American Nuclear Society Robotics Competition

University of Florida

"Florida Belle"

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Introduction

The objective of this project was to design an autonomous mobile robot capable of finding three different types of objects, differentiating them, and depositing them in their respective receptacles. The robot is known as the “Florida Belle”, similar to the war planes of the World War II era. The robot has “nose art” and carries “The Bomb”, a smaller robot designed to be tossed into the opposing side of the playing field to confuse and annoy the competition.

Approach

The basic working principle behind our solution to the problem is wall-following. Since all critical points on the playing field are situated along a wall, we believe that if the robot stayed close to a wall at all times, it would invariably run into one of these critical points (i.e. objects or dumping bins). Another essential element in our approach was speed. There were two reasons why speed was critical to our method: each match only lasts 5 minutes, so the faster our robot could find and deposit objects into their bins, the higher the chance that we could get all objects to their respective bins. The second reason why the robot needed to be fast was the way we were picking up the objects. The “Florida Belle” is equipped with a large bulldozer-type scoop in the front, so that it can get underneath objects and pick them up, and to get underneath the objects, the scoop must be moving at a relatively high speed. In order to minimize the time it would take us to get all the objects, we decided to try to pick up all three objects in each corner at the same time. The basic sequence of behaviors employed by the robot could be easily summarized: find a wall and run along it at a high speed until there is an obstacle in the way. If this obstacle is another wall, check to see if there are any objects in the scoop, and if there are, tilt back the scoop back and lift it up, then turn and follow the next wall. While the scoop is being raised, the robot will determine which type of object it has picked up, so that it knows which bin it needs to go to. When the scoop is raised (because the robot is holding an object in it), the “Florida Belle” will keep following walls until it runs into another obstacle. If the obstacle is another wall, then start following along that wall. If the obstacle is another set of objects (tea box, rice bag, or can), steer around it and find the next wall. If the obstacle is one the goal bins, maneuver in front of the appropriate bin and dump the objects.

Platform Design and Actuation

The design of the platform is an integral part of the functionality of the robot. Many features were incorporated into the robot to enable it to survive the rigors of the technique that we are trying to implement. The number of moving parts were kept to a minimum to try to cut down on the possibility of equipment failure. The lift base and the front wheels share a common stainless steel axle that transmits shock of the robot slamming into a wall into the entire body. The need to ram the side walls was derived from the necessity of the force needed to put the three objects into the scoop. Many experiments were performed to determine the optimum way to pick up three objects at one time and it was resolved that a large scoop traveling at a predetermined ideal velocity was the best way to move the maximum amount of objects in the set amount of time. Plastic gears are used because of gear sets that were preexistent in the laboratory where the robot was developed. This choice in equipment required the implementation of some techniques to ensure that the plastic gears would survive the torque that the high torque motors put on them and the shock of impact that comes from the robot slamming into objects. The mount that the motors sit on is a floating plate that flexes up and down to absorb excessive loads. This relieves much of the stress that the drive train has to endure and reduces the down time on the robot from broken parts. The wheels and attached gears also have a flexible coupling between them to absorb any shock that might be transmitted from the wheels to the gears. Any robot subjected to environment that this robot performs in should be prone to breakage but it has been found that through our use of a wood body and flexible bonding compounds such as epoxy has enabled the robot to survive countless impacts during testing. The placing of a large scoop on the front of the robot necessitated the placement of a counter weight on the back of the robot to prevent it from flipping on its front. The size restrictions placed on the robot and the amount of weight that has to be lifted play a part in determining the placement and weight of the counterweight. This also had to be taken into account when determining the survivability of the robot during impact. The use of large motors for the scoop lift and drive motors dictated the many batteries that were used in the design, so the battery compartment was designed to hold many standard six and eight cell battery packs for ease of implementation and the power needed for battle, which also act as the counterweight. A large hobby servo is used to control the angle on the front lift and is also incorporated into the battery compartment. Sensor placement was also a key element into body design and the placement of the sensors accounted for many on the unique features of the body, such as the lip on the front of the robot for the potentiometer “feeler” and bump sensor mount. It also has to be easy to work on so an open architecture design was used in the design of the body. Any of the two panels that enclose the body can be quickly removed for working on any of the internals of the robot. This allows for quicker adjustments and ease of implementation of new components.

Circuit Boards

Microprocessor

The robot uses a Motorola 68HC11E9 microprocessor to control the sensors and actuators. A Motorola evaluation board (EVBU) with an 8 MHz crystal was used. To add to the HC11’s functionality, a Mekatronix ME11 board was added, which provided the HC11 with 32Kbytes of RAM, 8 digital outputs, partial memory address decoding, 40 kHz signal modulation, and an H-bridge motor driver. For reasons which will be explained later, we opted not to use the motor driver or the 40 kHz modulation hardware; we also added a memory-mapped octal latch in order to increase the number of digital outputs we could control.

Motor drivers

As was mentioned above, the HC11 expansion board has an on-board dual H-bridge IC motor driver, which was our initial option for motor control. We were uncertain as to what size or type of motors "Florida Belle" would eventually have, so we did not know if the 500 mA that each H-bridge could supply would be enough to drive our motors. We also wanted to be able to control 3 motors (right and left drive motors, and a lift motor), which means we would need extra circuitry to drive the 3rd motor. For these two reasons, we opted not to use the IC motor driver, but rather to build our own. We wanted a motor driver which would be able to handle large amounts of current if necessary, and still be relatively simple to control through the HC11 microcontroller. To control the motor current, a TIP Darlington transistor with high current gain (>10000) and capacity (6 A continuous) was used. This transistor was driven directly by a digital output, so that when the output pin went high (+5V), the motor was enabled. The speed of the motor was controlled through pulse-width modulation (PWM) of the output pin. The pin can be pulsed with duty cycles anywhere from 0% to 100%, corresponding to speeds from 0 to 100%. The direction of the motor was switched through a DPDT relay, which could be turned on or off with another digital output from the HC11. Therefore, in order to control each motor on the robot, two digital output pins were needed, so for the three motors on the "Florida Belle", 6 digital outputs were used. See Figure 1 for a schematic of the motor drivers.

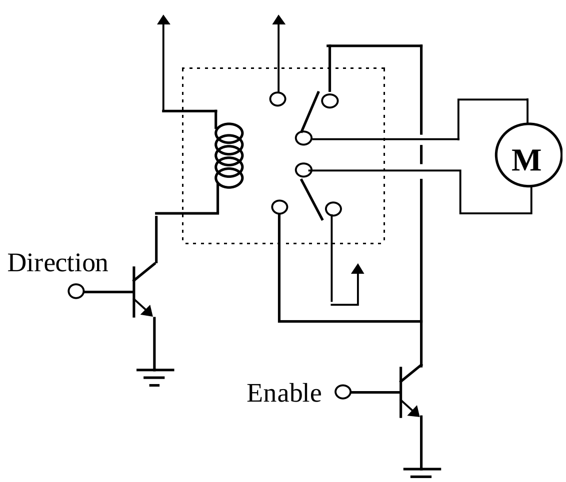

Figure 1. Motor driver schematic

Infrared flare

A system was devised which would essentially blind any competing robots which happened to use modulated infrared light as a sensor. We called this system the "infrared flare" because it emits very high-powered frequency modulated infrared light. The IR light is actually modulated at different frequencies, which are switched by the microcontroller in a time-slicing fashion.

Sensors

"Florida Belle" has no active sensors, all sensors are purely resistive or contact elements. The three types of sensors used were: contact switches, potentiometers and cadmium sulfide (CdS) photocells.

Wall following

Since our basic strategy to find the objects was to make the robot follow a wall until it hit a corner, we needed an effective and simple way to follow walls. What we came up with were "feeler arms", each of which consisted of a spring-loaded potentiometer with a strip of interlaced plexiglass attached to the potentiometer shaft. The arm extends out from the robot's body about 3 inches in such a way that as the robot approaches a wall, the arm is pushed toward the robot's body, turning the potentiometer. Two of these feeler arms were mounted on the left side of the robot, one in the front and one in the back, so that as the feelers were pushed into the robot's body, by looking at the potentiometer values it would be possible to tell the robot's distance from the wall and direction relative to the wall. A linear dynamic algorithm was developed that would always orient the robot parallel to a wall at an arbitrary distance.

Bump sensors

Contact switches were used as front bumpers, so that the robot could determine whether it had run into an object. There are two separate functional bumpers: one bumper is mounted on the front of the scoop, so that when the scoop is lowered, the robot can run into a corner, and realize that it has hit a wall and needs to stop. The second bumper is mounted behind the scoop, and this one is in place for when the scoop is raised.

Wall and Bin Detectors

There are three forward-looking, front-mounted CdS cells which are used to determine whether "Florida Belle" is in front of a wall or a receptacle bin. Two of these cells are mounted on the left side of the robot, one at 1" height, and the other at 2" height, the third cell is mounted on the right hand side at 2". These cells work in conjunction with the bumper in the following way: after the robot has bumped an object, it will stop and sample the three CdS cells. Because of the geometrical configuration of the three cells, the robot can decide whether it has run into a corner, an object, or a bin; according to what it has hit, the robot will take a different course of action.

Scoop sensors

After the robot has rammed a corner with its scoop lowered, it must determine whether it has managed to capture any objects in its scoop. To do this, there are 13 CdS cells mounted on the bottom of the scoop looking upwards. These cells are connected in series and fed into one of the processor's A/D ports. If any one of the cells is covered by an object which is in the scoop, the equivalent resistance of all the cells will increase dramatically, so sampling the scoop sensors can tell the robot whether it is holding any objects.

Object weight detection

The "Florida Belle" will be able to differentiate between objects by how much they weigh. The weight difference between 3 bags of rice and the other objects is quite appreciable, which made detecting weight differences a trivial problem. The weight differentiation was accomplished by sampling how much current was being drawn by the lift motor as it lifted whatever objects had been captured. A simple voltage divider circuit was built which would produce a voltage that was proportional to how much current was being supplied to the lift motor by the motor driver.

"The Bomb"

As was mentioned earlier, the "Florida Belle" will initially hold a smaller robot in its scoop which we have named "The Bomb". This robot will be dumped into the opposing team's side of the arena with the sole purpose of confusing their robot and to push the other team's objects around.

"The Bomb" is a very simple robot which only has two motors and a Motorola M68HC11E2 processor. Its basic behavior is to move around in random directions for random amounts of time.

Conclusion

Designing and building robots is not easy. Through the course of this project we found that designing and programming a robot to perform the simplest of tasks is a very non-trivial process. Even though this specific robot was designed to work in a totally static environment and programmed to perform a very specific job, it was relatively difficult to come up with a fully stable and reliable algorithm which would work with a high degree of reliability and precision. Although it would be possible to have the robot follow a map of the playing field, since its layout would be known ahead of time, we opted to take a relatively simpler approach. We believe our method to be very robust, since the robot does not always need to know its exact position.