Trans Am: An Experiment in Autonomous Navigation

Jason W. Grzywna, Dr. A. Antonio Arroyo
Machine Intelligence Laboratory
Dept. of Electrical Engineering
University of Florida, USA
Tel. (352) 392-6605
Email: grzywna@ufl.edu, arroyo@mil.ufl.edu
URL: http://www.mil.ufl.edu

Abstract

Autonomous vehicles have applications in every walk of life. The challenge of creating a vehicle that could perform simple driving tasks such as lane following and lane changing to avoid collision is a difficult one. This project examines and proposes a solution to that challenge. The solution constructed is addressed as a model, or simulation, of larger possibilities.

The solution system is developed from both an electrical and mechanical standpoint. The basic theory behind the design is that a microprocessor equipped with simple sensors and control systems can successfully provide actuation through mechanics to accomplish obstacle avoidance, lane acquisition, lane following, lane changing based on lane conditions, and even lane re-acquisition when necessary.

Results indicate that lane following systems of unparalleled possibilities are possible. A model system has been constructed that performs the above tasks listed as the basic theory behind the design. This system on a larger scale with complex systems could drive on roadways and shuttle people around town.

The contribution of this work is laying a foundation for larger scale road vehicle autonomous mobility. The project permits future design efforts a working prototype system, which provides a baseline capability for continued research.

1. Introduction

Autonomous vehicles have applications in every walk of life. I wanted my project to have a strong base in reality. I chose to design a model autonomous car not only because it is practical, but also because it is needed. The technology and information derived from my research will be forward compatible and can serve as a stepping stone to produce an even more complex autonomous vehicle.

The design goals of Trans Am were to create an autonomous vehicle capable of performing navigation in common traffic situations while still preserving many components of a car. Turn signal and brake signal systems are modeled. Ackerman's steering is also modeled.

To be practical the car Trans Am would have to perform tasks that a normal car would have to perform. I call these the behavior criteria. The major behaviors Trans Am performs are obstacle avoidance, lane/ track acquisition, track following, lane changing based on track conditions, and lane re-acquisition. Also included in Trans Am's logic are routines to know which lane the car is in, and to also know when to begin searching for the track again. Trans Am continually responds to physical collisions, and gives visual indications of turning and speed change on its turn signals and brake lights.

The integrated system of Trans Am consists of the the lighting system board, IR emitters and detectors, the CDS array, the CDS illumination array, the collision detectors, the actuators, and the Mekatronics MTJPRO11 board which contains the microcontroller, and the memory.

The mobile platform was developed using AutoCAD release 14. Two preliminary designs were tested before the final design was decided upon. The frame is constructed of balsa wood. The front steering system designed to follow Ackerman's steering principles was designed using a spindle housing from a hobby supplier mounted in a wooden support rig. The back wheels are mounted directly to the drive motors.

Actuation of Trans Am is controlled directly by the microcontroller. Pulse width modulation is used to turn servos, which in turn are the direct controllers of locomotion and steering. Trans Am is a simple design. Its servos, or actuators, are all the same model. They have been modified to perform differently.

The sensors like the actuation system were designed to be simple. IR detection is present in the system for short-range object detection. It is utilized by emitting focused IR light and using a detector tuned to the emitted light frequency. An analog signal is then extracted from the detector, and a range can be calculated. The track acquisition/ following sensor system is composed of a shielded array of CDS cells accompanied by an array of ground illuminating lights. A triangular shape array gives nose and two extremes (left and right). These reading can be used to center on a track. The last simple sensor is the momentary contact collision switch. It is used to sense moving collisions.

Trans Am performs as a real car under the criteria cited. The results I have found indicate that large-scale navigation systems of unprecedented capability are possible. I would like to be involved in the development of such a system. Currently programs like PATH at the University of California, Berkeley, and Carnegie Mellon University are working on similar research.

2. Integrated System

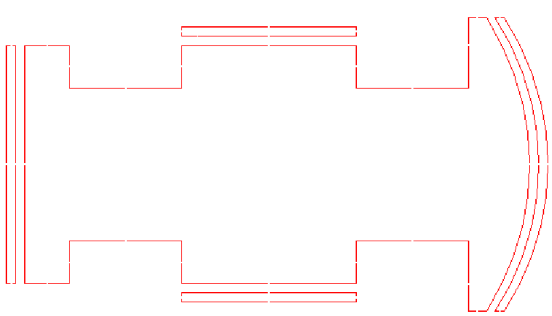
2.1 The Microcontroller

The core processing unit of Trans Am is the 68HC11E9 microcontroller. It is an advanced microprocessor which contains additional memory and specialized hardware to perform analog-to-digital conversion, memory mapping, and pulse width modulation (PWM).

The microcontroller is mounted on a Mekatronics MTJPRO11 board. This board expands the 68HC11E9s functionality even further. It adds 32Kbytes of SRAM, 8 input channels for analog signal, 5 PWM digital outputs, 8 digital outputs regulated with 330 ohm resistors for infra-red LEDs, 3 digital inputs, five-volt serial communications interface, 40KHz square wave generator, 5V voltage regulator, and a low-voltage inhibit reset circuit. The microcontroller board also features 4 input port enable lines, and 4 output enable lines for expansion.

3. Mobile Platform

The platform is constructed from .125" thick balsa wood. The early design was built to test the control systems and the motors. It was triangular with two drive wheels and a caster at the nose. This design does not provide the control necessary to model an automobile. The second and final design makes use of mechanics present in cars today. An approximate Ackerman's steering model is used. Ackerman's theory uses geometry to describe a system in which the inner wheel during a turn turns tighter then the outer wheel to account for better control and stability. This design also has four wheels, a necessity when modeling automobiles of today. The steering system in the final design was created using spindles and brass tubing from a hobby shop. Four thin brass tubes all placed inside one another coated with teflon lubricant provided the front axle and spindle. The front wheels were mounted on the spindle shafts, and the spindle assembly was connected to the steering servo by way of a metal tie link. The back wheels were mounted directly onto the gear motor servos. The platform was drawn in AutoCAD release 14. And cut out on a modified T-Tech Circuit prototyping machine.



4. Actuation

4.1 Drive Train

The drive train of Trans Am consists of two motors. Each back wheel is independently driven by a modified servo, which functions as a motor. Each back wheel is mounted directly to the servo. The servos were modified in the sense that they now rotate continuously forward or reverse, they still can have graduated speeds.

4.2 Steering

The steering system is actuated by an unmodified servo. This servo is connected to the front wheels spindle assemblies by way of tie-links constructed from a metal coat hanger.

Standard servos are controlled using a pulse width modulated (PWM) signal. This signal tells the servo how far it should turn, and at what speed. The modified servos have been changed so that they never know when they reach the location they are instructed to find, but they can discern the speed at which to get there. Therefore they become speed-varying motors essentially. The motors are controlled through a PWM signal from the 68HC11E9 on digital port PA3 for the left, and port PA7 for the right. The width of the signals themselves were calculated through trail and error and set as constants in the software. There are a total of 11 speeds. Five graduated forward speeds, five reverse graduated speeds, and a speed of zero.

4. Sensors

4.1 Infra-red Subsystem

The infra-red detection subsystem consists of IR emitters and detectors. The system measures the amount of IR light present in its path and determines if an object is present. The emitters are modulated at 40kHz in hardware, they produce a wavelength of 940nm. The detectors are tuned to 'see' that wavelength to attempt to prevent noise from other light. They have also been modified to produce an analog signal (in their original form a digital signal was produced). Trans Am has three forward looking IR detectors and three forward spraying emitters. The emitters are shielded with black tubes to focus a controlled beam of light in the desired direction. The forward most IR emitter projects a beam from the center nose of the car. A high mounted detector looks forward for direct path collisions. The other two emitter/ detector combinations are mounted in front of the front wheels. They are vectored outward away from the car. This configuration provides vision for both obstacle avoidance and wall following

4.2 Tracking Subsystem

The tracking subsystem consists of two major elements: the cadmium-sulfide (CDS) cells and the ground illumination system. The entire array is mounted under the front section of the vehicle. It is contained in a shielded box constructed as part of the body and sealed.

The CDS cells react with light and function as variable resistors. They are biased with resistors in a voltage divider configuration. They provide an analog signal with the signal magnitude directly correlating to the amount of light present on the sensor. The cells are shielded a step further. They are recessed in black tubing so the only light that could reach them would have to be reflected off of the floor directly below.

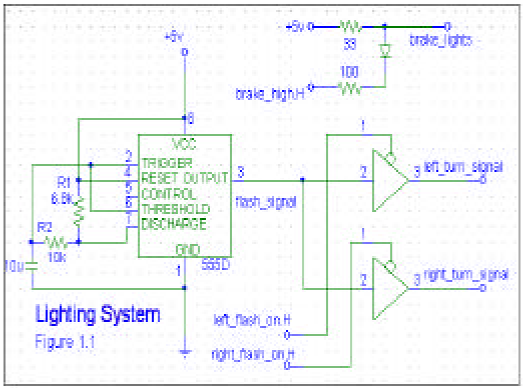
The ground illumination system consists of five green light emitting diodes. They provide a constant light source underneath the shielding and are angled to reflect into the protective tubing that contains the CDS cells.

4.3 Collision Detection

Bumpers are present on all four of Trans Ams sides. They are all connected through on analog port on the board. Each consists on momentary switches wired in parallel. The bumpers are mounted to the switches themselves, and work well for moderate speed collisions. From each bumper assembly an input to the differentiating resistive network is formed. The differentiating network is set of resistors of unique values in a voltage divider configuration. This network is part of the MTJPRO11 board, it is well documented in the literature for the board.

4.3 Collision Detection

Trans Ams turn signals and brake lights are controlled from within the lighting system. A separate board was built using one of the output expansion ports of the MTJPRO11, in conjunction with a latch. The signals in the latch control tri-state buffers which in turn either allow the lights to be on off. The flashing circuit is an RC network built from the 555 integrated circuit. The brake circuit is a voltage divider using a diode to control output based in signal from the microprocessor.



Lighting System
Figure 1.1

Conclusion

Trans Am performs as a real automobile under the criteria laid forth for this experiment. The results I have found indicate the large-scale navigation systems of unprecedented capability are possible. I would like to be involved in the development of such a system. Current programs like PATH at the University of California, Berkeley, and Carnegie Mellon University are working on similar research. The technology and information derived from my research will be forward compatible and can serve as a stepping stone to produce an even more complex autonomous vehicle.

Acknowledgements

I gratefully thank Professor A. Antonio Arroyo for his continued support of my work and the work of the others in the fields of electronics and robotics. I would also like to thank Ivan Zapata and Scott Jantz, for without their vast knowledge and presence within the Intelligent Machine Design Laboratory this project might not be what it is today.