Smart Autonomous Vehicle in a Scaled Urban Environment

Functional Description and Complete Block Diagram

Team: Elyse Vernon, Tom Joyce, Frayne Go, Devon Bates

Advisor: Dr. José Sánchez

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Introduction

Autonomous vehicles have become of increasing interest with defense research. The Defense Advanced Research Projects Agency (DARPA) has held its Grand Challenge and Urban Challenge in 2004, 2005, and 2007. These competitions have set some of the most elite schools against one another in a competition to build a fully autonomous vehicle. Recently Google has also announced its "Google Driverless Car"; a fleet of full scale autonomous cars which have logged over 300,000 hours completely accident free[1]. If an autonomous vehicle were to become available on the market, then it would have far reaching benefits; from increasing road safety to allowing those with physical and vision disabilities to drive. For the Smart Autonomous Vehicle in a Scaled Urban Environment (SAV-SUE) project, the team will bring the concept of an autonomous vehicle to a small scale.

SAV-SUE will integrate environment detection via a camera input and a digital signal processor (DSP) for image processing with microcontroller-based vehicle control. Fig. 1 illustrates a high level system block diagram for the system. The camera will be mounted in the cab mimicking a driver's vision unless the size of the vehicle dictates otherwise. The camera will send signals to the DSP to determine the environment. The DSP will interface with the primary controller which will be a microcontroller. Sensory information will also interface with this primary controller. The primary controller will communicate with the vehicle's Multi-Function Unit Controller (MFU), which will operate the motors and lights to achieve the desired actions of the vehicle. This vehicle will be the Tamiya MAN TGX 26.540 6x4 XLX replica-quality semi truck cab, built to a 1/14-scale.

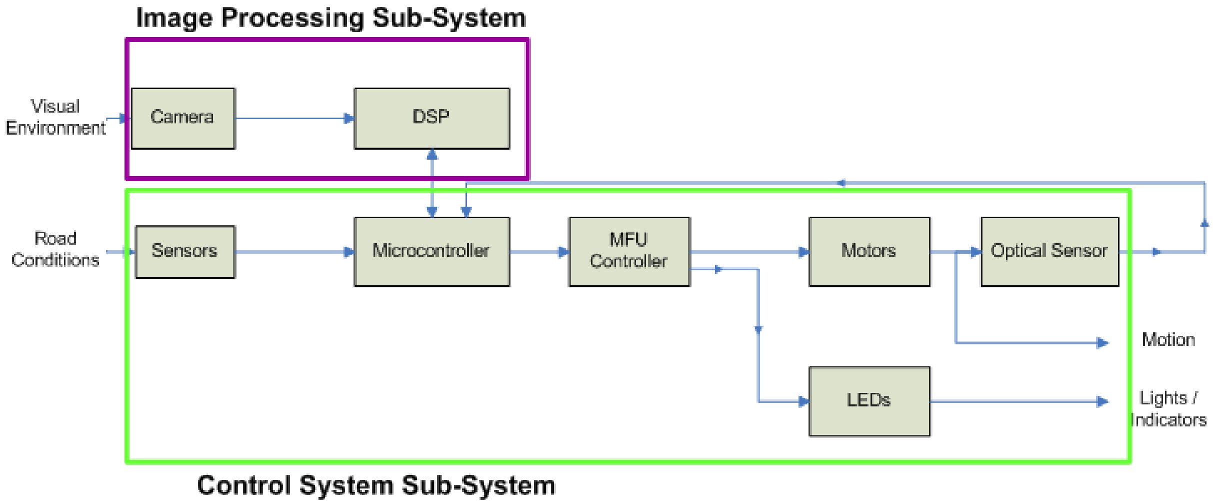

Fig 1: "SAV-SUE High Level Block Diagram"

Objective

Ultimately, the team’s objective is to achieve autonomous control such that the vehicle approaches a scaled intersection at a given cruising speed while staying in its lane, detects a stop sign, stops before a stop line, engages a right turn signal, and executes a right-hand turn into the appropriate lane. This project will be completed to allow for expandability for future senior projects.

Functional Description

Though SAV-SUE is primarily focused on operation of its vehicle through vision-based controls, the team must also design the scaled urban environment in which the vehicle is to operate. Based on geometric analysis and vehicle characteristics, the team has determined the size requirements of the scaled roadway intersection. Fig. 2 depicts the layout of the environment as it will be constructed in space allotted in Bradley University’s engineering building.

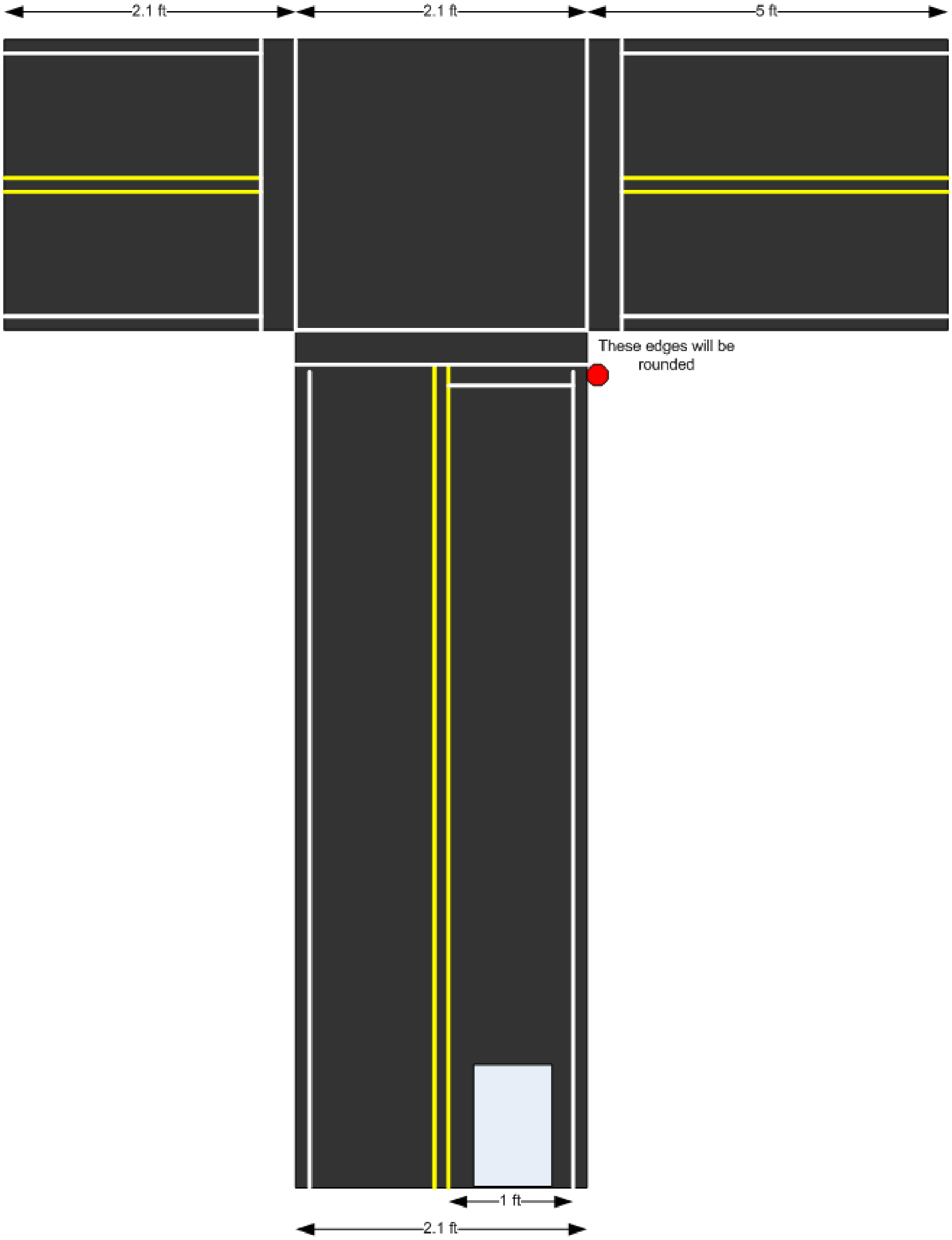

Fig 2: “Scaled Urban Environment Dimensions”

Subsystem 1: Image Processing

The main goal for the image processing subsystem is to detect stop signs and traffic lines on the road using image processing algorithms. The image processing calculations will be performed in the DSP unit. The DSP will receive a stream of frames from the camera attached to the car. It will then attempt to recognize any possible traffic signs, but specifically a STOP sign, on the road allowing the control system to respond accordingly. The general algorithm for stop sign detection will be to use color segmentation, shape detection, and categorization. The individual processes for each step have not been decided yet. Some of the algorithms the team is investigating are HOG (Histogram Oriented Gradients), color thresholding, and edge detection. The team will use MATLAB (Mathworks, Natick, MA) to perform algorithm verification and testing.The algorithm that yields the most accurate and consistent results in real-time will be chosen for DSP implementation.

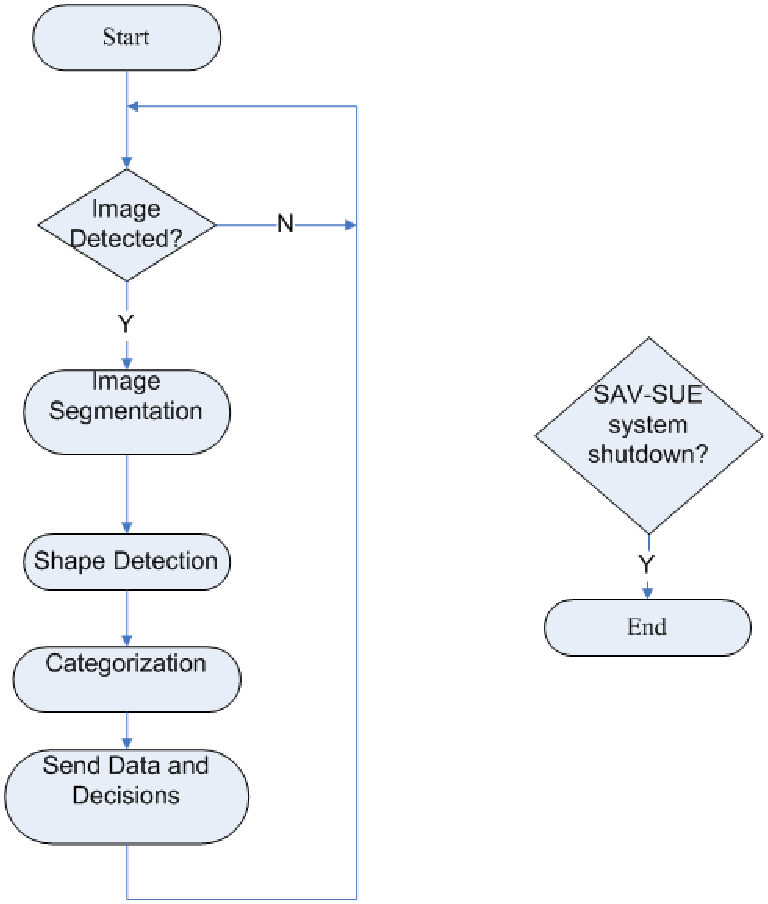

Fig 3: "Image Processing High Level Software Flowchart "

The image processing subsystem must operate in real-time (i.e. must be fast enough for the control system to react to the environment). Another important feature is to avoid false negatives, where the system does not recognize a stop sign, in addition to false positives, where the system recognizes stop signs that do not exist. Possible environmental factors-that the image processing system will have to account for are lighting conditions, stop sign conditions, and image distortions. The algorithm the team utilizes will have to be able to adapt to those conditions and still perform with consistency.

Subsystem 2: System Control

The primary goal of the system control subsystem is to achieve an accurate model of the system, account for that model on the primary controller, reverse engineer the MFU controller to communicate effectively between the primary controller and MFU, and integrate communication data from the DSP and sensory input to achieve autonomous decision making. This subsystem will be responsible for the system outputs, which are vehicle movement and engagement of brakelights and a turn indicator. It will also be responsible for the communication between all system devices.

The system control team will perform extensive modeling and analysis of the system using Simulink (Mathworks, Natick, MA). This will involve determination of motor parameters as well as overall system parameters such as the inertia of the entire truck, which will affect stopping distance. This modelling process will determine parts of the microcontroller software design to achieve the desired system responses.

Motor and indicator control will be achieved by reverse engineering an existing, commercial off-the-shelf controller called the Multi Function Unit Controller (MFU) designed by Tamiya Inc. In its intended application, the MFU receives instructions from a radio receiver. The team will use the primary controller via a microcontroller to replicate the de-modulated radio signals that the MFU will recognize. In the beginning stages of the project, the team will reverse engineer the signals to be replicated.

For autonomous control, the primary controller will be communicating with the DSP used for image processing. The DSP will alert the microcontroller about its environment by sending signals upon object detection, and the microcontroller with react accordingly. Specifically, detection of a STOP sign will prompt a stopping algorithm stored in code memory. The team will also implement an algorithm used for lane detection to make sure that the vehicle can complete a turn while staying in its lane. Fig. 4 shows the high level main loop for the microcontroller assuming an interrupt communication scheme.

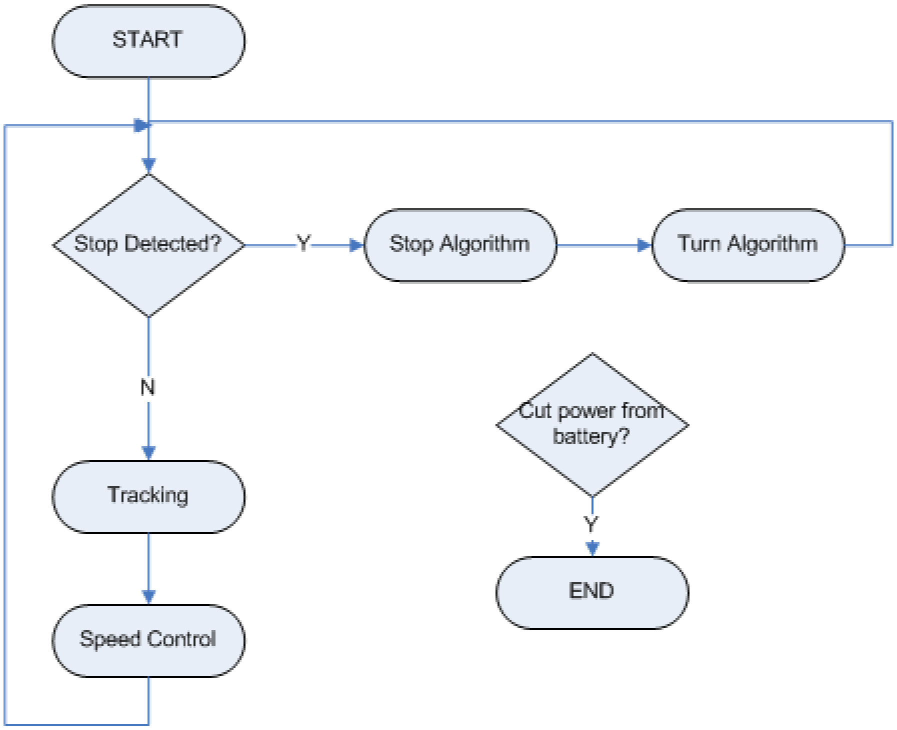

Fig 4: “Primary Controller High Level Software Flow”

As the primary controller is operating, it is also receiving sensory feedback for closed-loop control. Ideal closed-loop control serves to eliminate output error by subtracting the difference between desired and actual output performance. System sensors have yet been determined. The team has considered the use of an optical sensor on the motor shaft to determine the actual vehicle speed. Use of the optical sensor is contingent upon the space available near the motor’s shaft.

Conclusion

In order to ensure successful completion of SAV-SUE, the team needs to have an in depth understanding of both the image processing and vision-based system controls subsystems. Both of these subsystems need to synergize seamlessly in order to ensure achievement of the project objective.

References

[1] Owen Thomas. (2010 September 7). *"Google's Self-Driving Cars May Cost More Than A Ferrari."* [Online]. Available: <http://www.businessinsider.com/ google-self-driving-car-sensor- cost-2012-9>.