Vision Guidance Development for a Ground Robotic System

Akihiko Kumagai, Shamala Chickamenahalli,
Aju Mathew, Sanjeeve Sharma, and Robert Thompson
Wayne State University

Abstract

This paper describes a student project that involved the design and construction of a ground robotic system guided by a vision system. The project has been carried out by students in Engineering Technology, Electrical and Computer Engineering, and Computer Science. The project has served to meet the senior project requirement of several of the students in the division.

The construction of this experimental robotic system is based on a golf cart. A 3.5 horsepower DC motor powers the movement of the vehicle. A CCD camera mounted at the front part of the vehicle captures the road image and this image data is sent to a PC. Then this PC processes the acquired image and transmits a command signal to a stepper motor system controlling the vehicle's steering wheel for direction control. Through this project, students experience building of a mechatronics system and implementing a software system that commands the functions of various components in an orchestrated manner. This system building experience will be a great asset to these students who will work in the extremely high-tech multi-disciplinary industrial environment of today and in the future. The project is also aimed at the international student competition event for this type of robotic vehicle. By setting a goal like this, students learn how to work in a team, which is another essential skill required in the real world. The paper will describe this project's coordination, management and cooperation that were handled by the students under the guidance of the professors.

The technical part of this paper focuses on the development of the vision guidance navigation algorithm. This algorithm is designed to navigate the vehicle along a course prescribed by the left and right boundary lines. The CCD camera of the vehicle captures the images of these lines within a rectangular image window. Then a light intensity profile along a horizontal line drawn across this rectangular image window is obtained. The motion command to the steering wheel stepper motor is generated by comparing the centroid of two light intensity peaks representing those boundary lines to the current orientation of the vehicle.

I. Introduction

Towards closing the competency gaps in technical and communication skills in emerging graduates, industry has begun expecting the engineering and technology curricula to instill the overall qualities in the emerging graduates, such that a product development cycle goes smoothly in industrial settings. Nationwide several programs have begun collaborative and cooperative programs to strengthen the oral, written and team skills in the students. The growing importance of teamwork amongst multidisciplinary student population is evident from the numerous papers available in literature. The SAE Energy-Efficient vehicle design is one example of student design competitions that promote student contribution in engineering design of a product [1]. Students have designed, constructed and tested a solar-electric boat [2]. Robotics has been a very appropriate field where multidisciplinary teams can work together and get a product design experience. It is also an excellent interdisciplinary field that involves efforts from students of electrical/electronic, mechanical and computer engineering and computer science fields. Regular semester robotics courses highlighting microprocessor applications and stepper motor applications in robotics are offered at institutions [3, 4]. Also projects in robotics have been perceived as special channels through which learning in engineering and computer science education is enhanced [5, 6]. Drawing attention of engineering and technology students nationwide and around the world is attempted through several competitions. The international Autonomous Ground Vehicle competition held every summer is where students have an opportunity to demonstrate their original design, development and team skills [7]. Apart from these, several regional competitions held to increase student participation [8] are reported. The FIRST robot competition that involves high school students has gained increased appeal [9]. A model for participants and instructors about treating outcomes of highly competitive competitions is well-reported [10].

This paper concerns an inter and multidisciplinary team development of a robot ‘Wayne Rover’ (Figure 1) at Wayne State University. Challenges that the project has created for students and faculty in several departments since its concept grew from a golf cart, and its first entry in the Autonomous ground vehicle competition in 1997, are detailed. The team experiences, the learning and the enormous opportunities it constantly generates, and the key elements are discussed in a somewhat technical tone. Educational content, student role and current status of the project is provided along with the possible future challenges.

II. Vehicle Design

The vehicle consists of mechanical and electrical modular components commonly used in today’s industrial applications. This modular based design allows a number of students to work at the same time but pursuing his/her own part of responsibility without interfering others’ work.

Figure 1 Wayne Rover

In addition to this advantage of task clarification and separation, troubleshooting of a modular system like this can be systematically performed as each module component has its own diagnostic routine. Therefore a troubled module can be quickly identified and isolated. In the Detroit area where Wayne State University is located, the demand of system engineers is very high. The experience from this project to build a system should greatly help students to increase their chance of getting the good technical jobs they want. It also gives them confidence going into the real world.

The base vehicle used for this project is a golf cart, Textron EZ-GO Model X444. The outer shell of the original vehicle was removed and a rectangular aluminum platform was installed on the vehicle. All major modular components are laid out and mounted on this aluminum platform, approximately 32 inches high, so that debugging and maintenance work is performed ergonomically.

Figure 2 shows the hardware diagram of the navigation system. A CCD camera, Pulnix TM-7CN with 3.5-mm wide-angle lens captures a sequence of road images. This image data is sent to the frame grabber board, DT3152 inside the host PC. Based on the algorithm described in the next section, the host PC outputs the digitally coded command signal to navigate the vehicle first to the Velleman K8000 I/O board. Then the I/O board sends this digital navigation code further to the stepper motor system, API M343 stepper motor with API 315x indexer/driver, to manipulate the steering wheel mechanism. The speed of the vehicle is measured by a tachometer installed at a back wheel of the vehicle. This analog signal is sent to an analog input port of the I/O board. Then the host PC sends signal to the DC/DC converter to control the speed of the vehicle based on a PID control scheme.

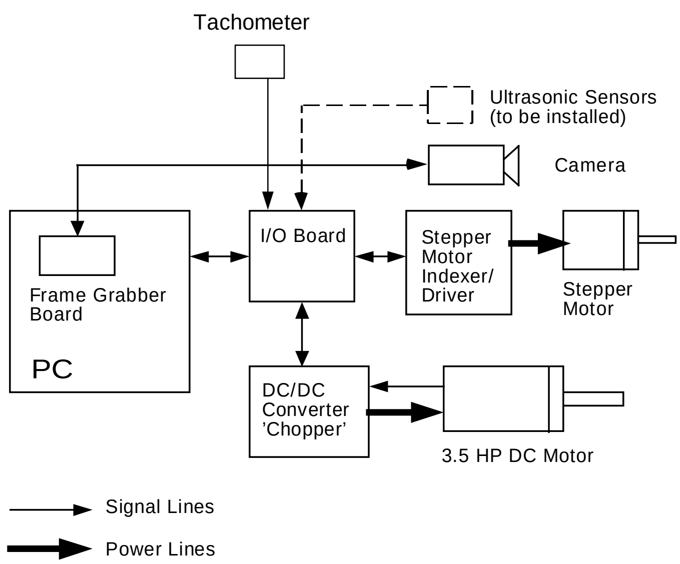

Figure 2 Hardware diagram

III. Development of Navigation System

The objective of the navigation system is to make the vehicle follow along a course given by two white lines. The process of navigation starts from taking a road image using the CCD camera described earlier. The CCD camera is mounted at the front part of the vehicle in a tilted manner to capture the front vicinity image of the vehicle (See Figure 3). An example of a captured image is shown in Figure 4.

The concept of our current navigation scheme is to first draw a horizontal line within the 480 × 640-pixel array image window as shown in Figure 4. Then along this horizontal line light intensity represented by 0 to 255 gray scale value is plotted. We call this plot as a line profile. The line profile of the road image of Figure 4 is shown at the lower right corner of the same figure. Two white lines are observed as two peaks using this line profile scheme. The navigation command (degree of left or right turn) of the vehicle at a given moment is generated by comparing the current direction of the vehicle and the centroid of these two peaks representing two white lines. The current direction of the vehicle is indicated by the vertical center line of the rectangular image window (vertical line at 320 (x) in the 480 (y) × 640 (x) rectangular image window). If the centroid is on the left of the center line, the vehicle is turned left. If the centroid is on the right of the center line, the vehicle is turned right. Depending on how far the centroid is located compared to the vertical center line, the sharpness of turn is calculated.

The program development for this navigation scheme is done using C++ to customize the vision software called Hlimage++. Since the summer of 1998, the vehicle has been autonomously functional using the navigation scheme described above. The current navigation development group consisting of three students has the following plan to improve the navigation capability including obstacle avoidance.

- Use of multiple horizontal lines for line profiling. The purpose of this modification is twofold. The first is to increase reliability in white line detection in case one line profile failed to detect it. The second is to obtain more spatial data for navigation.
- Study on visual characteristics of some selected obstacle objects using line profile, ROI, bob analysis, and filtering tools provided by Hlimage++. This visual processing data will be used for developing an obstacle avoidance scheme.
- Installation of an ultrasonic sensor system to detect obstacles. The signal from ultrasonic sensors will be combined with the image data from the vision system to give an appropriate obstacle avoidance decision.

We also have a plan to output the navigation command based on the image data using a neurofuzzy software package such as MATLAB’s Fuzzy Tool Box.

IV. Student Role and Educational value

The project has involved participation of undergraduate and graduate students from engineering technology (ET), electrical and computer (ECE) engineering and computer science departments. Over the past two years, this project had active involvement of at least ten undergraduate ET students including minority and women and ECE students and four graduate students. The

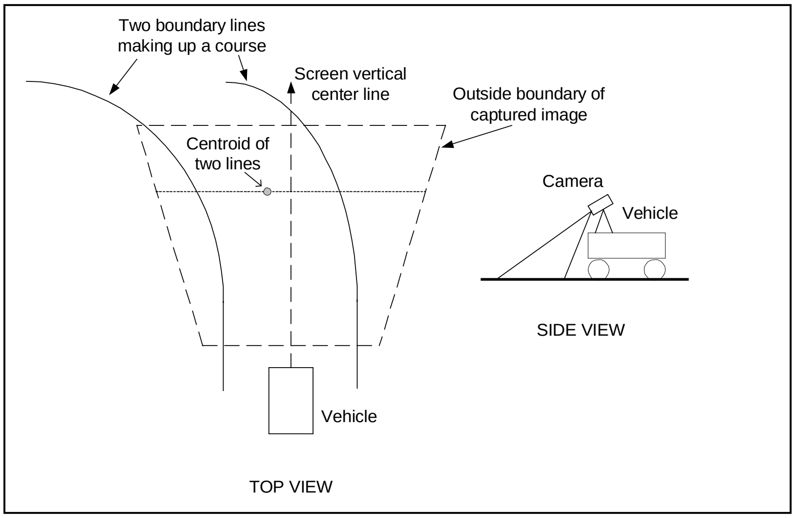

Figure 3 Road image capturing using a CCD camera

students began this work by first converting the golf cart into the future ‘Wayne Rover’ by repainting the body, and removing the seats and the other not required mechanical parts. As a second stage, they designed a top platform surface to enable mounting of the computer with the vision board, control computer, the camera, parallel I/O board, stepper motor controller, dc motor control chopper, control relays and the emergency brake system. Two students brainstormed and arrived at the scheme for remotely controlling the vehicle using a ‘Remote control Toy’. One of the students designed the scheme for interfacing the stepper motor signals from the control computer to the stepper motor controller. Another student designed the emergency stop scheme of the vehicle. One student designed the layout of all the components and carried out the wiring of the power, control and signal circuits. The initial fixed step stepper motor steering angles to respond to commands from the control computer were developed by another student.

Two graduate students with background in Visual C++ established the communication between the stepper motor control computer and the vision guidance computer. Two more graduate students are currently enhancing the C++ programs for accurate autonomous mode of operation. The faculty advisor and the co-advisor play an important role in advising, guiding and insuring progress of the project. The local SME and the local TACCOM branch have been supportive of this project. Students have also assisted in demonstrating the vehicle guidance to TACCOM authorities and at a regional SME meeting last month. The project has also gained wide spread recognition within the college of engineering at WSU and has received some funding. The donations from SME and others are utilized to procure the components for the project. One of the active minority participant students, was a recipient of the WSU NSF-AMP program. Project components fulfill the senior project requirements in the division on a regular basis.

V. Impact and Future Challenges

The impact of this project is several folds. Discussions, team efforts, co-operation, and communication amongst team members and with the professors have begun to impart greater

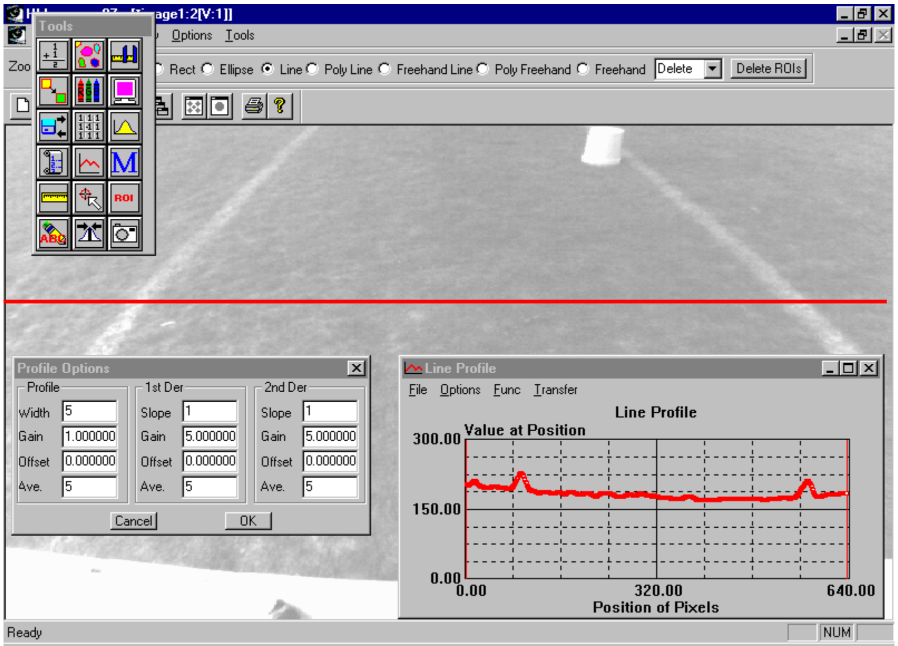

Figure 4 Example of captured road image

confidence levels in students and in presenting themselves. Commercially the project helps their preparation to market themselves better and fulfils the requirements of present day employers. The experience provides them exposure and experience in product design, computer hardware and software, industrial electronics, troubleshooting, real-time data communication, etc. It also strengthens the hands-on experience of students.

The project serves as a model for the WSU College of Engineering in addition to the other projects and to the division of engineering technology students in particular. It provides an opportunity for the professors to effectively interact with students. It also results in advancement of research in robotics, Mechatronics, electric machines, industrial electronics, and significant scholarly publications. This being a student-centered project provides the professors with occasions to be observers and only provide guidance when needed. This example also proves activities at divisions where funding for research is possible.

VI. Conclusions

A student project that involved the design and construction of a ground robotic system guided by a vision system is described. A project being carried out by students representing Engineering Technology, Electrical and Computer Engineering, and Computer Science is discussed. Student and faculty roles and educational impact are highlighted. The continuing importance of this project in instilling better hands-on opportunities for emerging graduates from engineering and technology programs is emphasized. Endless opportunities for students and professors in robotics, industrial electronics, and electromechanical disciplines are identified.

VII. References

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AKIHIKO KUMAGAI
A. Kumagai is an Assistant Professor of Engineering Technology at Wayne State University, Detroit, MI. He earned his B.S. and M.S. in Mechanical Engineering from the University of Florida in 1983 and 1985 respectively, and his Ph.D. in Mechanical Engineering from University of Wisconsin-Milwaukee in 1993. His current teaching and research interests include manufacturing, kinematics, dynamics, robotics and controls. Prior to joining WSU, he worked for Motorola and United Technologies Automotive to pursue various Manufacturing and Automation related projects.

SHAMALA CHICKAMENAHALLI
S. Chickamenahalli is an Assistant Professor in the College of Engineering at Wayne State University, Detroit, MI. Dr. Chickamenahalli is PI of a NSF-sponsored Greenfield coalition project in electric machines. She received a bachelor and master of electrical engineering degrees from, India, in 1983 and 1986. Dr. Chickamenahalli obtained a Ph.D. in electrical engineering from the University of Kentucky in May 1995. She worked in industry for four years.

AJU MATHEW
Aju Mathew is a graduate of Wayne State University. He received his Bachelor of Science degree in Electrical Engineering Technology in May 1998. He is currently working as a Controls Engineer for Patti Engineering, a systems integrator located in Rochester Hills, MI.

SANJEEVE SHARMA
Sanjeeve Sharma is a graduate of Wayne State University. He received his Masters of Science degree in Computer Science in December 1998. He is currently working as a computer engineer at Flextronics International in San Jose, CA.

ROBERT THOMPSON
Robert Thompson is an undergraduate Electrical Engineering student in the College of Engineering at Wayne State University, Detroit, MI. He is pursuing a bachelors degree in the areas of Electrical and Computer Engineering. He is actively involved in micro-controller, computer-camera control and vehicle network research at the University.