Automatic Fire Fighting Robot

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***ABSTRACT* — THIS CONFERENCE PAPER WILL GO OVER THE AUTOMATIC FIRE FIGHTING ROBOT DESIGN AND THE OBJECTIVES THAT WERE EXPECTED TO BE ACCOMPLISHED WITH THE PROJECT. THE SIZE OF THE ROBOT CAN BE SCALED UP DEPENDING ON THE APPLICATION AND REQUEST, PROVIDING A WIDE GAMUT OF USES FOR THE DESIGN, AS IT CAN BE USED FOR SMALL-SCALE FIRE EXTINGUISHING, MEDIUM-SCALE FIRE EXTINGUISHING, AND ALL THE WAY UP TO LARGE-SCALE FIRE EXTINGUISHING.. THE ROBOT IS ABLE TO DETECT FIRE ON ITS OWN USING THREE INFRARED (IR) FLAME SENSORS AND MOVE TOWARDS THE FLAME TO PUT OUT THE FIRE. THE MAIN GOAL OF THIS PROJECT WAS FOR THE ROBOT TO DETECT AND EXTINGUISH A FIRE, GIVING OTHERS A SENSE OF SAFETY DUE TO THE PRESENCE OF THE ROBOT.**

***INDEX TERMS* — AUTOMATIC, EXTINGUISH FIRE, ROBOT, IR SENSORS, POWER BANK, WATER.**

I. INTRODUCTION

House fires occur several times throughout the year and typically end in catastrophes, raising a big question of what can be done to prevent these events. It is estimated that there are around 358,500 house fires every year in the United States alone. According to the Federal Emergency Management Agency (FEMA), more than 3,000 Americans die every year due to these fires. The majority of these house fires can be prevented by acting quickly to put out the fire. However, there are times when the start of the fire isn't noticed by whoever is around and sometimes there is no one in the general vicinity to be able to put it out. This was one of the main reasons and motivations behind the creation of our automatic fire extinguishing robot.

The robot will be able to detect fire when it ignites and use the information relayed to the various components to move towards the flame and put it out. The data triggered by the presence of a flame are detected by the IR flame sensors that are implemented in the design. The IR sensors send signals to the MCU that interprets the signal received and decides what to do based off the signal. The MCU can receive signals from 3 different sensors, and depending on which one detects the fire, a different course of action is selected by the MCU. When the MCU decides to extinguish the fire, it activates the servo motor and the pump in order for it to spray the water in a wider area and be able to better cover and extinguish the detected fire. Once the fire is extinguished, the robot goes back to stand by mode where it is waiting for one of the sensors to detect a flame and start the whole operation loop once again.

II. SYSTEM COMPONENTS

This section is going to cover the most important components of the robot in order for the design to be fully operational. These components execute the main functionalities of the robot. Smaller components like resistors, capacitors, switches, and fuses won't be discussed in this section.

A. Microcontroller

The microcontroller is the brain unit of the whole project. The microcontroller that was used for our robot was the ATmega328. The microcontroller that was used in our design is the same one that is used on the Arduino boards, which was used for testing. This was one of the many reasons why it was selected. The Arduino Uno is known for being less complicated when it comes to programming, especially when compared to other microcontrollers. The ATmega328 also has 28 pins, which was more than the required amount to accommodate all the components in the design of our project. The microcontroller has two internal oscillators that have different frequency values. One oscillator is clocked at 8 MHz, and the other oscillator is clocked at 128 kHz. The microcontroller also has an internal RAM of 2KB SRAM. In addition to these features, it also has a low power consumption which was important for the purposes of our project.

B. IR Flame Sensors

The sensors are a crucial part in the functionality of the robot. They are responsible for detecting the fire and providing the information for the MCU so that it is able to control the other components of the robot. Three sensors are used in the design of our robot. One sensor is located at the front of the robot, while the other two are angled and positioned on the right and left sides for it to be able to cover a wider range of detection of fire in the area it is in.

The sensors implemented are infrared sensors. Infrared sensors can detect the infrared light that is emitted from the flames. Using three sensors angled differently allows the robot to cover a wide area. The sensors are angled in a way that allows them to maximize their efficiency in covering as much area as possible. The infrared sensors used were also inexpensive and could be easily acquired.

C. Motor Driver

The motor driver was an important component for the functionality of the robot. The motor driver that was used in the robot design was the L293D. The motor driver is responsible for controlling the movement of the DC motors depending on the input that is received from the microcontroller.

D. Water Pump

The robot needed a component to spray water when the flame sensor detected a fire, and the water pump was the component selected to do that. In this project, the pump that was used was a mini submersible DC water pump. The pump operates at 5 Volts which was what we needed for this project. It also has an adequate flow rate of 100 L/H. In addition, the pump also has a low power consumption which was a very desirable characteristic for our project.

E. Servo Motor

The servo motor was another essential component of the project design. It is responsible for adding rotation to the water container and the pump in order for it to cover a larger range when the pump is activated. The SG90 servo motor was the servo that was used in this project. The SG90 servo motor is a reliable option for the project because it has a typical operating voltage of 5 Volts, and it is also very flexible, with a rotation of 360° and a speed of 120 RPM.

F. Motors

The motors were responsible for moving the robot from one point to another. They were connected to the motor driver, which controlled the movement of both DC motors in our project.

For this project, two DC motors were used in order for the robot to move around. The DC motors operate on a 5 Volts power supply that comes from the motor driver. These motors are generally used for smaller sized robots, as our design entails, but can be scaled up to better fit a larger robot. Each motor has a low typical current of 140 mA, which was ideal for the specifications of this project. In addition, a 5 Volts power supply was used to drive the motors and no regulation was needed.

G. Relay

Another crucial hardware component in our design included a relay. The relay was used to connect the pump to the power supply. The pump can't be connected directly to the microcontroller as the microcontroller does not supply enough power in order for the pump to run. The relay was used to connect the microcontroller output with the power of the power supply. When the signal from the output of the microcontroller was sent to the input of the relay, which was in the high-level trigger, it connected the normally open and common terminals of the relay to power the pump with the power supply. The relay acted as a switch in our project design.

H. Power Supply

The power supply was one of the most important parts of the project. It is responsible for powering the entire robot and keeping it operating for our desired time. For this project, the best option for a power supply was the Anker PowerCore 10000. This power bank is able to supply 5 Volts to the entire project. It has 10000 mAh of battery, and since the project requires 1500 mAh when all the components are operational, this power supply can keep the robot running for at least 6 and half hours.

Under normal circumstances, the robot will not be fully operational all the time and will be on standby mode for a decent duration of time. As a result, the practical operating time of the robot is greater than the calculated value. This power bank also has a low current feature. This feature allows the power supply to remain operational even in standby mode when there is not much current being drawn by the robot. Another important factor is that it has a built-in voltage regulator to keep the output voltage stable at all times, which is crucial for any project design.

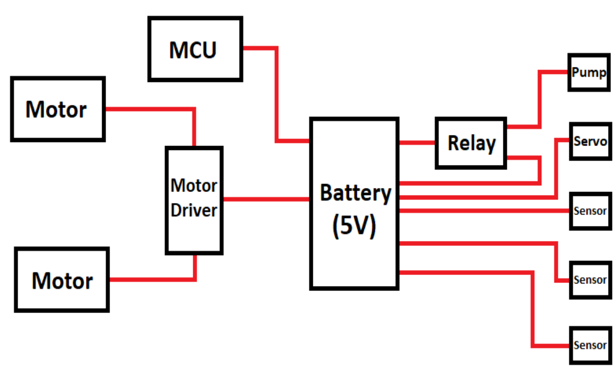

Figure 1: Power Design

The power diagram provided above is a visual representation of the main hardware components in our design and the voltage required for each component to operate along with its connections to the other components.

III. SYSTEM CONCEPTS

To get a better understanding of our overall project design, a complete system diagram is shown below.

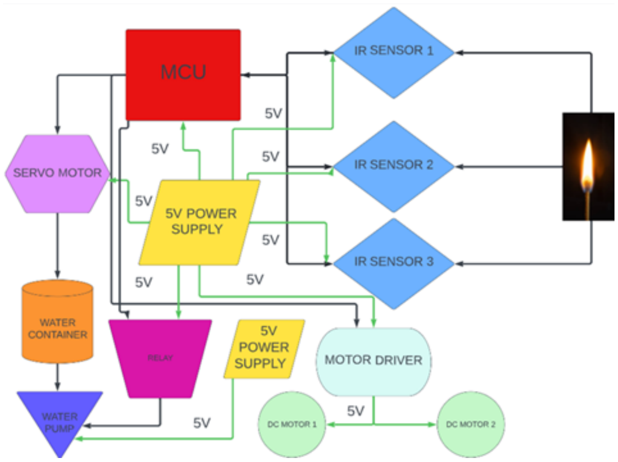

Figure 2: Overall System Diagram

The heart of our project, the MCU, is the ATmega328 chip. Connected to the MCU chip are the three infrared (IR) flame sensors. They are critical in our design as they initialize the detection of a flame and are the only means through which flame is detected by the robot. There is also a submersible water pump to extinguish the flames which is driven by a relay. The servo motor helps control the direction that the water it sprayed towards. The last piece of our design is the motor driver, which controls our two DC motors and allows the robot to detect and move towards the detected flames. All the components in our design operate at the same voltage (5 volts), which removes the necessity of any kind of voltage transformation. The necessary 5V voltage is supplied to the components via a power bank housed within the robot itself.

A. Motivation and Goals

The motivation for creating a fire extinguishing robot came from our desire to innovate a device that could help keep humans safe without the risk of putting others in harm's way. House fires as well as fires occurring outside have been a pressing issue for many years. The creation of a fire extinguishing robot could become particularly useful and beneficial to the safety of others. Having a device in the house that could detect a flame and put it out within seconds could result in a much less devastating incident.

The goal of this project was to design a functional robot that could detect a flame using an IR Flame Sensor and maneuver its way to put the fire out. Our primary focus was to make sure the robot we designed was accurate and precise with every detection of a flame. Another objective was to make sure the robot was well designed in order for it to be able to move around freely and get to specific places without having any issues or damage caused to the robot. Basically, the goal was to have the design be as simple and effective as possible.

B. Specifications

The specifications outlined below are key design requirements we implemented in order for our robot to function how we wanted.

Specification	Description (Value)
Robot Size	25 cm – 30 cm
Number of Sensors	3
Robot Weight	Less than 2 Kg
Sensing Range	30 cm
Extinguish Time	3 seconds
Robot Movement Speed	2 Km/H
Robot Power Supply	5 V
Response Time	Instantaneous once within range

Table 1: Robot Specifications

C. Safety Standard for AMR (Autonomous Mobile Robots)

The R15.08 defines the safety standards for Industrial Mobile Robots (IMR). With the new advancements in technology and the versatility of these robots, new safety requirements have arisen. It was crucial to have these standards set in place as there are risks to these vehicles and their systems.

The Robotic Industrial Association (RIA) issued R15.08-20 part I, which discusses the safety standards for industrial mobile robots and their attachments (i.e. wheels, manipulators). Part I is for the manufacturer to examine and understand how to design and manufacture a safe IMR. With each new robot, a relevant Risk Assessment analysis must be met.

Part II of the document is still in the works. This section will specify the safety requirements for mobile robots installed in particular conditions. To go more in depth, this part will include the appropriate speed of the robot depending on the presence of safety sensors and escape clearance for operators. “With Part 1 you will have a safe robot, with Part 2 you will have a safe robot professionally installed in a given working environment.” Part 3 will eventually describe the user responsibilities for safe operation of the mobile robots and their systems.

IV. HARDWARE DETAILS

The major components discussed in Section II, System Components, will be discussed in further detail. This section will outline our hardware used for our robot, its purpose in the design, and how we implemented each part.

A. MCU

The ATmega328 is the main control unit of our design. In initial testing stages, we used the Arduino Uno to test the functionality of our proposed project. We then further developed our idea by just implementing our project using the MCU. In order for the MCU to operate like an Arduino would, we had to build and test the circuit on the breadboard. This design required a 16 MHz crystal, a 10 K resistor, two 22 pf capacitors, and a 10 uF capacitor.

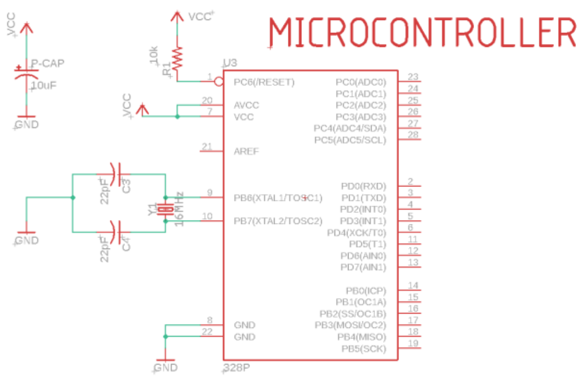

Figure 3: Schematic of MCU

The schematic above illustrates the circuit design we had to implement in order for our project to function properly without using the Arduino Uno, but rather uses the ATmega328 chip individually, isolated from the Arduino board.

B. IR Flame Sensors

The IR flame sensor detects the presence of fire or other infrared sources in the environment. It does this by detecting a flame or light source with a wavelength in the range of 760 nm to 1100 nm. Features of the IR flame sensor include an adjustable threshold value and a two-state binary output. The sensor is also small and compact and very easy to mount. The robot contains three flame sensors pointing in different directions in order to get a precise reading on where the flame is located. The working of this three pin sensor is made up of a few key components including a YG1006 NPN Phototransistor, LM393 Comparators IC, variable resistor, power LED, and an output LED.

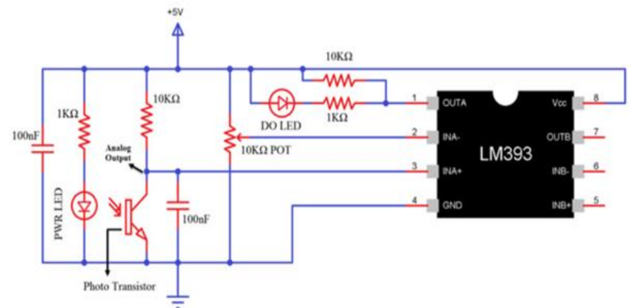

Figure 4: Schematic of IR Flame Sensor

C. Servo Motor

A servo motor is a device that allows for precise control of angles and/or linear positioning through the use of linear or rotary actuation. These devices can come in an array of sizes as well as quality and complexity. Servo motors are often used in closed loop control systems and tend to require a dedicated module that is specifically designed for servo motors. The purpose of the servo motor for the sake of the project is to make sure that the water pumped is aimed at the precise location that the fire is detected in order to avoid wasting water by pumping it to an incorrect, or imprecise, location.

D. Water Pump and Relay

Submersible water pumps are sealed motors that are coupled to the pump body which is then submersed in the water reservoir. The advantages of submersible water pumps compared to other types of pumps is that they do not suffer from pump cavitation. Pump cavitation is a problem that happens in a lot of pumps when in an area of high pressure, a pocket of water vapor or bubbles can begin to form disrupting the flow and, in some cases, even damaging the machinery the pump is connected to. Considering the project at hand, since fires cause an increase in pressure in the area due to the rapid thermal expansion of gas in a closed area, the group concluded that a submersible pump would be the way to go in order to avoid the issue of pump cavitation.

A relay module is an electrical switch that is operated by an electromagnet, which is activated by a low-power signal from a microcontroller. When it is activated, the electromagnet is either pulled open or closed.

The pump draws a lot of current that can not be supplied by the MCU alone, which is why the relay is especially useful for our design and it is what drives our pump.

E. Motor Driver and DC Motors

The L293D Motor Driver is a key component in the assembly of our firefighting robot. The driver was used to run the two DC motors, controlling both speed and direction. There are two different techniques that provide a method to control both speed and direction.

In order to control the speed, we used the technique of PWM (Pulse Width Modulation). PWM is done by taking the average value of the input voltage and adjusting it by sending a series of ON-OFF pulses. The average voltage is proportional to the width of the pulses, which is known as the duty cycle. A higher duty cycle results in a greater average voltage and therefore a higher speed being applied to the DC motor, which may sometimes be necessary for the project.

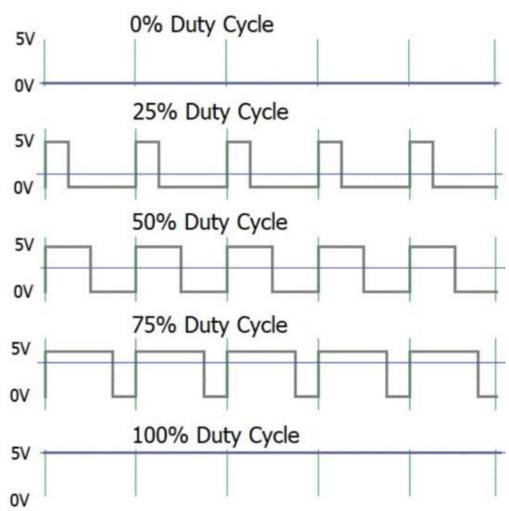

Figure 5: PWM Demonstration

The second technique will control the rotation direction, which will be done by using an H-Bridge. The DC motor's spinning direction can be controlled by changing the polarity of its input voltage. An H-Bridge circuit contains four switches with the motor at the center. When two particular switches close at the same time, the polarity of the voltage applied to the motor reverses, causing a change in the spinning direction.

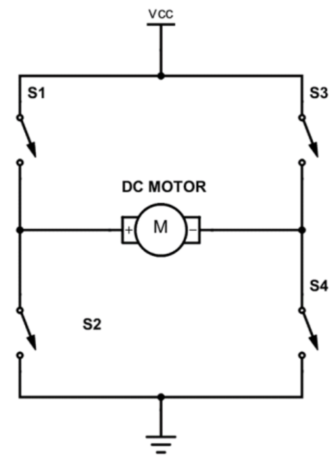

Figure 6: H-Bridge Visualization

There are many ways to make a ground-based robot move and one of these methods which is not only more reliable, but also easier, is using wheels powered by one, or multiple, DC motors. There are many variations of wheels and motors that one can use depending on the task that you want to accomplish as well as different configurations for each. Wheels can vary in size and count, and the motors can vary in size, the amount of power that they generate, and the necessary input voltage and amperage for them to work. The DC motors that we have chosen for our project operate at 5 volts, making them very compatible with our project design and allowing us to implement them in a simple but effective way, since the rest of the components also work at the same voltage.

V. SYSTEM SOFTWARE

The software of the firefighting robot can be broken down into two main functions, these being looking for a fire as the first, and fighting a fire as the second. The bridge between these two functions is the flame Boolean variable that, when set to true by one of the three IR sensors, will transition the robot from searching to fighting it.

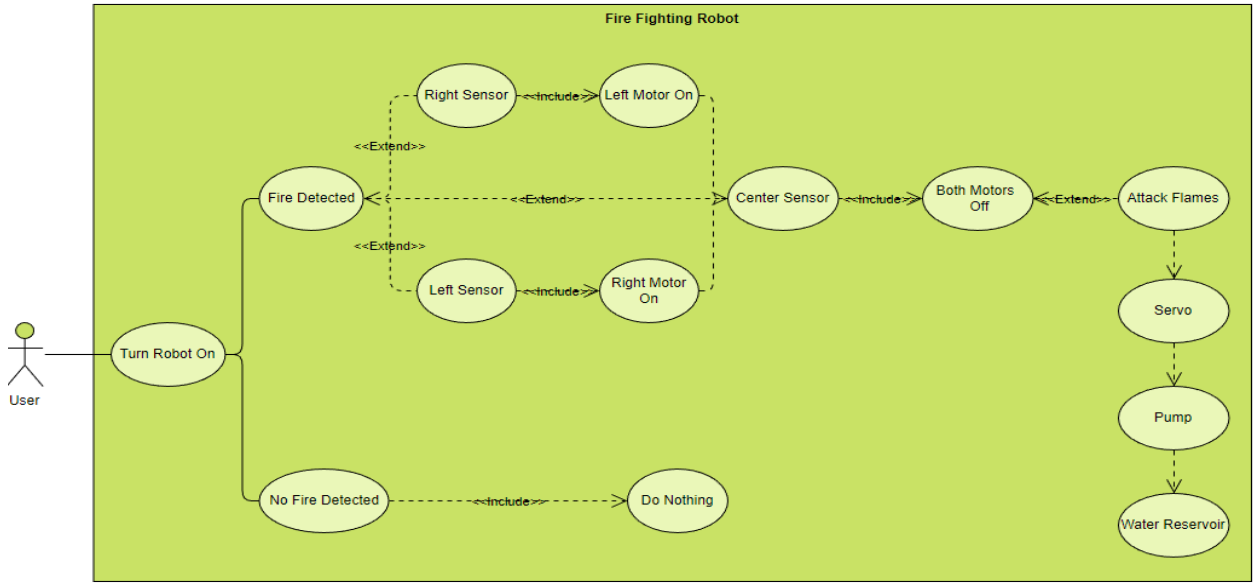

Figure 7: Fire Fighting Robot Use Case Diagram

A. Sensor

The sensors are the only input that the robot takes in. There are three IR sensors strategically placed at the front of the robot, positioned at different angles, that help give it approximately 150 degrees of vision. The sensors will output a Low signal, or digital 0, until they detect an infrared heat source where they will then output a High signal or digital 1.

Sensor Input	Flame	No Flame
Sensor Output	1	0

Table 2: Sensor Output

In order for us to make use of the outputs of the IR sensors we created a Boolean variable that is set to true only when the center sensor outputs a High signal. This allows us to control the direction the robot faces, which in turn greatly increases the fire fighting capabilities of the robot.

B. Motor

The motor output is very simple and the movement of the robot is determined based on the input that is received from the three IR sensors. However, the signals for the motor are opposite that of the sensors. If they are set to a high signal the motors are off, but if they are set to a low signal then the motors turn on and are moving forward. For example, if the left sensor is able to see a flame, it will send a signal to turn the right motor on, which will then cause the robot to turn towards the left, which will cause the robot to face the fire head on, which will usually turn off the right and left sensors. If the right sensor sees a flame it will turn on the left motor which will drive the robot to the right causing it to once again face the flames head on, and also likely turn off the right and left sensors. However, if the center sensor sees a flame it will seize up the robot and transition it into fire fighting mode. This action has a higher precedence than the other two functions which means even if the left or right sensors detect flames, which is unlikely to happen if the robot is facing the fire, the robot will not turn the wheels and move anywhere until it can put out the fire detected that is right in front of it.

IF	**THEN**
All sensors == 0	Left motor == high Right motor == high *Robot moves does not move*
Center sensor == 1	Left motor == low Right motor == low *Halt movement and trigger extinguish*
Left sensor == 1	Left motor == high Right motor == low *Turn Left*
Right sensor == 1	Left motor == low Right motor == high *Turn Right*

Table 3: Sensor Input to Motor Output

This allows the robot to fight the fires better and more efficiently by giving it the widest range of attack on a given fire and making sure it fully puts out the portion of the fire in front of the robot before turning to fight any other flames, avoiding a disruption in the robot's internal logic in the case that multiple fires are detected all at one time.

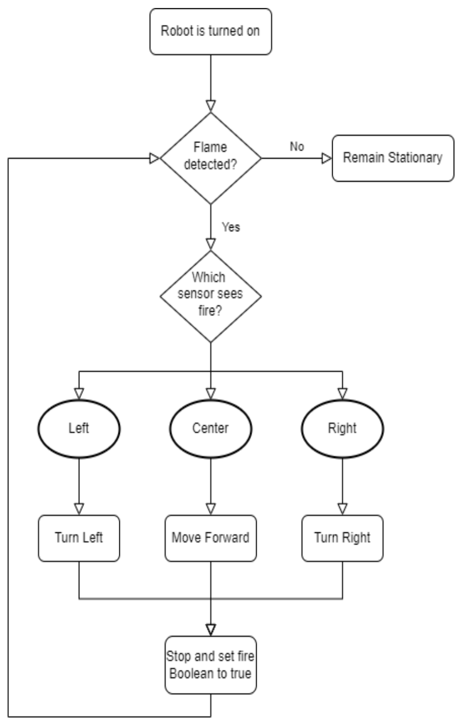

Figure 8: Motor Movement Flow Chart

C. Servo

The servo code, while still simple, is more complex than the code for the other portions of the robot. This is by design as we wanted to keep the robot as simple as possible to allow for quick and easy adjustments to the way the robot functions given the extreme flexibility of the design and its ease of scalability. When the robot is turned on it sets the servo to the center value for the range of motion used in the fire fighting. When the flame Boolean is set to true it will halt the robot and begin the servo movement.

The servo begins by adjusting the value of the servo position to the right by one point and then stopping for a millisecond. This will loop 45 times at which point it will begin moving to the left 90 times, finishing its loops at 45 degrees to the left of the starting point. It will then snap back to the middle or starting position. If there is still a flame in front of the robot then the flame Boolean variable will still be set to true, which means that it will begin the loop again until there are no more flames in front of the robot.

D. Pump

The pump is the most simple of all the components in the robot to control because it only has a toggle. The pump does not have directional controls so the only important part of coding the pump is figuring out where the best place to put the toggles is, and where to delay other parts of the code to accommodate for the spin up time of the pump.

The pump is toggled once the flame Boolean variable is set to true, but it comes after the motors stop and the servo is set to the correct position to sweep across the flames. This requires a delay to be programmed on the servo so that it doesn't begin sweeping the front of the bot before the water makes it out of the tube attached to the water pump.

The pump also shuts off half a second before the end of the rotation ends on the sweeping of the servo to allow the pump to spin down, and the water to reach its target before the robot reevaluates whether or not there are flames in front of it. This keeps the robot safe from water damage in the case of the flames being extinguished and the robot begins moving forward, since keeping the electronics safe from water damage is a very important part of the design and implementation.

E. Testing

Testing the parts of the robot was rather simple. By taking the main function you want each part to perform from the main code you can isolate each part and perform individual tests on it using different values. Our testing consists of moving each moving part forward and backward while programming pauses to make sure the parts function as intended. For example, first, to test the sensors we used the onboard LED of the Arduino Uno so that when a flame was present it would light up the LED. Second, to test the pump we turned it on and off in 3 second intervals. Once finished with the individual testing of each part, to test the robot it needs to be put together to do trial runs to test the functionality of all the parts working in tandem. The parts can work individually, but what is more important is to check that the communication between the components is working perfectly.

VI. CONCLUSION

In conclusion, this project is an automatic fire fighting robot that was inspired by seeing the constant need for fires to be put out safely, removing humans from harm, and having a reliable means to do so. In creating this robot, all of these things were considered in the design and implementation, and as such, the three main considerations in the process of the project were to have a simple design, an effective design, and an easily scalable design. Simplicity was important so that it would be easy to use, easy to fix, and easy to improve or adapt to different uses. Effectiveness was necessary so that the user would feel safe in using the robot. If the robot is not effective then it basically defeats the purpose, since this project attempts to remove the dangers that fires pose to all people. Lastly, scalability was very important since fires come in all different sizes, temperatures, and sources of origin. Without sponsorships, it is difficult to create a large-scale robot, but the design created is so scalable that developing a large robot would not be much more difficult than a small one.

This project demonstrates how to build an automatic fire fighting robot from the ground up in a way that is accessible and easily programmable. Using a few electronic components all operating at 5V and an easily programmed ATmega328 chip, this paper takes the reader through all the hardware and software implemented in the design. Some of the skills required in the design and implementation of this project included: knowledge of electronic circuits, power design, computer-aided printed circuit board (PCB) design, soldering, programming, knowledge of embedded systems, and computer-aided design (CAD).

A. Acknowledgements

The group would like to acknowledge and offer its sincere gratitude to the help provided by Dr. Samuel Richie and Dr. Lei Wei as our advisors and Senior Design II professors, as well as Dr. Zakhia Abichar for his help during the testing phases of the project. The group would also like to thank the review committee for taking their time to review our project we have worked so hard on and dedicated our time to the past two semesters.

B. Biography

Gabriel Martinho Bizuti is a 23 year old senior at the University of Central Florida. He will be graduating with his Bachelor of Science degree in Electrical Engineering in December of 2022. Gabriel hopes to pursue a career in the microelectronics area and/or digital signal processing area. He hopes to get a full time job offer from a company soon.

Sydney Brown is a 22 year old senior at the University of Central Florida and will be graduating with her Bachelor's of Science in Electrical Engineering in December of 2022. She plans on working for the family business as one of the Electrical Engineers, specializing in PLC Programming.

Juan Cuervo is a 24 year old senior at the University of Central Florida and will be graduating with his Bachelor's of Science in Computer Engineering in December of 2022. He is hoping to get a full time offer from a company soon and go back to school to further his education.

Noah Schrock is a 23 year old senior at the University of Central Florida. He will be graduating in December of 2022 with a Bachelor's of Science in Computer Engineering. Noah has not decided what path to pursue with his degree yet, but has a couple outstanding job offers from internship employers.

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