Smart Autonomous Vehicle in a Scaled Urban Environment

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Introduction

The focus of this project is the design of an autonomous vision-based control system such that a 1/14 scale vehicle (RC MAN TGX 26.540 6x4 XLX) can navigate a proportionally scaled environment.

Objective

The top level behavioral objective is for the vehicle to approach an intersection, halt at the stop line, execute a right turn, and stay within lane lines at all times.

Motivation

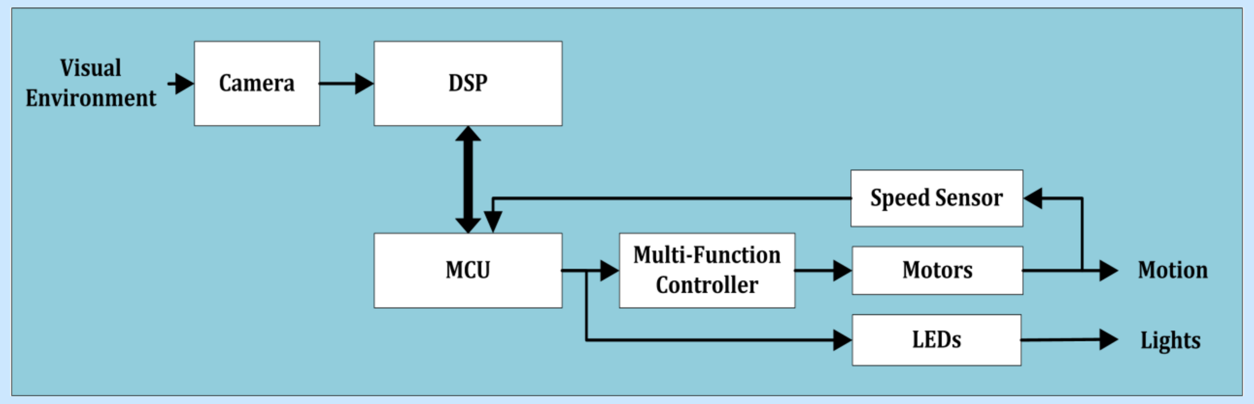
The motivation for the project comes from the growing field of autonomous vehicle research. Recent large-scale autonomous vehicle research started with the Defense Advanced Research Projects Agency (DARPA) and have continued with work done by Google with their fleet of autonomous vehicles.

Significance

Autonomous vehicles have the potential to save millions of human lives by decreasing human error. In addition, autonomous vehicles can be designed to operate more efficiently than human operators and give people with physical impairments the ability to drive on their own.

Architecture

The project comprises an image processing and vehicle control system. A camera takes a picture of the environment and sends this data to a digital signal processor (DSP), where the image is analyzed. Once the DSP has processed the data, information is communicated to the microcontroller (MCU). The MCU then interprets this information to adjust the motion of the vehicle.

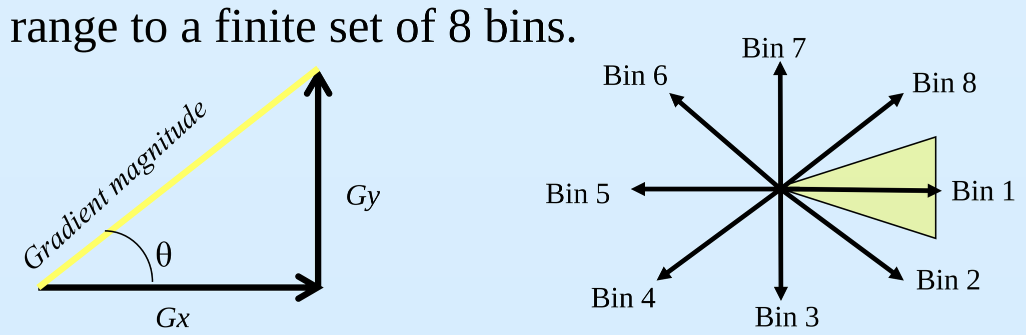


System Architecture

Methods

Image Processing Methods

The basis for both image processing algorithms is gradient calculations. The gradients for the x- and y-directions are calculated and then used to calculate the gradient magnitude and orientation. The orientation is sorted from a 180° range to a finite set of 8 bins.



Gradient Magnitude and Orientation Bins

Histogram of Orientated Gradients [1]

The histogram of oriented gradients algorithm is used for feature description. The image is characterized by gradient magnitude and edge direction.

Gradient Magnitude Calculations

Support Vector Machine [2]

$$w = \sum_i a_i * x_i$$

$$\mathcal{L}(z) = \mathbf{sign}(w * x - b)$$

A support vector machine uses non linear mapping to separate data sets into two separate classifications. For the stop sign detection, images will be classified as stop signs or not stop signs.

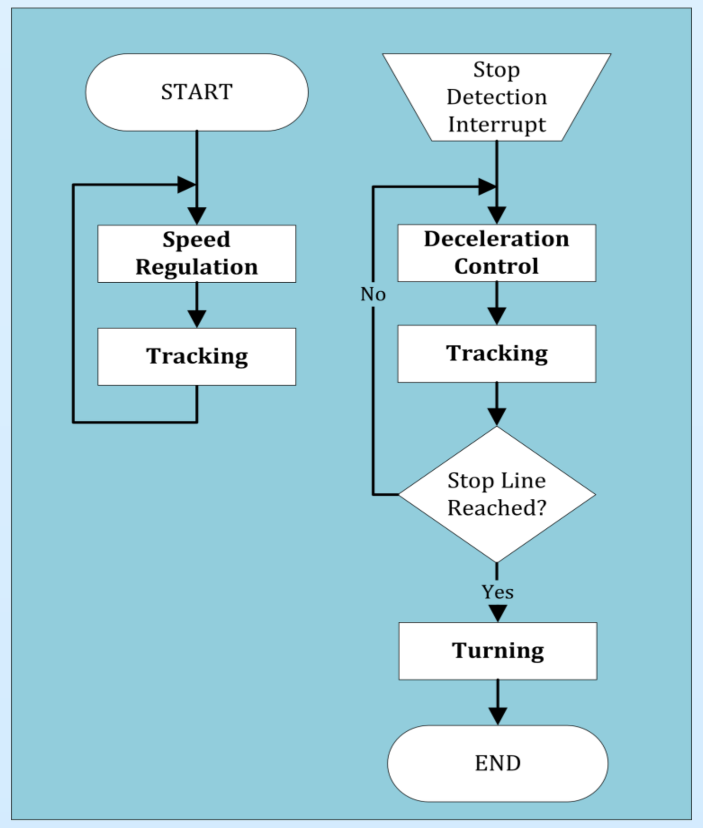
Canny/Hough Edge Detection with Vanishing Points [3]

Lane line detection is done through the use of Canny/Hough edge detection with vanishing points (CHEVP) algorithm. Using a projection of the two (ρ,θ) lane lines projected in to the distance the degree of variation from steering straight ahead is calculated by the Hough transform.

Lane Detection Diagram

- Each red block represents the lane partition.
- The blue line is the calculated result of the Hough transform.
- The yellow line is the projection of the line into the distance.

Vehicle Control Methods

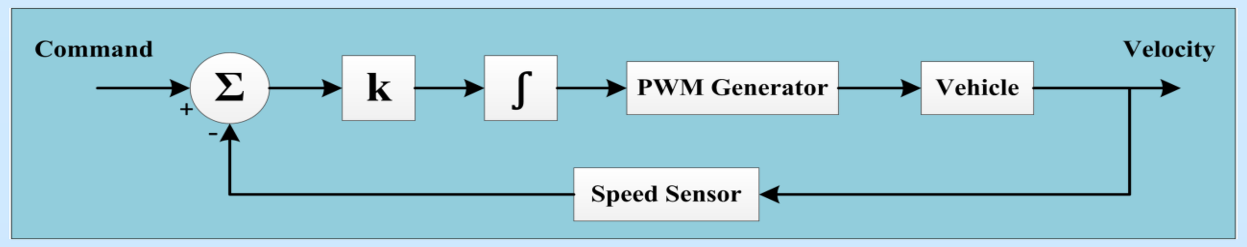


Controller Main Loop

- The MCU integrates four primary algorithms:
  - ➢Speed Regulation
  - ➢Lane Tracking
  - ➢Deceleration Control
  - ➢Turning
- Communication of stop sign detection initiates a stopping sequence after which a right turn is executed.

Speed Regulation

Vehicle speed is regulated with the use of proportional integral control using an error feedback signal.



Speed Regulation Block Diagram

Lane Tracking [4]

$$R = \frac{\boldsymbol{Wheelbase}}{\boldsymbol{sin(\theta_{steer})}} + \frac{\boldsymbol{Track}}{\boldsymbol{2}}$$

$$T_{steer} = \frac{\frac{\theta_{corr}°}{360°} * 2\pi R}{V}$$

- Steering characteristics are modeled by approximating a turning circle.
- The adjustment period T_{steer} must be calculated to correct the steering angle.

Deceleration Control

- A new speed command is updated every sample.

$$Acc = -\frac{V_i^{\,2}}{2D}$$

$$V_{next} = V + Acc * T_{sample}$$

- The new command is calculated using the constant deceleration model of kinematic theory.

Turning

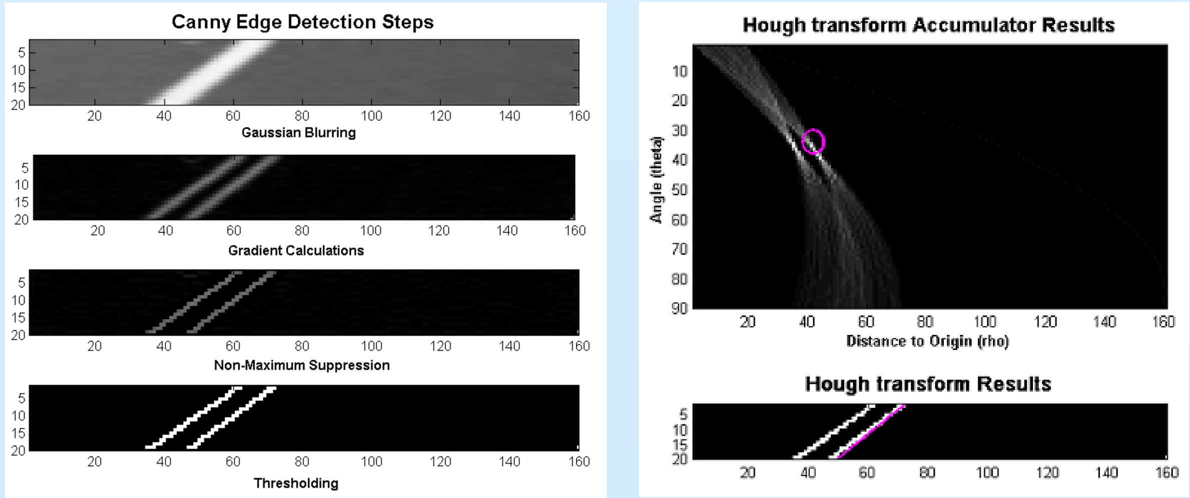
The turning model is created by comparing the smallest turn radius of the vehicle to that of the intersection. The difference is used to compute the distance of straight travel before executing a right turn at the maximum steering capability of the vehicle.

Results

Image Processing Results

Simulation of the stop sign detection algorithm resulted in an 80% success rate on a set of 15 test images. The teaching set is built from 30 test images, of which 15 are stop signs.

Implementation of the Lane Line Detection on the DSP can accurately match a (ρ,θ) line representation to the lane image using the accumulator from the Hough Transform.

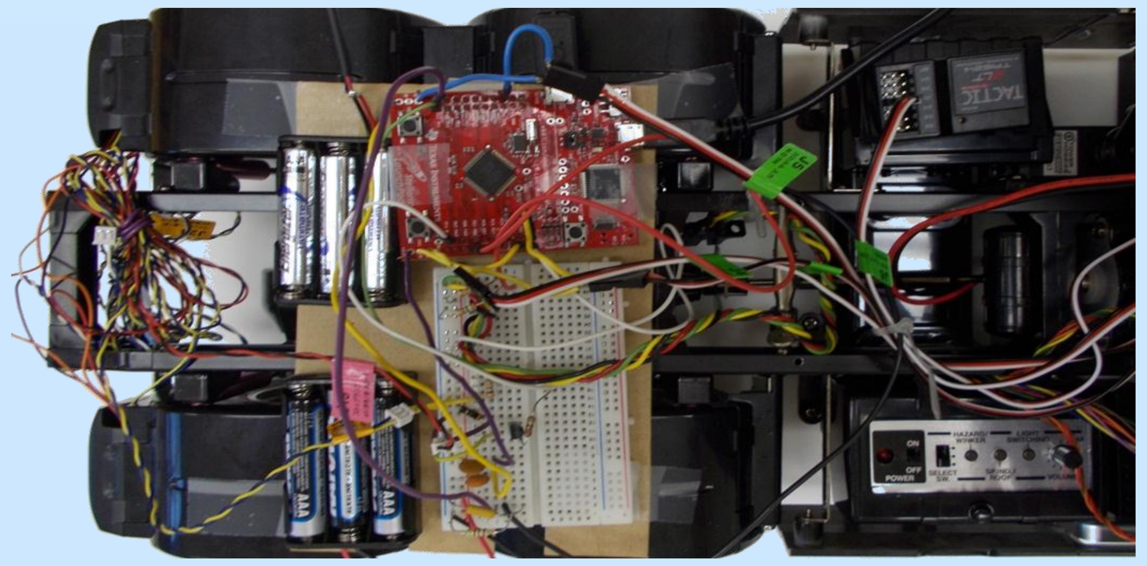


Canny/Hough Edge Detection DSP Results

Vehicle Control Results

Precision

- ➢ 0.4% speed sensor
- ➢ 0.7% speed regulation
- ➢ 1% lane tracking
- ➢ 5% deceleration control



Vehicle with Control System Electronics

Conclusion

The research completed for this project has the potential to decrease the costs associated with autonomous vehicle technology, thus accelerating technical advancements in the field.

References

[1] C. H. Chen. *Detection and Recognition of Alert Traffic Signs* . Stanford University, California.

[2] J. C. Platt, “Sequential Minimal Optimization: A Fast Algorithm for Training Support Vector Machines”. Microsoft, Tech. Rep. MSR-TR-98-14, 1998.

[3] Y. Wang. (2003, October 1). *Lane Detection and Tracking Using B-Snake*. Image and Vision Computing. [Online]. Vol. 1 (22). Available: http://www.bradblock.com/Sequential_Minimal_Optimization_A_ Fast_Algorithm_for_Training_Support_Vector_Machine.pdf

[4] Kroll, Jess. (2010, September 24). *How to Calculate a Turning Circle* [Online] Available: <http://www.ehow.com/how_72257 84_calculate-turning-circle.html>.