Implementation of Real-Time Object Segmentation and Recognition Models in Small Embedded Systems

Kaden Suderman – Masters of Electronic & Computer Engineering 2023-24
Supervised by Dr. Adnan Elahi

Abstract

With the swift evolution of computer vision and artificial intelligence technologies, focus has shifted dramatically to enhancing the driving experience through deep learning.

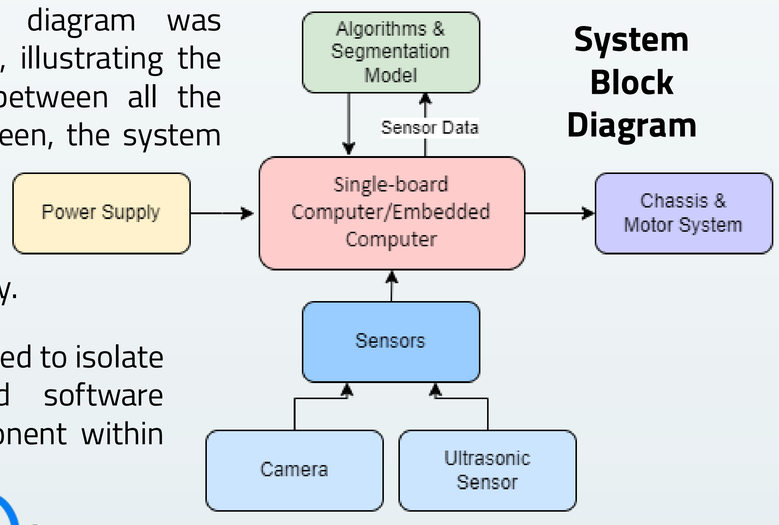
This project aims to develop a miniature smart-vehicle powered by an embedded computer utilizing self-driving software integrated with deep-learning models. **The effectiveness of small, on-board deep learning models will be contrasted with that of large, external deep learning models capable of one-shot learning, a technique which generalizes the class of unknown objects**. Ultimately, the system will navigate a test environment, with comparative analysis performed on the results of each model's ability to adeptly identify key objects

Aims & Objectives:

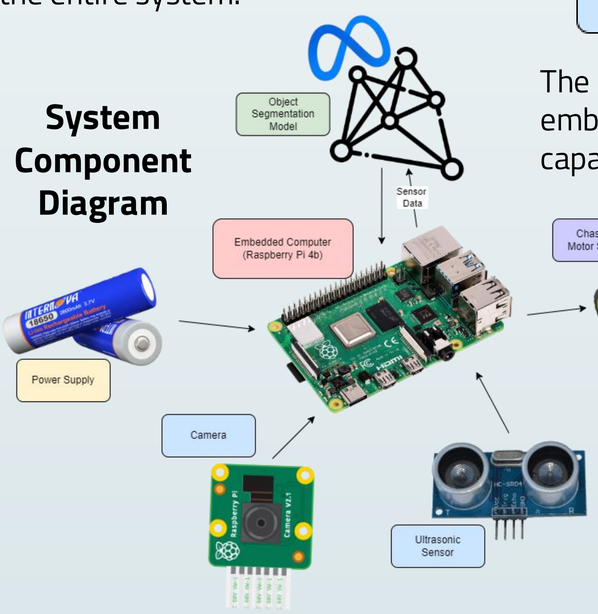
- Develop a miniature smart-vehicle for autonomous navigation.
- Establish best practices and advancements in self-driving technology.
- Integrate object segmentation algorithms and self-driving software.
- Perform comparative analysis of multiple segmentation models.

1. Hardware and Software Design

To begin, a data flow diagram was constructed of the system, illustrating the function and connection between all the involved components. As seen, the system design centers on a single embedded computer which processes all incoming data and distributes it accordingly.



Next, research was performed to isolate the ideal hardware and software candidates for each component within the entire system.



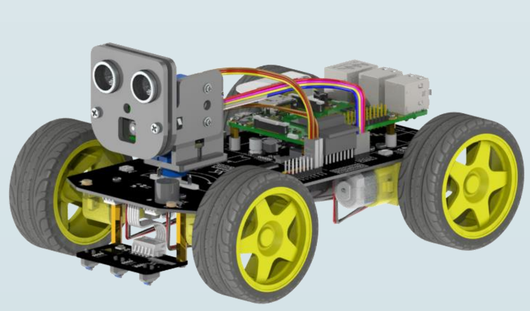
The Raspberry Pi 4b was chosen as the embedded computer for it's processing capabilities and usage in similar research.

FastSAM was chosen as the segmentation model. It is a reduced dataset version of Meta AI's Segment Anything Model (SAM) and is run externally, enabling deep-learning on the small embedded system.

2. Road Detection Algorithm

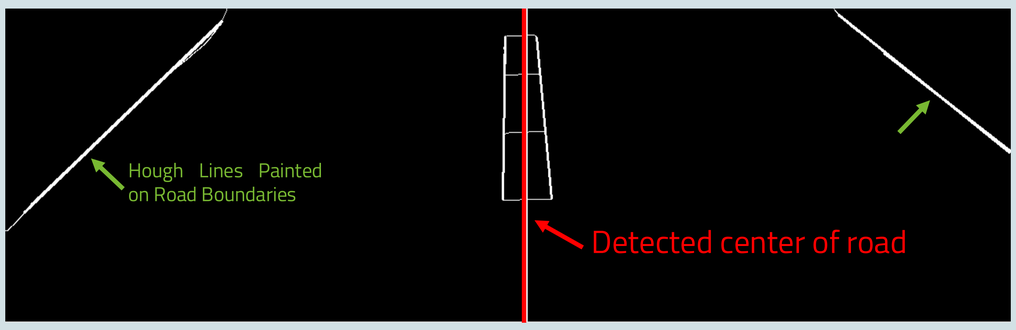
Using the connected Raspberry Pi camera, automatic lane detection was built into the system, using Canny Edge-Detection and Hough Line algorithms to process each frame.

Road detection was performed onboard the Raspberry Pi, with image segmentation being streamed to an external computer, processed, and relevant data returned.



Complete Vehicle System

Road Detection Output Stream

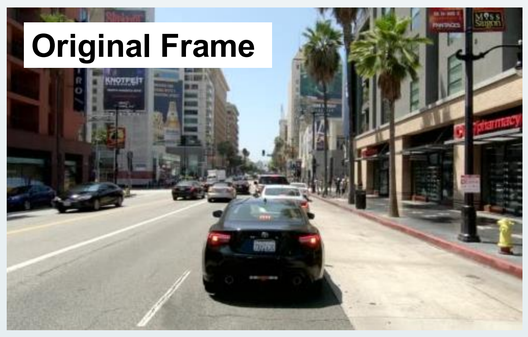


3. Object Segmentation and Zero – Shot Learning

To supplement the road detection algorithms, deep learning models were integrated into the system. Cutting edge models such as FastSAM are capable of generalizing identifiers of unseen object classes using zero-shot learning.
With Zero-Shot learning, AI Models can learn to recognize and classify new data using relationships and attributes instead of labeled examples.

4. Results

Results are positive, showing real-time full image segmentation possible at 20-30 frames per second.



According to system preferences, segmentation can be focused on specific targets, such as roads or road signals like stop signs.

Enabling the use of large-scale deep learning models on small embedded systems expands their capabilities to perform complex tasks with greater accuracy and efficiency, thus unlocking new possibilities for edge computing applications.

5. Future Works

1. Completion of self-driving functionality assistance from results of real-time model inference.
2. Analysis of FastSAM model results versus alternative real-time image segmentation models.
3. Full demonstration of all system components integrated running in real-time, providing live information, and operating in demonstrational testing environment.

6. Acknowledgements

I would like to thank Dr. Elahi for his continual insight, guidance, and contribution to this project.