DESIGN OF AN AUTONOMOUS ROBOT FOR A SIMULATED SEARCH AND RESCUE GAME

By: Jared Dunning and Justin Moore

ABSTRACT

Robots play an important role in search and rescue missions as they have the ability to navigate through hazardous terrains and reach victims that a human rescuer may have trouble reaching. This paper presents detailed design of an autonomous robot to perform search and rescue mission on a game field. The primary design requirement is to locate and transport two red and two yellow wooden cylinders representing causalities to their drop-off zones as quickly as possible. The cylinder colors represent severity of victim injuries with red being severe and yellow being less severe. A major design challenge was to select a suitable microcontroller. A PICAXE-40X2 microcontroller was selected due to its small footprint, large onboard memory and faster processing. Ultrasonic sensors were mounted on the robot to detect any obstructions in its path. A Pixy (Cmucam5) camera module was used as a fast vision sensor to detect the colored cylinders and guide the robot to their locations. A servo-controlled catcher was installed to lift and hold the cylinders during travel to the drop-off zone. A UAFS student team will field this robot in the forthcoming IEEE Region 5 Annual Meeting Robotics Competition to be held in Kansas City, Missouri.

INTRODUCTION

In late October 2016, a group of Electronics Technology students laid plans to field a competitive robot in the 2017 IEEE Region 5 robotics competition held in Kansas City, MO. There were many hurdles to overcome especially since our university has never built or fielded a competitive autonomous robot. The competition was a simple “search and rescue” operation in which the robot must navigate a maze of walls and obstacles to locate simulated disaster victims and return them to simulated evacuation points. The victims were colored red or yellow (red representing a more severe casualty) and they were to be returned to their respective red or yellow evacuation point. Teams were scored based on the number of victims rescued and the time necessary to complete the tasks.

DESIGN DETAILS

To begin this project, considerable research was necessary to create the best solution to the problem of sorting colors into binary values that a machine can process. Two plans were developed to solve this. The first was to reverse bias LEDs and use reflected light from the colored object. By passing light of a certain color through a color filter and into a reversed biased LED, a small current fluctuation appears through the LED of that specific color. By amplifying the current change and digitizing the result, we would have a moderately effective method for detecting color.

The second method was significantly easier. The PIXY CmuCam5 is a self-contained color and shape recognition digital camera that processes images with on-board software and outputs only the relevant information via serial communication to the user’s processor. From there, this data can be used to provide the robot with the data necessary to locate and extract the colored block. While this solution seems simple, enormous amounts of time were spent learning to decode the information sent and creating a program to deal with the substantial amount of data being sent to the processor. We chose only to use the data most pertinent to our task; the "X" coordinate, the signature number, and the distance of the object. Other data was disregarded.

For the main processor, we had myriad options available to us but we chose a simpler solution due to the low level of expertise of the students involved in this project. Arduino seemed the most obvious solution but it requires knowledge of a language which none of us were familiar with. Revolution Education provided a simple solution. Based on the Microchip brand of PIC microcontrollers, the PICAXE system allows almost full availability of features but using a much simpler BASIC language structure that is more reflective of our level of skill. The 40 pin PICAXE 40X2 microcontroller was selected for its available input/outputs and its speed as well as large memory capacity and overall durability. It allowed us to easily create programs for solving the individual tasks outlined for this competition.

To allow us to sense the walls of the course, we selected the HC-SR04 ultrasonic modules which use echo location (40kHz ultrasonic signal) to determine the distance to nearby objects or walls. This method is reasonably accurate at distances of a foot or more but that accuracy decays the closer the sensor is to an object.

To power our machine's movement, we originally used a direct drive setup that had the power for the wheels taken directly from the motor's output shaft. This design was cancelled in favor of a geared motor setup that allowed the robot greater control over low end torque and the acceleration/deceleration curve. We selected 4 Jameco Reliapro Gearhead motors (12v) each mated to a 3.15" wheel with rubber tread tire. These motors create large torque figures and can accelerate/decelerate in mere milliseconds. With all four wheels powered, our robot could scoot along at high speed while being nimble enough to navigate the tight course.

To control the motors, we selected an H-Bridge circuit built by the team. While this worked relatively well, it lacked the accuracy we had originally hoped for. It was scrapped in favor of the L298N motor driver module which featured higher power output and 2 separate channels of motor control. This unit allowed the motors to turn in forward or reverse completely unhindered and fully independent of the other motors. PWM (Pulse Width Modulation) was used to control the speed of rotation of the individual motors.

We employed a custom power supply module that provided a filtered and regulated 5 volt output for all of the components. Filter capacitors on the input and output sides of the regulator module gave a smooth and ripple free voltage from the 9.6 volt NiMH battery pack. The battery pack is extremely compact and its unique "nun chuck" configuration allowed us freedom to mount the battery in any location that seemed stable. With 2000 mAh capacity, this pack would power our robot for close to an hour of continuous use.

The gripper appendage comes from the LynxMotion family of robotic actuators. Mated with a servo, this unit has a strong grip. We chose the Futaba s3003 high-torque servo for its low current draw and high 101 oz/in of holding power. We mounted the gripper loosely on a flexible mount that, when gripper is closed, provides both a solid grip and a lifting motion to pick the victim up from the floor of the playing field. This method gave us the benefit of finding a hardware solution to a potential software problem. Clever design can negate the need for additional software to regulate extra motions.

Finally, the chassis was designed to be semi-octagonal in shape to make maximum use of the 8"x8" footprint of the chassis while still allowing it to rotate within the confines of the playing field. We found polystyrene plastic to be very easy to work. Using only an Exacto knife and a ruler, we scored the plastic and simply snapped off the parts we needed. Epoxy adhesive holds the chassis together while hook and loop fasteners allowed us to build the machine in modules that could easily be removed and replaced.

PROTOTYPE TESTING

To properly examine the selected components a full scale mockup of the playing field was built and a test "mule" was built from stiff cardstock. All test parts were fitted to this chassis for evaluation. During this period of experimentation, numerous problems arose. We discovered that the ultrasonic HC-SR04 sensors were very prone to interference. Coupled with their poor sampling rate, these modules are not adequate for the tight confines of the course and aren't capable of keeping up with the motion of the robot. We had to reconfigure the mounting point of the Pixy camera several times to obtain optimal field of view while rejecting environmental "noise". This is another example of a hardware solution to a software problem.

We encountered problems with the motor control circuit we built. The H-Bridge circuit we used was delightfully fast but, although it was controlled digitally, it contained no short circuit protection. As a result, a simple error in coding the processor can burn up the circuit. We experienced this problem which rendered our circuit useless so we began working with the L298n motor driver module instead. This controller had built in protections and was also digitally controlled and we experienced no further problems with it.

Our original design had the drive wheels mounted directly on the output shaft of a 12 volt motor. This configuration was intended to save space as it contained no gear drive of any kind. Testing proved that this design is inherently flawed due to the broad acceleration/deceleration curve. When navigating a tight course, it's important to be able to start and stop movement instantly. With no gearbox, the momentum of the robot caused it to roll for several inches after the stop command had been issued. This setup was scrapped in favor of a slightly less powerful motor/gearbox combination to allow the robot to halt its movement instantly.

For electrical power, our team agreed that a nickel-metal hydride (NiMH) battery pack would be sufficient. Our original choice was a sub C, 6 cell, 7.6 volt, 3000 mAh pack. While power supply was adequate, testing showed that the heavier battery made turns more difficult. Our next and final choice was a sub AA, 8 cell, 9.6 volt, 2000 mAh pack. This pack was much lighter and came in a configuration that allowed us to test many different mounting positions to obtain optimal turning. Since our robot drew a maximum current of 2 Amps, this battery would power the machine for 1 hour of continuous use.

Originally, the gripper was powered by a standard Futaba s-servo with a torque of 42 oz/in. This servo was powerful enough to grip the victims but had no power left to lift. We switched it out with the Futaba s-3003 with a torque of 101 oz/in. Current draw was slightly higher with the more powerful servo but remained within the limits of our power regulator module's 2.4 amps limit.

COMPETITION

The competition was held on April 9th at the Intercontinental in Kansas City, MO. Three competition fields were assembled in the hotel's ballroom with work stations for all teams in attendance. Teams were allowed access to these facilities for the entire evening prior to the competition and many teams, such as ours, worked throughout the night running tests and debugging code. 34 teams were registered but a few weren't in attendance. Many teams left before the competition began due to component failures and poor design, and even more were unable to field their machine as a result of coding issues. Our robot ended the competition ranked 19th.

CONCLUSION

While we had hoped for a better overall score, we are certainly proud of the work we have done and the manner in which we represented our university and our program. We learned that the competition was not simply about who could score the highest. It quickly became obvious to us that designing and building a prototype is a very daunting task. A task which several of our competitors could not overcome. Our research was effective at teaching us the advantages and limitations of the various components and design choices we made as a team. Moving forward, these types of projects will benefit from the conclusions we reached and the information we gleaned from this process.