A ROBOTIC PLATFORM FOR STUDENT SYSTEM DESIGN

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ABSTRACT

The goal of the project described in this paper, is to develop a platform for undergraduate engineering students to use in system analysis and design courses. We chose to develop an inexpensive robotic platform. The robot is intended to be autonomous, under the control of an on-board microcontroller. In the first revision of the hardware, a three wheeled design will be used, with the intention of being used indoors, on smooth surfaces. Students in their first year of college education will purchase the components, and assemble the robot. After analyzing the baseline design, they will be encouraged to incorporate new sensors and actuators in the subsequent laboratory courses.

Keywords: System Design, Mobile Systems, Robotics

INTRODUCTION

One of the challenges the telemetry community faces, is locating new talent that has an interest in – and ideally experience with – system level design, integration, testing and evaluation. Traditional college level laboratories give students experience working with test equipment, and help them understand many of the engineering principles taught in lecture courses. However narrowly focused laboratory experiments do not necessarily prepare students for system-level design. Another difficulty with highly focused laboratory experiments is that while they may be a necessary part of a student's education, many do not find them very motivating. This can influence the attrition rate, and reduce the number of highly qualified individuals who will choose to complete their engineering studies.

Many universities with science, technology, engineering and mathematics (STEM) emphasis have outreach activities intended to attract pre-college students into the STEM areas [1]. Attitudes toward various careers are often formed well before students enter college. The U.S. Education Department's National Center for Education Statistics recently indicated that fewer than half of high school seniors were enrolled in a science class [2]. In 2006, the National Science Board reported that approximately one-third of 4th and 8th grade students, and even fewer 12th grade students, could demonstrate proficiency in mathematics and science categories on assessment exams [3]. These statistics show that high school students lack interest and motivation in these technical areas. This trend, if left unchecked, could limit the amount of promising new talent available to the telemetry community.

Pre-college education programs seek to promote interest in STEM careers by improving coursework, as well as encouraging participation in "hands-on" and extracurricular activities. One high profile program in this area is the FIRST Robotics Competition [4]. The goal of the project described below, is to address the same area, but with a lower price point that would make it available to a wide range of both pre-college programs and college-level laboratory courses.

The project will provide students with a system-level design experience, using an inexpensive robotic car platform. The high level project goals are to excite summer camp students in engineering, to easily implement laboratories in correspondence with the car that will teach engineering students real-life applications of basic electrical and computer engineering principles, and to create an affordable product for universities and students alike to purchase and create. The proposed robotic car solution which will be outlined in the following section would allow students to create a car that could map an environment, follow a given path, and sense different aspects of its environment.

ROBOTIC CAR SOLUTION

The robotic car solution developed in this project will use a variety of digital and analog electronics, along with sensors, motors, and mechanical actuators to perform various tasks. Students will gain experience identifying, assembling, using and destroying many the components that they will encounter later in their education and professional careers. Hopefully this physical contact with the components will help them understand and visualize how systems operate – more so than being introduced to new components through the use of schematic drawing symbols.

To insure the robotic platform is inexpensive, and portable, it will be powered by conventional AA rechargeable batteries. Students will gain experience in characterizing the battery performance over a charge and discharge cycle, along with building a voltage regulator to power the remainder of the device. Safety issues regarding batteries will also be addressed during the development.

As currently envisioned, the car will have three wheels. This design was chosen to keep the cost of the car as low as possible. With three wheels, it will not be necessary to use a suspension system. The two front wheels will be independently driven, while the rear wheel will be a free-spinning roller or caster. Each of the front wheels will be connected to a gear box coupled to a low power DC servo motor. The motors will operate independently of each other, and can be driven in the forward or reverse directions through the use of dual H-bridges.

The car will be able to sense the color of the surface it is traveling over, through the use of infrared (IR) sensors. An array of IR sensors will allow the robot to perform line tracking tasks, and can also be useful to determine when it is crossing into a new area, or has reached a predetermined boundary. An optical sensor, such as those found in optical mice, will also be included on the underside of the car. This will allow the car to determine its motion relative to the floor, but will not provide information on the color or texture of the surface. Additional optical sensors may be placed around the perimeter of the car, for obstacle detection and avoidance.

There are plans to include a 2-axis accelerometer on the car, to assist with inertial navigation. This may also also help to determine when the obstacle avoidance devices have failed. One of the projects will use the IR sensors, mouse tracking sensors, and accelerometers to develop a map of the environment, which should allow the car to avoid obstacles in the future. The variety of sensors will also give students experience with sensor data fusion, and the issues that come up when inconsistent measurements are made by different sensors.

The platform will be controlled autonomously, using an embedded microcontroller, in other words it will not be remotely controlled by a person or computer. The current plans are to use an 8051 based system. The primary communication, and programming, of the microcontroller will be through a universal serial bus (USB) connection, although wireless Ethernet, or other RF or IR communication links may be added in the future. Figure 1 shows how the components of the robotic car solution will connect and communicate.

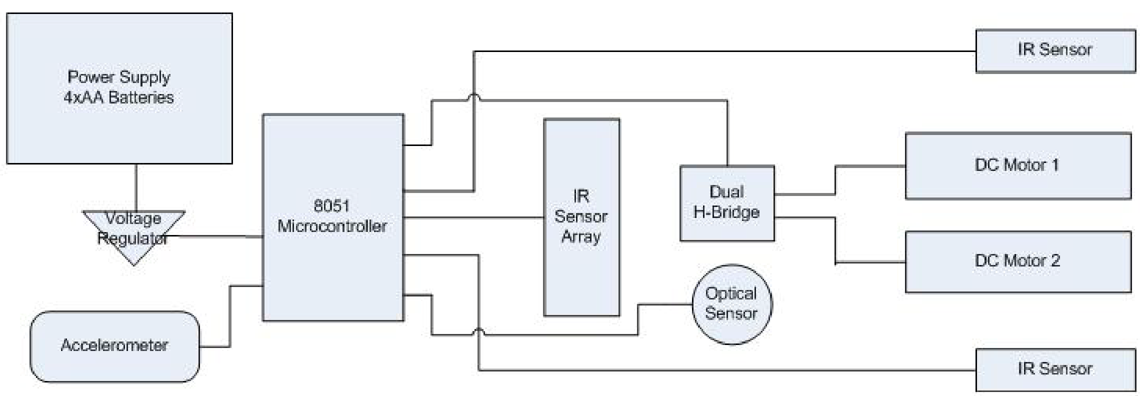

Figure 1: Component Diagram of Robotic Car Solution

The hardware and software design of the car will be open source. In addition there will be unused I/O ports on the processor, and experimental space left on the printed circuit board, to encourage students to add sensors and actuators at a later date.

To keep the cost low, the car will be designed to be used indoors on smooth surfaces. This should be sufficient for both summer camp / outreach activities, and typical college-level laboratory experiments. The target price point for the components of the car is $125 to $150, which is approximately what a student would spend on a textbook for a class.

There are a variety of platforms that provide somewhat similar functionality. For example the inexpensive OWI Weasel Robot enable line following and obstacle detection, but do not have the sensor functionality to allow mapping and do not include an accelerometer for physics type data. Many preexisting solutions are either very expensive or do not have enough functionality to provide a variety of potential engineering laboratory implementations. The following Table 1 compares some existing robotic platforms to the platform developed within the scope of this paper.

Robotic Platform	**Line Following**	**Obstacle Detection**	**Mapping Sensors**
Robotic Car Solution	Yes	Accelerometer	Optical Sensor
Weasel Robot by OWI	Yes	Bump Switches	N/A
TekBot by Oregon State Univ. [5]	Yes	Bump Switches	N/A
CEENBot by Univ. of Nebraska-Lincoln [6]	N/A	Optical Sensors	N/A
LabRat by Rolla Engineering [7]	Yes	I/R and Bump Sensors	Optical Sensor

Robotic Platform	**Controlled**	**Charging**	**Cost**
Robotic Car Solution	Self	Rechargeable NiMh	$125.00
Weasel Robot by OWI	Self	AA Batteries	$23.00
TekBot by Oregon State Univ.	Self	Rechargeable NiCad	$125.00
CEENBot by Univ. of Nebraska-Lincoln	Remote	NiMh or NiCd	$175.00
LabRat by Rolla Engineering	Self	AA Batteries	$175.00

Table 1: Comparison of Robotic Platforms for Students

As shown by this table, while some other designs such as the TekBot can compare in cost to the proposed design, it does not have the same variety of sensors that can be utilized for different laboratory experiments. However, the TekBot solution does enable buyers to add in additional sensors for an extra cost. Other solutions that have similar sensor functionality as the proposed solution do not compare in cost. While developing the prototype for the robotic car, it was determined that developing an inexpensive design would be a high priority, so students would have the financial capability to afford the design. By developing and implementing this new robotic car solution, sensors were able to be hand-picked to create an inexpensive yet feasible solution.

IMPLEMENTATION

In order to formulate and implement this project solution, the first step was defined as to research and acquire the parts needed to construct the robot. All of the sensors, motors, microcontrollers, and electrical pieces desired will be collectively chosen based on their electrical requirements and experimental capabilities.

Next the design of the robotic car must be created as well as the printed circuit board for the car. Upon completion of these two tasks, the car must be put together and tested to make sure that it is capable of functioning. Once the robotic car is connected, the cars functionality must be developed. The first challenge is to interface the motors with the microcontroller to make sure the car can correctly navigate basic directions: forward, turning, and reverse. Next an algorithm will be developed and implemented that will enable the car to follow a black line on the ground.

The next goal will be determining the motion of the robotic car. The direction of movement for the car will need to be refined so that later, once a mapping algorithm is developed, it will be capable of creating an accurate map of the car's surrounding environment.

The last tasks that will need to be completed to implement this robotic car solution are development of the mapping and obstacle avoidance algorithms. The mapping algorithm will make a map of the environment that the robot is in based on the direction that it is moving. The obstacle avoidance algorithm will enable the robotic car to move around obstacles that it contacts.

ASSESSMENT

Projects such as this can provide a very educational experience that many students, giving many students a base knowledge they can hold onto and use while attempting to learn how the individual parts of the robotic car works. Jumping into mathematical theory is not necessarily the best way to fully understand how an object works. Summer camps can easily give a hands-on and knowledgeable experience of how the pieces of a device works and this device was specifically created to be used in this type of situation. Many people that find a career in technology found themselves taking apart and analyzing devices to better understand them at early ages. This robotic car is easy enough to assemble that one does not need heavy understanding of each part, but also complicated enough to give them a diverse learning experience. One does not always have to know how each specific component of a device works as long as a working model is created which enables observation of the goal and duty of each part.

The learning experience with this device does not end at summer camps however. As this robotic car uses devices used in modern equipment, students in Electronic Circuitry courses will find themselves using circuitry they have learned about in theory and potentially have not had the chance to test. The infrared detectors could individually be used in a laboratory to determine output differences based on what colored surface the detector is traveling over. The observable power needed for each individual device gives ample opportunity for different types of experimentation. Learning how to read levels of supplied power and using different devices to lower the voltage supplied to different devices is a valuable lesson in itself.

As shown, the robotic car takes several algorithms to perform its functions. One function that could be examined in a lab is the infrared detection function. The infrared detection function could be implemented by trial and error based on the positioning of the infrared detectors on the car. When trying to make an algorithm that would follow a colored line on a floor, it could take students several tries to develop an algorithm that can follow sharper turns based on which IR detector first noticed a change. Accelerometer functionality also has the potential to initiate a few more algorithmic optimization experiments or even some physics type experiments. The accelerometer is mainly used for obstacle detection, and students in a laboratory environment could differentiate readings that should result from the car hitting an object, and readings that should result from the car slowing down or decelerating to a stop. The difference in these situations are needed to be known when using the accelerometer within the mapping algorithm. All in all, a diversity of experiments can be created within the scope of this robotic car.

CONCLUSION

This paper described the motivation for, and initial design of, an inexpensive robotic car which can be used in pre-college recruiting activities, and university-level electrical and computer engineering courses. The car will operate under the direction of an embedded controller, and will have a variety of sensors to provide it information regarding it's environment.

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