Firebot: Design of an Autonomous Fire Fighting Robot

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Abstract

Firebot is an autonomous robot that was created to compete in the IEEE SoutheastCon 2003 Hardware Competition. This paper discusses the development of each component of the robot that is designed to find a small fire represented by a light emitting diode in a model home and extinguish it. This paper will talk about each component of the robot from the start signal to the robot platform to the line following and room finding and finishing with the fire detection.

1. Introduction

Every year IEEE Region 3 holds the SoutheastCon Conference in which teams from different universities can compete in the Hardware Competition [1]. The Hardware Competition of the 2003 IEEE SoutheastCon requires designing and building a robot that will go through a model of a house and detect and extinguish a small fire. The robot is initially lowered in the designated home area and will start within 30 seconds upon hearing the starting signal. It will then go through the house structure that is made of black painted wood. The walls are 23 cm high and 2 cm thick with doorways 23 cm wide. All measurements are guaranteed to be accurate to 4%. The floor plan is shown in Figure 1 [1]. There is a 1.9 cm line made with white Tartan General Purpose tape across each doorway and running down the center of each hallway. This design allows for the robot to use line following in order to maneuver.

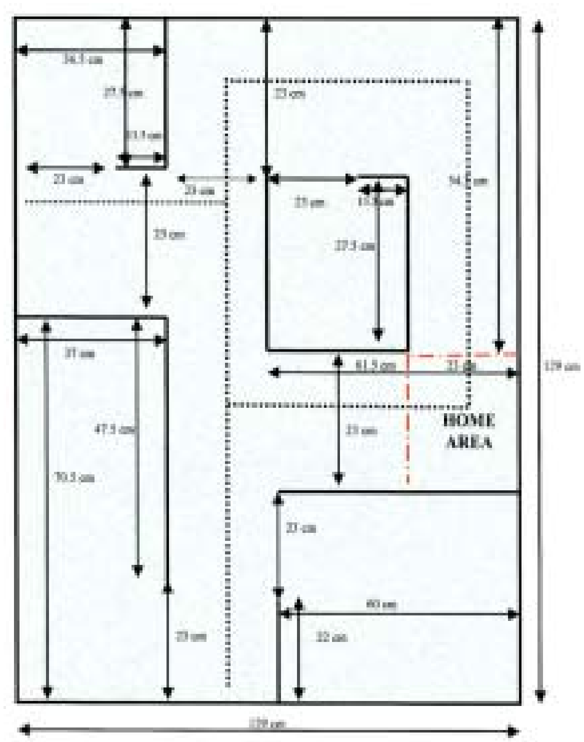

Figure 1: Floor Plan

The small fire is represented by a cylindrical red object with six red light emitting diodes (LED). The candle can be found in any of the four rooms. Once the candle is found it will be extinguished by the robot by covering the candle with a cup. If the candle is knocked over it is considered as spreading the fire and the team will be disqualified. After extinguishing the fire the robot should return to the home area without entering any other room along the way. The goal of this project is to create a robot to complete this task in the shortest amount of time.

2. Platform

2.1 Frame

Firebot's frame, shown in Figure 2, is constructed of 1/8 inch thick balsa wood. There are three layers, each separated by metal standoffs. The dimensions of the frame were designed so that it is able to fit within the 21 cm x 21 cm x 20 cm home area and maneuver through the maze.

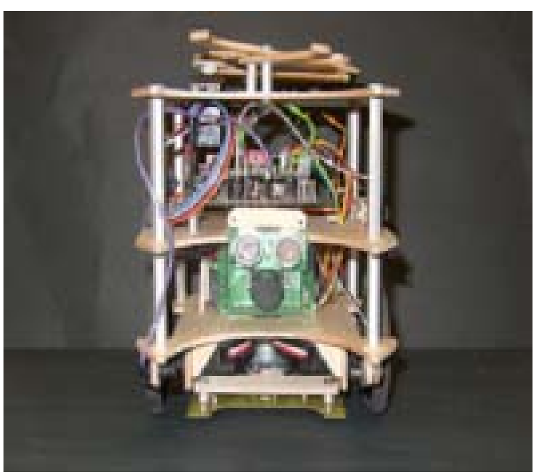

Figure 2: Platform

The power supply consists of eight 1.5 Volt AA nickel-cadmium rechargeable batteries which are mounted on the bottom layer. The supply voltage passes through five volt regulators which powers the board and servo motors.

The robot has two servos that are fully hacked for use as motors. Originally, two voltage regulators were added to keep a constant voltage on each motor allowing the robot to go straight given the same values. This did not give the expected results but prevented the motors from varying in speed depending on the current battery charge.

The top layer has an apparatus, shown in Figure 3 that holds the cup. The apparatus consists of two arms, one is fixed and the other is controlled by an unhacked servo.

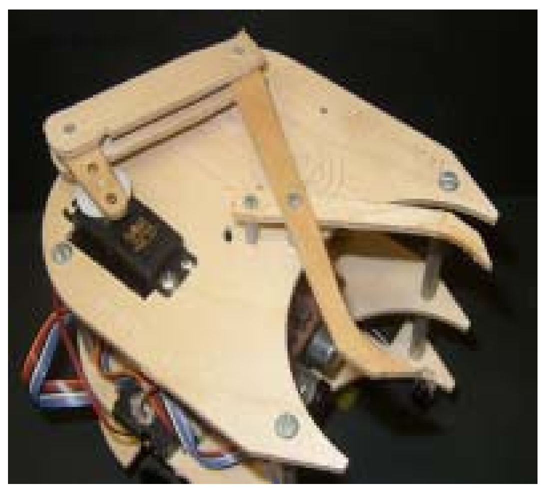

Figure 3: Cup Releasing Mechanism

2.2 Board

An AVR based microcontroller was chosen for the robot computer system. In this case an Atmel ATMega 128 processor was chosen. This processor provided 128 kilobytes of onboard flash for programs through a

JTAG interface. The processor also has a 10 bit analog to digital converter (ADC), two UARTs, and multiple timers including both output compares and input capture devices. A board developed by optiCompo Electronics, using the ATMega 128, allowed the RS232 protocol to be used on UART0 thereby allowing the processor to communicate to a PC. This is extremely useful while debugging the system. Because the optiCompo board brought out the processor pins in a series of male headers and because several external sensors and motors are needed, a breakout board was designed and manufactured at the University of Florida's Machine Intelligence Lab.

The code to control the robot was developed using a modified version of GCC. The software was retargeted specifically for the AVR platform. AVRGCC version 3.2 was used with AVR Studio 3.56 as a front end interface. After successful compilation the program was downloaded to the processor through a program called PonyProg2000 that was run on either Linux or Windows.

3. Behaviors

The behaviors are broken into four different sections. The robot must first wait for the audible starting signal. Then can begin moving through the house using line following. The next step is to find rooms in which to enter. The final step is to look for the LED candle and extinguish it upon detection. The robot must then return home.

3.1 Sound Filtering

The audible starting signal is a 1500 Hz sound that will commence within 30 second period after the robot is placed in the home area. The robot uses a microphone circuit with a simple amplifier shown in Figure 4 [2] to receive and amplify a signal with input capture. When the 1500 Hz is detected the robot can begin movement.

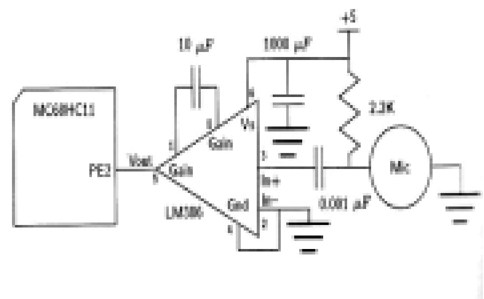

Figure 4: Sound Filter

3.2 Line Following

The line following sensor board is comprised of eight digital photo-reflectors arranged as shown in Figure 5. The board is mounted _ inch off the ground. It is centered directly beneath the servo motor holders, which allows the robot to turn in place.

There are six photo-reflectors placed in a rectangle configuration used to follow the line. When the two in the center are on then the robot knows that it is going straight and does not need to adjust its direction. When other sensors are on, the robot turns until the middle two are lined up again. The purpose of having two rows is to detect whether the robot is at an angle. This is not possible using only one line of sensors.

There are two outlying sensors that are used to detect when to turn. They are placed ahead of the wheels to compensate for stopping distance and placed further out to avoid confusion with the other sensors.

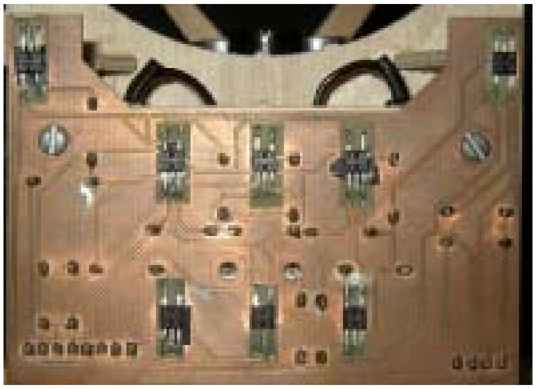

Figure 5: Photo-Reflectors

3.3 Room Finding

Room finding is accomplished using two infrared sensors centered on both sides of the robot. The IR sensors detect when an opening in the wall is present. This signals to the robot that the door is to the side and it is time to turn. In order for the robot to not be confused immediately after a turn, a front IR sensor is used to gauge the distance from the wall ahead.

Testing determined that the sensors did not have a high enough resolution to determine the farther distances that were needed in the front. The front IR was then replaced by a Devantech SRF004 ultrasonic range finder.

3.4 Candle Detection

The robot uses a CMU Camera to detect the fire. The camera communicates to the processor through UART1 and has a built in IR filter. This is helpful because of the use of IR for room finding. The camera processes the video stream onboard and then sends back several values over a serial connection. A GUI is provided by the camera that allows the user to see what colors the camera is detecting. These values are then used to calibrate the color of the candle.

The camera is then told what color to track. When the correct color is seen by the camera, the user is given the X and Y mean coordinates of the centroid of the color being tracked. Also a confidence value is sent, expressing the margin of error.

Based on the X-coordinate and confidence received, the servo motors are adjusted in order to keep the candle centered in the camera image. Once centered, the robot moves towards the candle, adjusting as needed. The robot continues to go forward until the break beam is interrupted.

The break beam consists of a CDS Cell and laser diode. They are mounted at the front of the robot's bottom layer positioned to face each other as shown in Figure 6. The laser diode creates a continuous beam that the CDS Cell detects. When an object blocks the laser path, this changes the voltage that is sent to the ADC, telling the robot that the beam is broken. When the beam is interrupted, the robot is in position to drop the cup. At this point the servo opens the arm holding the cup.

Figure 6: Break Beam

4. Conclusion

The challenge of creating a fire extinguishing robot to operate in lighting conditions that are not fixed is a difficult one. Completing each of the different components was not easy. However, Firebot's hardest task was integrating all of its components. The experience and the difficulties faced taught us valuable lessons that we can use on future projects.

5. References

[1] IEEE SoutheastCon 2003 Hardware Competition website [online]. URL:http://www.ewh.ieee.org/r3/jamaica/southeastcon/robot.html. Retrieved April 11, 2003.

[2] J. L. Jones and A. M. Flynn, "Mobile Robots,,, Wellesley, MA, 1993, pp. 118.