



Research Report

Autonomous Vehicle Guidance Evaluation

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| 16. Abstract (Limit: 200 words) <p>This report provides an overview of autonomous vehicle technology, specifically focusing on sensing and control technologies. It resulted from safety issues at the Mn/ROAD high-load, low-volume pavement test facility. Appropriate technology helps ensure the safety of the truck driver that provides loads to the pavement and the safety of traffic on I-94.</p> <p>Researchers currently are working to provide a semi tractor capable of driver-supervised autonomous operation at the Mn/ROAD facility. Such a driver-supervised system will allow the truck driver to monitor the operation of the automatic control system actively guiding the truck and will allow the driver to take control from the control computer when desired.</p> | | | |
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Autonomous Vehicle Guidance Evaluation

Executive Summary

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I. Introduction

The original scope of this contract was to provide Mn/DOT assistance in the area of autonomous vehicle technology, specifically focusing on sensing and control technologies. This was motivated by safety issues arising at the Mn/ROAD high load, low volume pavement test facility. Appropriate technology was to be used to ensure the safety of the driver of the truck providing loads to the pavement and the safety of traffic on I-94. The University also was to help Mn/DOT with technical evaluations of submitted proposals and was to develop a plan to evaluate the performance of an autonomous truck to be acquired by Mn/DOT.

Over the course of the contract, the needs of Mn/DOT changed, and the course of action taken by the University changed to adapt to those needs. The largest change associated with the program revolved around the truck acquisition. Originally, Mn/DOT was in discussion with Freightliner regarding the acquisition of a semi tractor-trailer capable of autonomous operation on the Mn/ROAD facility. The work with Freightliner failed to materialize. At the present time, the University is working with Navistar and Alliant Techsystems to provide a semi tractor capable of *driver supervised* autonomous operation at the Mn/ROAD facility. Such a driver supervised system will allow the truck driver to monitor the operation of the automatic control system actively guiding the truck and will allow the driver to take control from the control computer when desired. The truck will serve two roles: the first as a means with which to provide dynamic loads to the pavement on the high load/low volume portion of Mn/ROAD, and the second as a vehicle to perform driver supervised autonomous vehicle research and development.

The remainder of the executive summary briefly describes the effort and results put forth under this contract. Four documents support the brief description provided herein: first, the 1993 Technology Reinvestment Program (TRP) [TRP, 1993] proposal provides a comprehensive review of the state of the art in autonomous highway vehicles as of 23 July 1993 and a description of our long term research plans involving autonomous vehicle control and driver performance monitoring; second, the 1994 proposal to the U. S. Army's Tank Automotive Command (TACOM) [Mn/DOT, 1994] supplements the 1993 TRP proposal and provides a detailed description of the acquisition and integration of the Navistar semi tractor and the first year research and development activities; third, a report [RADAR, 1994] presents an analysis and experimental procedure to determine the applicability of Millimeter Monolithic Integrated Circuit (MIMIC) radar to highway vehicles; and fourth, the report [CRASH, 1994] purveys an analysis of current collision avoidance techniques and experimental procedure to develop, test, and evaluate a Potential Field (PF) and Artificial Neural Network (ANN) approach to collision avoidance systems.

II. Work Performed

As with any research contract, an extensive literature search (including the Transportation Research Information Search (TRIS)) was undertaken to determine current state of the art as defined by the literature; the results of this search are documented in [TRP, 1993], [Mn/DOT, 1994], [RADAR, 1994], and [CRASH, 1994]. Because results presented in the literature can lag actual results by a number of years, trips to conferences, national labs, and technology vendors were undertaken by University personnel. Conferences attended include 1993 and 1994 IVHS America conferences, the 1994 Association for Unmanned Vehicle Systems (AUVS) meeting in Detroit, and the IVHS America Safety and Human Factors Committee and the National Highway Traffic Safety Administration (NHTSA) workshop held in Reston, VA, March 21-22, 1994. Los Alamos National Lab and Sandia National Lab were visited in February 1994; Sandia had proposed to build an autonomous semi tractor-trailer to provide dynamic loads to a hot mix asphalt test track; however, Sandia did not win a contract and therefore did not build a vehicle. Technology vendors visited include Red Zone Robotics and K2T, both in Pittsburgh, PA. Red Zone has considerable experience with vehicle system integration; K2T produces Vision Based Neural Network lateral guidance equipment for autonomous vehicles. Trips were also taken with Steve Hay, Technical Liaison from the Office of Research Administration. Discussions were held with Erik Matella at ARPA, Bob Clarke and Ron Knipling at NHTSA's Office of Crash Avoidance, and Bill Rogers, Director of Research at the Trucking Research Institute of the American Trucking Association Foundation.

Based on the literature search, visits, and previous work done in CAMDAC's Robotics Lab, a research direction was established. Based on available technology, level of system integration, sophistication, marketability, and time to commercialization, it was determined that a vision based lateral guidance and radar based longitudinal control and collision avoidance approach to vehicle control show the most promise for commercial applications. The use of an open architecture was determined to be essential to allow developing technology to be incorporated and evaluated on our vehicles. Based on these decisions, work first began on the University's Autonomous Land Experimental Robotic Testbed (ALX), which is based on a Yamaha electric golf cart. Later, as a result of discussions with Navistar during the preparation of the TRP proposal, the decision was made to purchase a Navistar semi tractor to be used as an experimental testbed for large scale evaluations of technology to be used in autonomous highway vehicles.

Vehicle sensing and control research underway at the University include a study of a Differential Global Positioning System (DGPS) used to determine vehicle location for navigation purposes, a sonar sensor based obstacle detection system which is used to implement collision avoidance behaviors, the development of collision avoidance behaviors, and an effort to develop a machine vision system capable of identifying lanes in a variety of environments. Considerable effort was expended in preparing ALX for the Second Annual Student Unmanned Vehicle Competition which was held in conjunction with the 1994 AUVS meeting in Detroit. Unfortunately, due to a power supply failure on ALX, the vehicle was unable to compete. Had the power supply not failed, we are confident the vehicle would have finished in the top three. Lessons learned on ALX will prove highly valuable during the semi tractor-trailer experimental testbed system integration.

ALX is equipped with the same computer hardware, computer software, and operating system as will be found on the semi tractor experimental testbed. This was done for a number of reasons. First, using control hardware, software, and operating systems on the golf cart which are similar to those found on the truck affords familiarity to the student and other researchers, eliminating the learning curve for those who move on to the experimental semi tractor-trailer. Second, developments successfully implemented and refined on ALX may be ported to the experimental semi tractor-trailer with the least possible effort. Third, the hardware used on both ALX and the experimental semi tractor are the same as what is used in the Department of Defense-ARPA Demo II projects. Compatibility with ARPA's standard proves beneficial when applying for Defense Conversion (i.e., TRP) Funds.

The tractor to be used for the experimental semi tractor-trailer testbed has been modified to Mn/DOT requirements as set forth by Dave Johnson and Dave Stregge. Discussions have been held with both Eaton and Bendix in an attempt to acquire a Traction Control System/Anti lock Brake System (TCS/ABS) for the tractor. Bendix has tentatively responded with an offer to provide a Electronic Control Unit (ECU), modulator valves, wheel speed sensors, a wiring harness, and installation. Word has not been returned concerning software and hardware support.

After the truck is equipped with TCS/ABS, it will be shipped to the Twin Cities so that Alliant Techsystems may begin the system integration. System integration consists of determining the system architecture, purchasing required hardware and software, building necessary mounts, brackets, and wiring harnesses, and installing them on the truck and in the sleeper cab. System integration and system debug is expected to take 8 months after delivery of the truck. University personnel will assist and provide guidance to Alliant Techsystems during the system integration

time period. With the integration phase complete, the truck will be able to autonomously follow a route around the Mn/ROAD facility using onboard computer control and sensor technology. A driver will be in the truck *at all times* to monitor the status and performance of the control system.

In addition to the development and acquisition of ALX and the experimental semi tractor-trailer, respectively, four documents were completed. The current state of the art and applicability of automotive radar was investigated in [RADAR, 1994]. Through this work, potential vendors for the radar system to be installed on the experimental testbed were identified and contacted. From these discussions, a potential evaluation plan was developed. The present state of collision avoidance systems was discussed in [CRASH, 1994]. Numerous other programs were investigated, including those undertaken by NHTSA's Office of Crash Avoidance. The research program outlined in [CRASH, 1994] reaches beyond the work currently undertaken, and will make significant contribution to the collision avoidance knowledge base. Two proposals were also prepared under this contract. The first, [TRP, 1993], outlined a four year vehicle control and driver monitoring research program which if successfully implemented would offer considerable safety benefits to vehicles and drivers on rural interstate highways. The TRP proposal was not successful in absolute terms, but did foster relationships with the American Trucking Association, truck manufacturers, technology vendors, trucking companies, and Mn/DOT. The TRP effort also demonstrated that we are able assemble a consortium to support our work. The second proposal, [Mn/DOT, 1994] was more successful in absolute terms. This proposal described a one year program in which vision based lateral control and radar based collision behaviors would be integrated into a driver supervised vehicle control system. This proposal passed technical muster; TACOM has indicated that this proposal is first on the queue to receive funding for FY 1995 if sufficient new funds can be identified. The project proposed to TACOM would make extensive use of the Mn/ROAD facility.

III. Future Work

A continuation of the work performed for this contract is proceeding at the University of Minnesota. The continuation consists of three phases: the development of a computer based simulation environment used to perform mathematical and graphical analyses of vehicle control and sensing strategies, the continued use of ALX to develop and test novel collision avoidance technologies and strategies, and the development and subsequent research involving the semi tractor-trailer experimental testbed.

The simulation environment provides a low cost, no risk means with which to develop and evaluate novel vehicle control and collision avoidance strategies. One important feature of the simulation environment is that it will be developed in a manner which will allow humans to interact with simulation models of computer controlled vehicles. Public acceptance of vehicle control systems will involve both those who purchase the control systems and those who do not. For the successful deployment of computer controlled vehicles, human and machine interaction must not interfere with the normal patterns of traffic flow. Early use of the simulation environment will allow the design of systems which will function with minimal inconvenience to human operators.

ALX provides a low speed, low risk hardware platform with which undergraduate and graduate students can develop, test, and evaluate novel vehicle control technologies and strategies. ALX offers state of the art computer and sensor hardware in a lightweight, relatively safe vehicle. Full support of ALX is provided by a cart mounted mobile workstation, complete with generator. The semi tractor-trailer experimental testbed provides a means with which to develop, test, and evaluate control strategies optimized for highway applications. The intent is to use ALX and the experimental testbed sequentially. Initial research and development will be performed using ALX; once proven and refined for larger vehicles and higher speeds, vehicle control strategies will be ported to the experimental testbed. Because ALX and the experimental testbed use the same control computers, operating systems, and interfaces, the effort to port should be minimized. Details regarding how ALX and the semi tractor-trailer experimental testbed will be use for actual research are provided in [TRP, 1993] and [Mn/DOT, 1994].

IV. References

- [TRP, 1993] "The Smart Truck Consortium: Sensing and Control to Enhance the Safety and Driveability of Large Trucks," Proposal in Response to the Technology Reinvestment Program (TRP), July 1993.
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- [CRASH, 1994] "Collision Avoidance: Smart Trucks on Rural Roads," Mn/DOT Report #95-11, March 1995.

