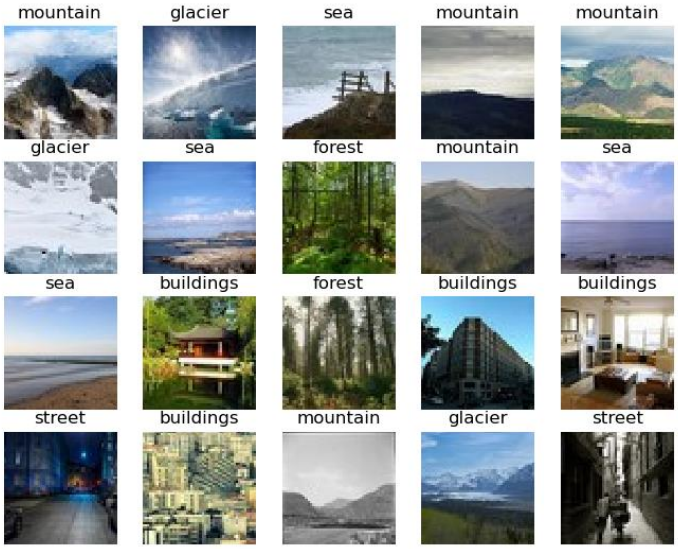


Links: Course Information

Goal:

Deployed a machine learning model on an STM32 Microcontroller to optimize inference speed, performance accuracy, and power consumption.

Outcome:

Machine learning model predicts landscape images from six classes with 80% accuracy and with a time for inference of 41.1ms (~24.32 inferences/second). Model runs on STM32 Cortex M4 Core.

Key Features:

Machine learning model:

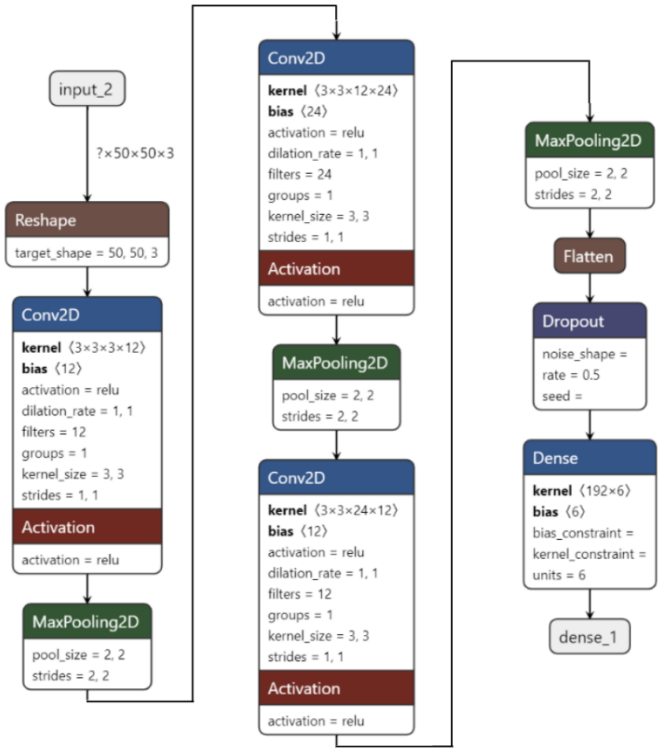
- Built and trained a convolutional neural network (CNN) using TensorFlow, outputting landscape classification
- Tested model architectures for optimal performance of 80% accuracy with minimal Flash and RAM usage

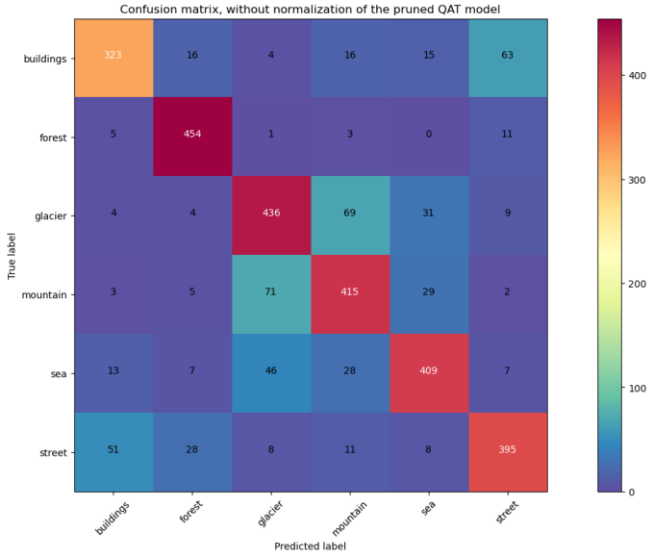
Hardware analysis:

- Quantized and pruned the model to reduce the size and memory usage for efficient inference
- Model size of 563 kB (71% of board Flash) and RAM requirement of 68 kB (55% of board SRAM)

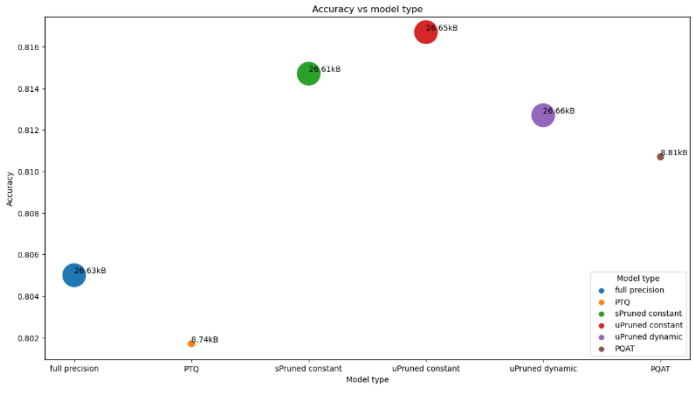
Optimization:

- Used a Prune Quantize-Aware Trained (PQAT) model for Flash reduction of 3x while maintaining <1% performance loss





Confusion matrix of PQAT model (above). Accuracy vs size comparison of different model optimizations, size expressed as radius (below).



Self-Driving Car Simulation

Tools and skills: TensorFlow, OpenCV, Python, ROS, Linux, Data analysis, Git

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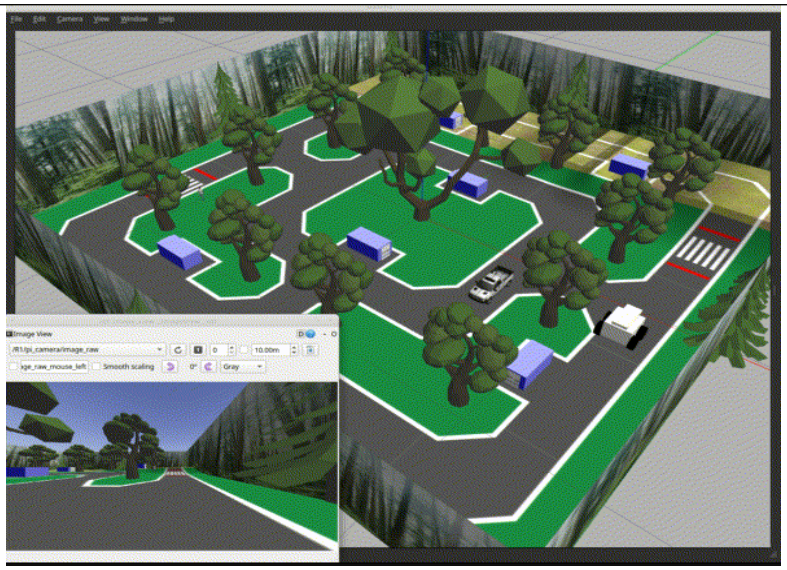
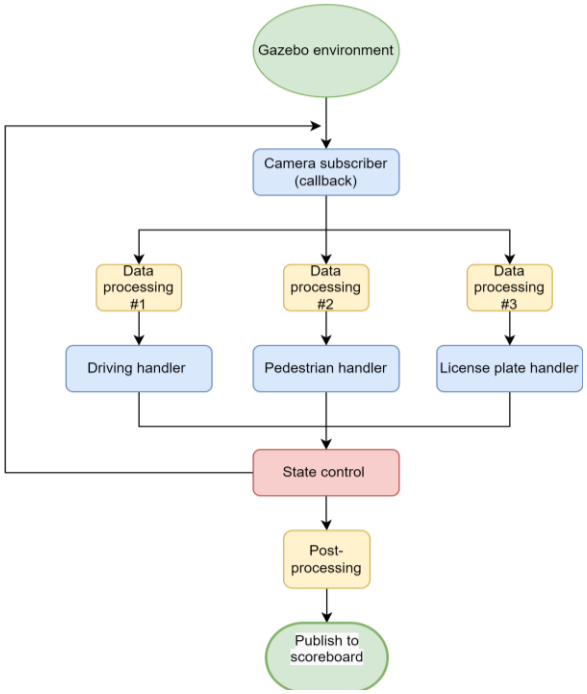




Links: Video Demo, Design Report, GitHub Repo, Course Info

Goal:

Programmed a self-driving robot in a Gazebo simulation capable of vehicle and pedestrian detection, obeying traffic rules, and successfully reading license plates.

Outcome:

Placed 1nd out of 16 teams and obtained the maximum possible points.

Key features:

Self-driving

- Image preprocessing using OpenCV and HSV filtering to remove any unnecessary information for input
- Built and trained a convolutional neural network (CNN) using TensorFlow, outputting linear and angular velocities

License plate reading

- Utilized homography and perspective transforms to ensure a consistent view of the individual characters for input
- Built and trained CNNs to determine parking ID, alphabets, and numbers individually

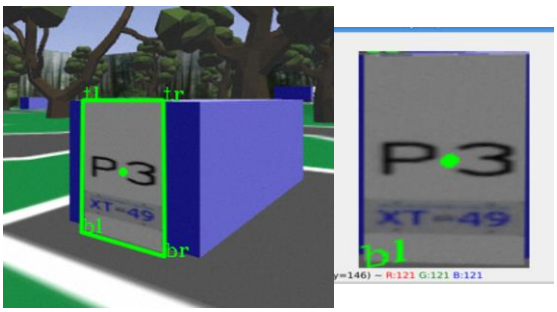
Data collection

- Trained, cleansed, and labeled 20000+ input images by employing a strong data collection method, resulting in high prediction accuracy of the neural networks

Pedestrian detection

- Utilized several computer vision techniques for crosswalk detection and determining the pedestrian's position

HSV filtered camera view for self-driving



Homography (left) and perspective transform (right) on a license plate

Preprocessed license plate characters

Treasure Collecting Robot

Tools and skills: C/C++, Oscilloscope/Multi-meter, Circuit analysis, Soldering, Control Algorithms

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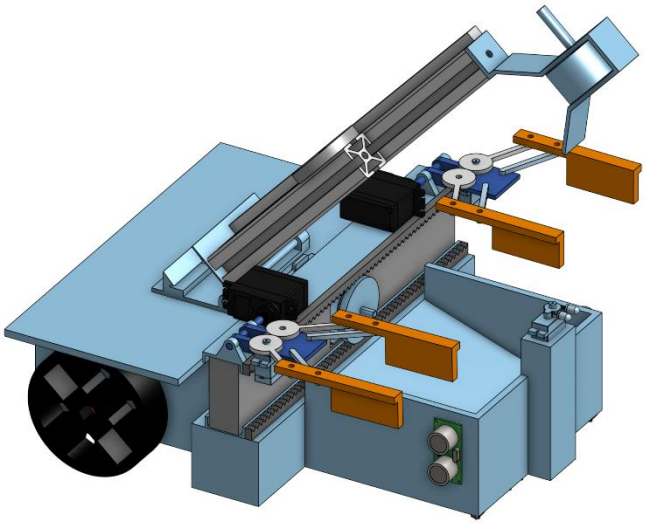
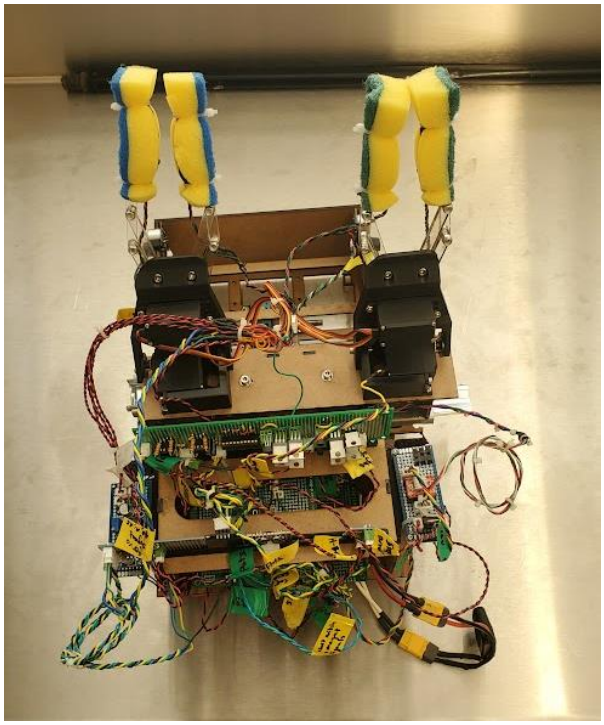




Links: Video Demo (download), GitHub Repo, Course Info

Goal:

Built an autonomous treasure collecting robot capable of line following, infrared signal detection and filtering, magnet detection and autonomous driving.

Outcome:

Semi-finalist robot placed 4th out of 16 teams. Stored and obtained 3 treasures.

Key Features:

Autonomous driving:

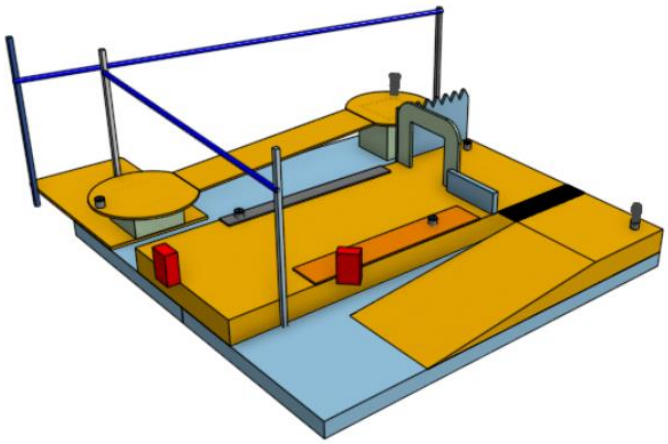
- Programmed a PD controller in C++ for autonomous navigation on STM32 Micro-controller
- Soldered phototransistor circuits for a reflection sensor to navigate following black tape on a white floor
- Infrared sensor circuits captured infrared signals from different beacons

Object detection and sensing:

- Designed and soldered bandpass filter for distinguishing infrared signal frequencies
- Wired sonar sensors to detect treasures
- Hall-effect sensors scanned treasures to detect magnetic fields for false treasures

Claw & treasure capturing:

- Double rack-and-pinion claw mount powered by stepper motor for placement and servo motor for grabbing motion



Competition surface CAD model (above). Side view of robot featuring claw mechanism and laser-cut chassis (below).