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Final Report

Philanthrobot
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1. Abstract

The purpose of IMDL was to create a fully autonomous robot capable of object avoidance and a special behavior. For my project I built Philanthrobot, a small autonomous donation collecting robot. It operates in a public setting and relies on being around people to operate. While it will avoid collision with obstacles, it will also locate the nearest source of body heat and track it using an infrared thermometer. Philanthrobot will use several infrared proximity sensors for obstacle avoidance and distance measurement, an infrared thermometer to locate and track body heat and movement, a pair of photo interrupters to identify when money has been placed into his donation's cup, and a series of bump sensors for collision detection. The Philanthrobot will also have audio playback capabilities which it will use to interact with its donors.

2. Executive Summary

Philanthrobot is a small autonomous donation collecting robot whose main purpose is to seek out potential donors and charm them into making a donation. Once Philanthrobot has received his donation, he will thank the person for their business and move on to search for his next patron.

Utilizing an Arduino Mega 2560 as its main microcontroller board, Philanthrobot has a number of sensors and actuators to accomplish this task. The human body heat detecting is accomplished by an IR thermometer that communicates to the Arduino using I2C. The object avoidance is taken care of by an array of three Sharp short range infrared proximity sensors on the front of Philanthrobot. As the objects get closer to Philanthrobot, he uses fuzzy logic to determine how to avoid the object. As a last resort, there is a set of bump switches at the rear of the robot in case he backs into a person.

Philanthrobot uses sounds and his LED eyes to interact with donors. Depending on his current state in the code, his RGB LEDs will display a different color. As he moves around and searches for his donor, he also will alert you of what he's doing using sounds. The Arduino Mega 2560 is connected through UART serial to an Arduino Uno board which is used solely for audio playback. The Arduino Uno utilizes the Ladyada Wave Shield to read .wav files stored on an SD card, and plays them through a powered speaker. This allows Philanthrobot to thank his patrons for their business, and to let you know that he's spotted you.

Overall, the project was a success and I learned a lot about robotics from the class. Philanthrobot has successfully achieved his goals and is able to not only locate potential donors, but charm them into donating as well.

3. Introduction

When people see someone trying to collect money for charity, they tend to ignore or try to avoid them lest they feel pressured into donating money. The Philanthrobot will solve this problem by attracting passersby and charming them. When people see and hear the Philanthrobot, their curiosity will draw them towards it. A small talking robot is more visually appealing and less intimidating than a person on a street corner and therefore more likely to collect donations.

The main goals of Philanthrobot will be:

- Obstacle avoidance
- Ability to locate people based upon body heat
- Tracking the person that was detected in case they move
- Charming people into donating
- Collecting donations

4. Integrated System

4.1 Microcontroller Boards

The Philanthrobot utilizes an Arduino Mega 2560 as the main controller for all of the sensor and actuation control and an Arduino Uno for audio playback. The Arduino Mega 2560 is a microcontroller board based around the ATmega2560. The board was chosen due to its low cost, abundance of peripherals, and previous experience with Arduino boards. The Arduino Mega 2560 can be purchased from any electronic hobby supply website for approximately $60 USD. The board has 256KB of flash memory, 54 digital input/output pins, 16 analog input pins, 14 pins available for PWM outputs, 4 serial ports (UART), 6 interrupts, an SPI interface, and one I2C (SDA/SCL) interface.

The Arduino Uno is a smaller version of the Arduino Mega 2560 and is built around the ATmega 328P. The Arduino Uno on the Philanthrobot is used solely for audio playback. The audio is stored on an SD card and read using the Ladyada Wave Shield attached directly to the Uno. The Arduino Uno receives instructions from the Arduino Mega 2560 through a UART serial connection.

4.2 Human tracking and sensing

The human detection will be done with a IR thermometer sensor that will detect body heat radiation. The IR thermometer is mounted to the Philanthrobot's head and communicates with the Arduino Mega 2560 through an I2C connection. In order to tell when money is given to the Philanthrobot, a photo interrupter is placed inside the donations cup that outputs a simple analog voltage to the Arduino Mega.

Photo Switches Arduino Uno Bump Switches Power Switch Thermometer IR Servos Arduino Mega 2560 Motor Controller IR Sensors Arduino Mega 2560 Motors Motor Feedback Arduino Uno SD Card Wave Shield Speaker

4.3 Object Avoidance

The Philanthrobot will avoid obstacles and bumping into its donors by relying on IR proximity and bump sensors. The IR sensors are close range from approximately 2 to 12 inches and mounted on the front of Philanthrobot.

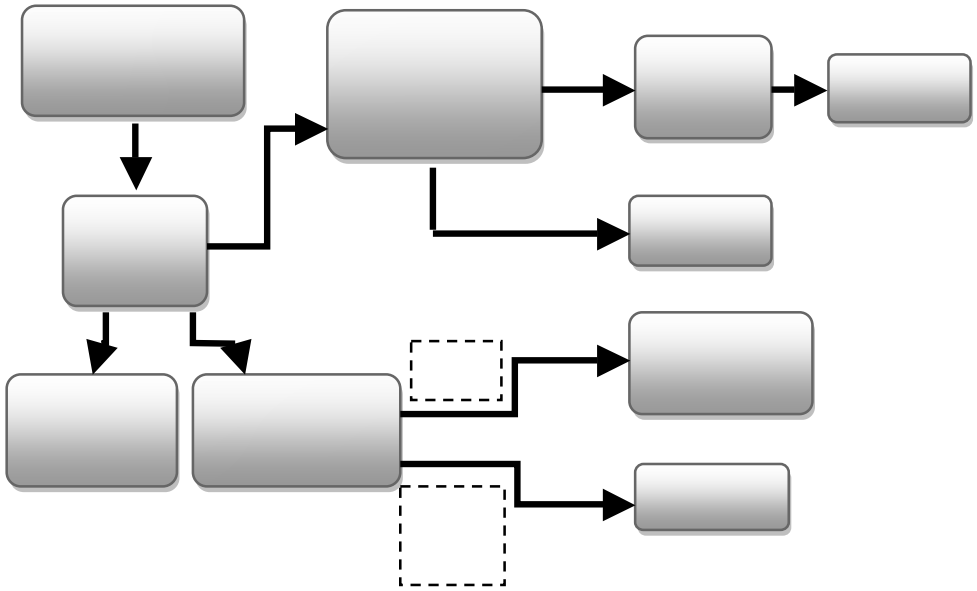


Figure 1: Power supply flow chart for Philanthrobot

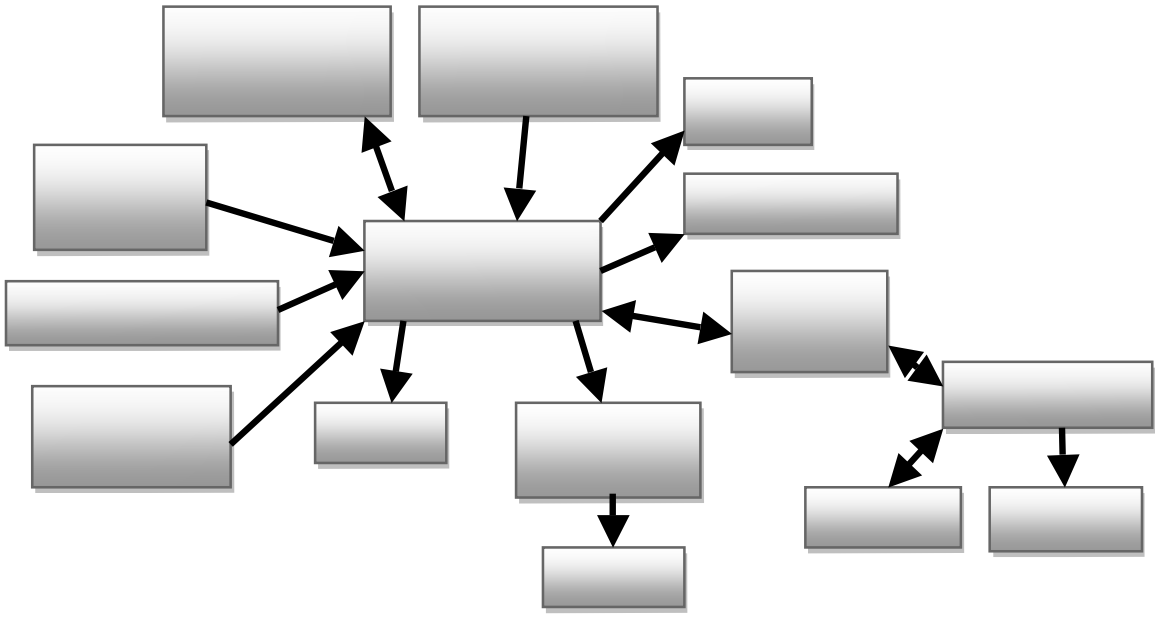


Figure 2: Integrated Control System for Philanthrobot

5. Mobile Platform

Since the main goal of the Philanthrobot is to collect donations, appearance is a big part of that. People would be more willing to donate to a friendlier looking robot, so I opted away from the cylindrical roombot design and drew inspiration from Wall-e. Philanthrobot needed some human-like features to interact with and the oversized head, box-like shape, and tiny stature were all used to increase the "cuteness" factor of the robot to ensure maximum donation collection from the audience.

Philanthrobot's platform was made out of balsa wood that was milled on the lab's T-tech machine. The balsa wood provided a cheap and light-weight solution for the Philanthrobot's platform that was easy to customize. Philanthrobot consists of two main sections: a body which contains the motors, arms, and object avoidance sensors, and a head which contains the infrared thermometer. The head sits upon a pan and tilt servo pair which allows the Philanthrobot to sweep the IR thermometer to scan the room for body heat. The servo rotates the head from 0 to 180˚ while the infrared thermometer records the temperature. The arms are attached to the body by servo and move the donation cup in response to the body heat and donation detection.

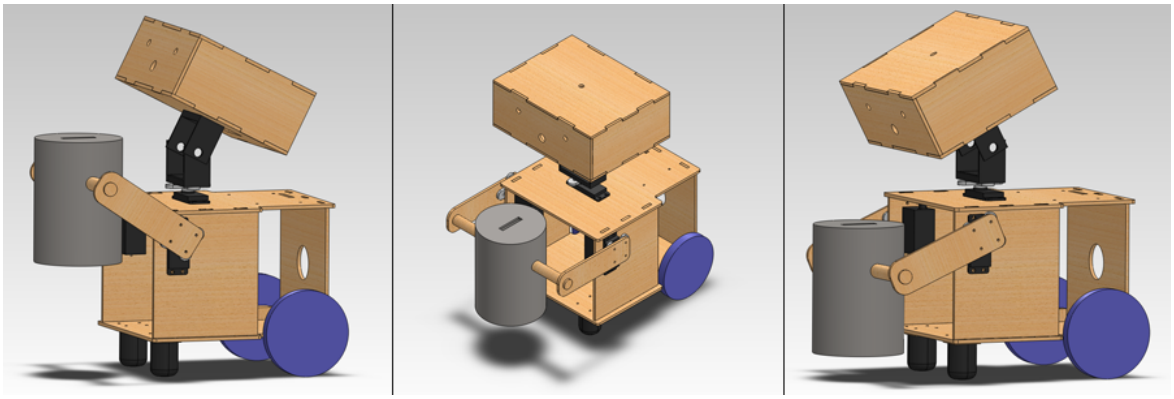


Figure 3: Solidworks CAD model of Philanthrobot's mobile platform

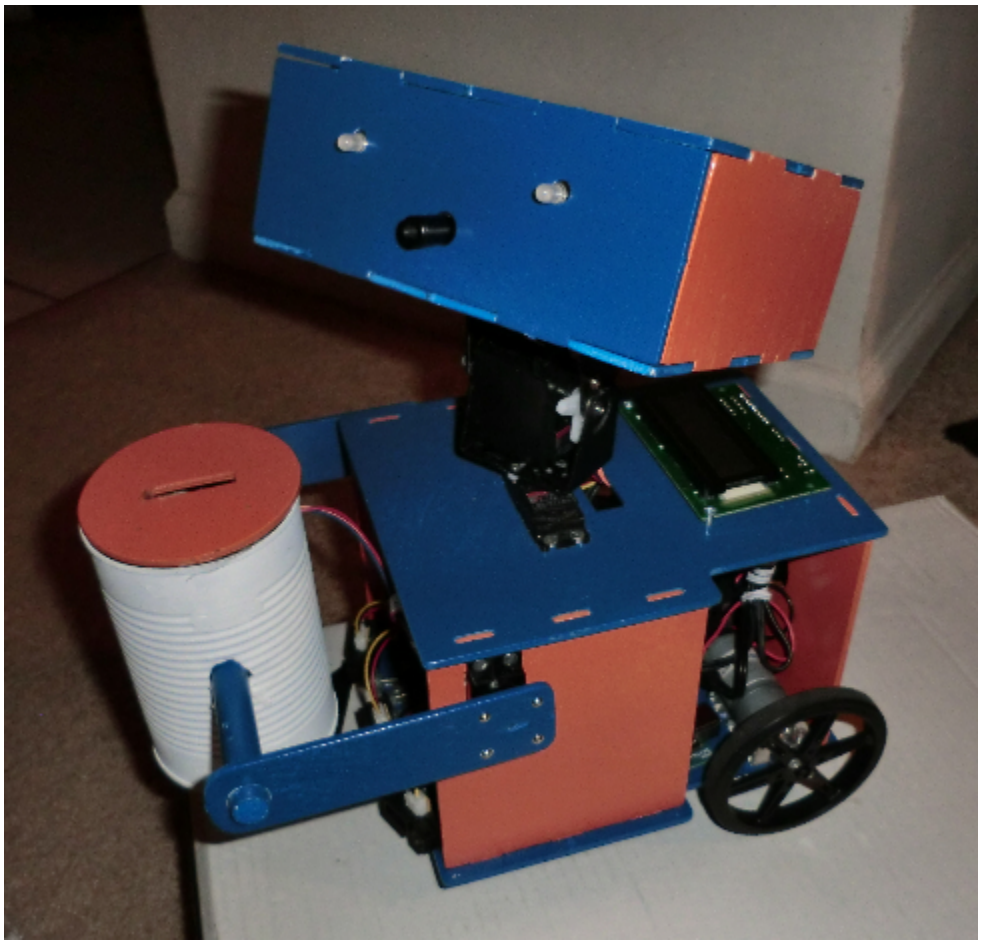


Figure 4: Fully constructed final design of Philanthrobot

6. Actuation

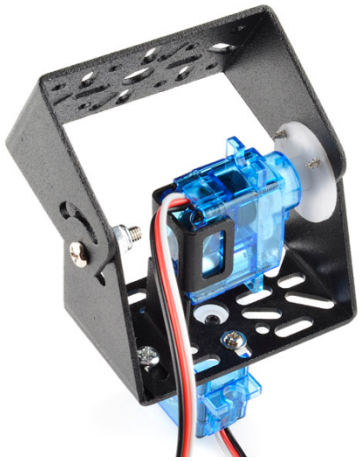
There are two types of actuators used in the robot, geared motors and servos. Two geared motors drive and steer the robot while a pair of servos control the arms and another pair of servos pan and tilt the head of the robot.

The two rear motors are 75:1 Metal Gearmotors (25Dx54L mm) from pololu. Since Philanthrobot is relatively small and lightweight, the 75 RPM and 85 oz-in torque provided by each motor is more than enough. The motors have a free-run current draw of only 80mA and a 2.2 A stall. Each motor is attached to a 3-in diameter plastic wheel with silicon tires using a 4mm D-shaft adapter. The third "wheel" is an omni-directional metal caster ball from sparkfun.

I originally bought the 298:1 Micro Metal HP Gearmotors from pololu for Philanthrobot. While they had comparable RPM and torque to the motors I am currently using, the motors were loud and noisy to the point of being distracting and the way that the motors attached to the wheels, sliding on the D-shaft directly without an adapter, ended up wearing and eventually cracking the wheels in half under the stress of the robots weight and motor torque.

http://www.pololu.com/catalog/product/1586 http://www.sparkfun.com/products/320

All of the servos on Philanthrobot are Hitec HS-485HB's purchased from HobbyTown USA. The servos provide 76.37 oz*in torque at the provided 6V from the voltage regulator. The servos are used to move the arms which are attached to donation cup. Since the arms are 5 inches long from the center of the servo horn, the servos can support roughly 15.72 oz each or about 2 lbs of weight total in the donations cup. One US penny weighs approximately 0.09 oz and one US quarter weighs approximately 0.2 oz so the Philanthrobot can hold quite a bit of loose change before the servos stall. The other two servos are mounted to the pan/tilt assembly purchased from Sparkfun. The servo placed inside of the pan/tilt brackets had to be modded in order to fit inside as the brackets were made for micro-servos, not full-size.



http://servocity.com/html/hs-485hb_servo.html http://www.sparkfun.com/products/10335

I stripped the original servo that was inside of the pan/tilt bracket, a Hitec HS-55 Feather servo. With a torque of only 16 oz*in, the servo didn't stand a chance under the weight of Philanthrobot's over-sized head. I replaced it with a stronger servo that could still fit in the pan/tilt bracket, a Hitec HS-81 Universal Micro Servo with 36 oz*in of torque. This servo lasted about a week before I eventually stripped it as well. Tired of wasting money and stripping micro-servos, I took one of the full-sized HS-485HB servos from Philanthrobot's arms, clipped off the mounting brackets, sanded down the nubs, and forced it into the pan/tilt bracket. It may not fit perfectly, but it has been the only servo so far to successfully support the weight of Philanthrobot's head.

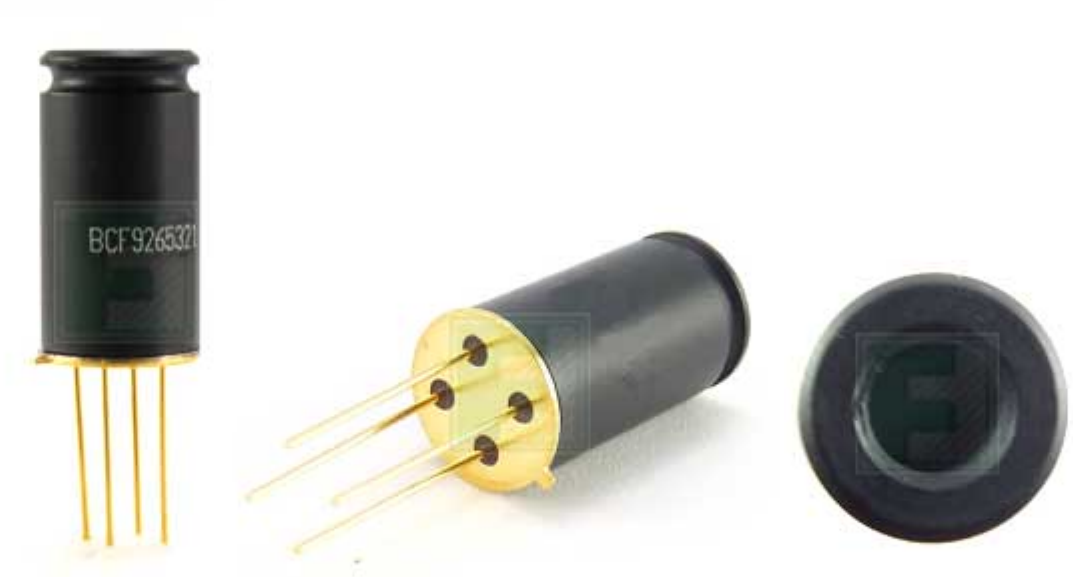
7. Sensors

The sensors utilized by the Philanthrobot are:

- Sharp Short Range IR - Three on the front center and diagonals for object avoidance
- IR Thermometer - Human body heat detection and motion tracker
- IR Photo Interrupter- Detect when an object is placed into the robot's donation cup
- Bump - Used as a failsafe to check if the robot runs into something

7.1 Special Sensor - MLX90614 Infrared Thermometer

The MLX90614 Infrared Thermometer is the Philanthrobot's special sensor. The MLX90614 is an infrared thermometer designed for non-contact temperature sensing. By reading the infrared light coming off of an object, the MLX90614 can sense object temperatures between -70 to 380˚C.

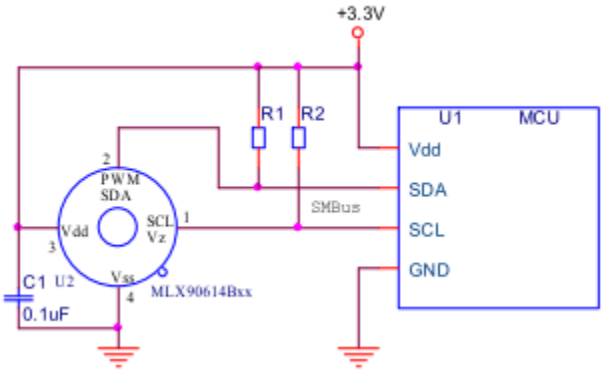


http://www.futureelectronics.com/en/technologies/semiconductors/analog/sensors/temperature/Pages/1705169-MLX90614ESF-BCF.aspx

The MLX device contains an internal IR thermopile detector chip and a signal conditioning DSP resulting in a high accuracy and resolution output. There are two different methods of output, PWM and I2C. I will be using I2C because of the greater output resolution and accuracy. The 10-bit PWM output has an output resolution of 0.14˚C, while I2C provides a resolution of 0.02˚C. The MLX datasheet boasts a temperature reading accuracy of 0.5˚C around room temperatures, but as of now I don't have any way of verifying this.

The measured temperature output is the average temperature of all of the objects in the sensor's field of view. In order to minimize the interference of ambient temperatures and to maximize the accuracy of object detection, the smallest field of view model was chosen. The

model of the MLX90614 that is used for this project has a field of view of only 10˚, compared to the available 35˚ and 90˚ models.



Circuit from the MLX90614 Datasheet

The model of the MLX90614 for the Philanthrobot uses a 3.3V supply voltage. Since I am using I2C instead of an analog output, the SDA and SCL pins are attached to the corresponding SDA and SCL pins on the Arduino Mega. There are 3 available pairs of I2C hookups, but I use analog pins 4 and 5. A pair of 4.7K pull-up resistors are needed between the SDA and Vcc and SCL and Vcc pin. I also have a 0.1uF capacitor between Vcc and GND as suggested in the datasheet.

7.2 Infrared Proximity Sensor Short Range - Sharp GP2D120XJ00F

Philanthrobot uses three Sharp short range IR proximity sensors for object avoidance. The sensors are mounted to the front of the robot and face the center and front right and left diagonals. The sensors have an analog output that varies from roughly 3.1V at 3cm to 0.3V at 40cm. Unfortunately the voltage output is not linear, so a power function was applied in order to convert the analog voltage to a distance.

http://www.sparkfun.com/products/8959

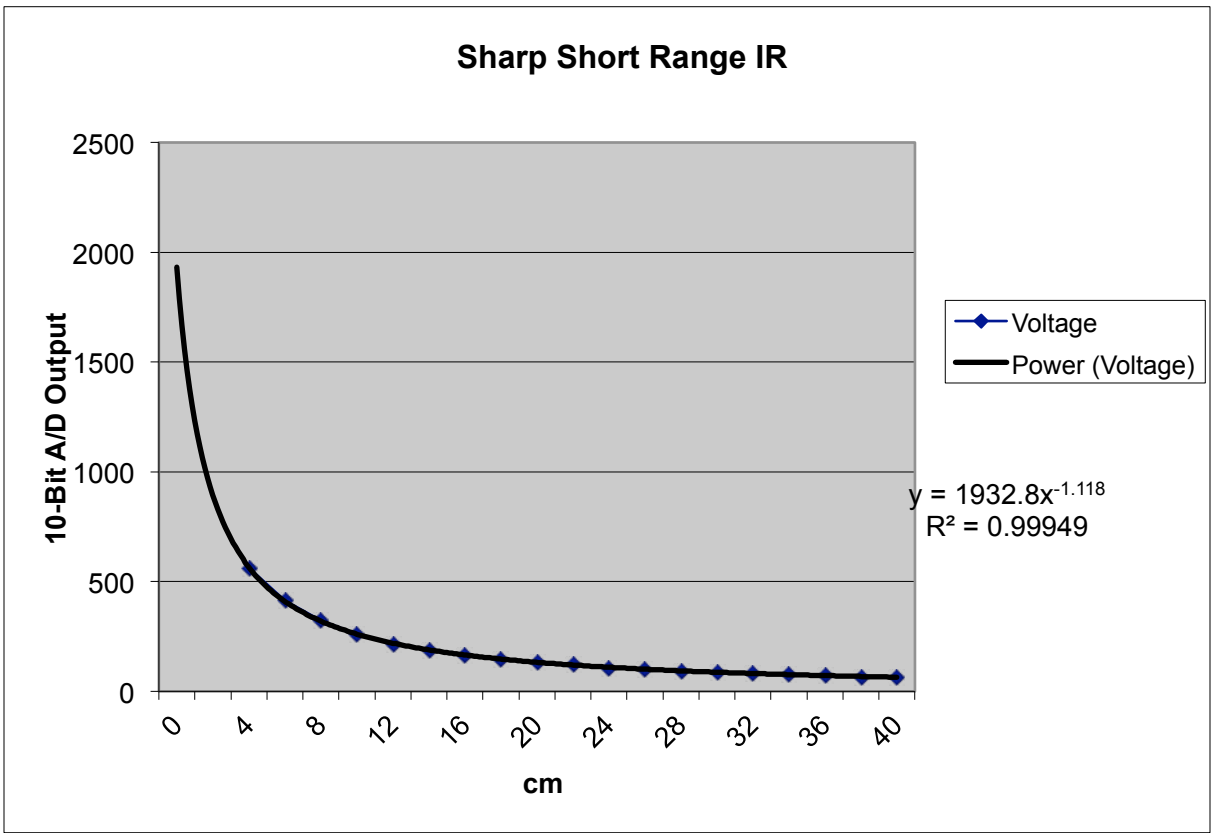


Figure 6: Analog output voltage for Sharp short range IR sensor

7.3 Photo Interrupter - GP1A57HRJ00F

This sensor is used to determine if a coin has been placed into Philanthrobot's donation cup. The photo interrupter consists of an infrared emitter on one side of the 10mm gap and a shielded infrared detector on the other. When an object passes between the two, it breaks the infrared beam and the analog output voltage pulls low. When the photo interrupter is at steady state it sits at high, or 5V. The corresponding breakout board was used to mount the photo detector.

http://www.sparkfun.com/products/9299

8. Behaviors_

When Philanthrobot is powered on, it will scan the room with the IR thermometer. The thermometer is mounted to the head of the robot which sits on a pan/tilt servo pair. The servos will sweep the room while the processor collects a certain number of temperature points. Philanthrobot will then take the highest temperature and determine the location of the heat source and move towards it. As it moves forward, it continuously records the IR temperature. If the temperature falls below the stored target temperature, Philanthrobot assumes that the person has moved and will start to sweep his neck servo. When a temperature is then found within range of the stored temperature, Philanthrobot turns to face it and updates the target temperature.

As Philanthrobot moves forward, it also checks it's IR proximity sensors to avoid objects. As objects get closer to the IR sensors, Philanthrobot slowly turns away from them. If an object nears the front right sensor, Philanthrobot will slowly turn left and vice-versa. If Philanthrobot runs into too many obstacles, it will assume that it is lost, stop moving, and re-start the process, sweeping the room looking for its target. In order to prevent Philanthrobot from object avoiding the donor that it is seeking out, if the temperature reading from the IR thermometer is within range of the recorded highest temperature, Philanthrobot will override the object avoidance routine.

Once Philanthrobot detects an object within 7 inches that has an equal or greater temperature to its target, it will begin the donation collecting sequence. Philanthrobot looks up at the person, shakes his donation cup in an irresistible fashion, and waits for a donation. If a coin is not place into the cup within 15 seconds, the timer will expire and Philanthrobot will assume that the person did not want to donate any money. He will look down at his empty cup depressed and turn around 180 degrees in hopes of finding another potential donor. If the photo interrupter detects a coin within the 15 second timer, Philanthrobot will thank the donor and then backs up and turn 180 degrees and start the process all over again.

Y Initial Temperature Sweep N N Move Forward N Cup Detected? Y Y Look Sad

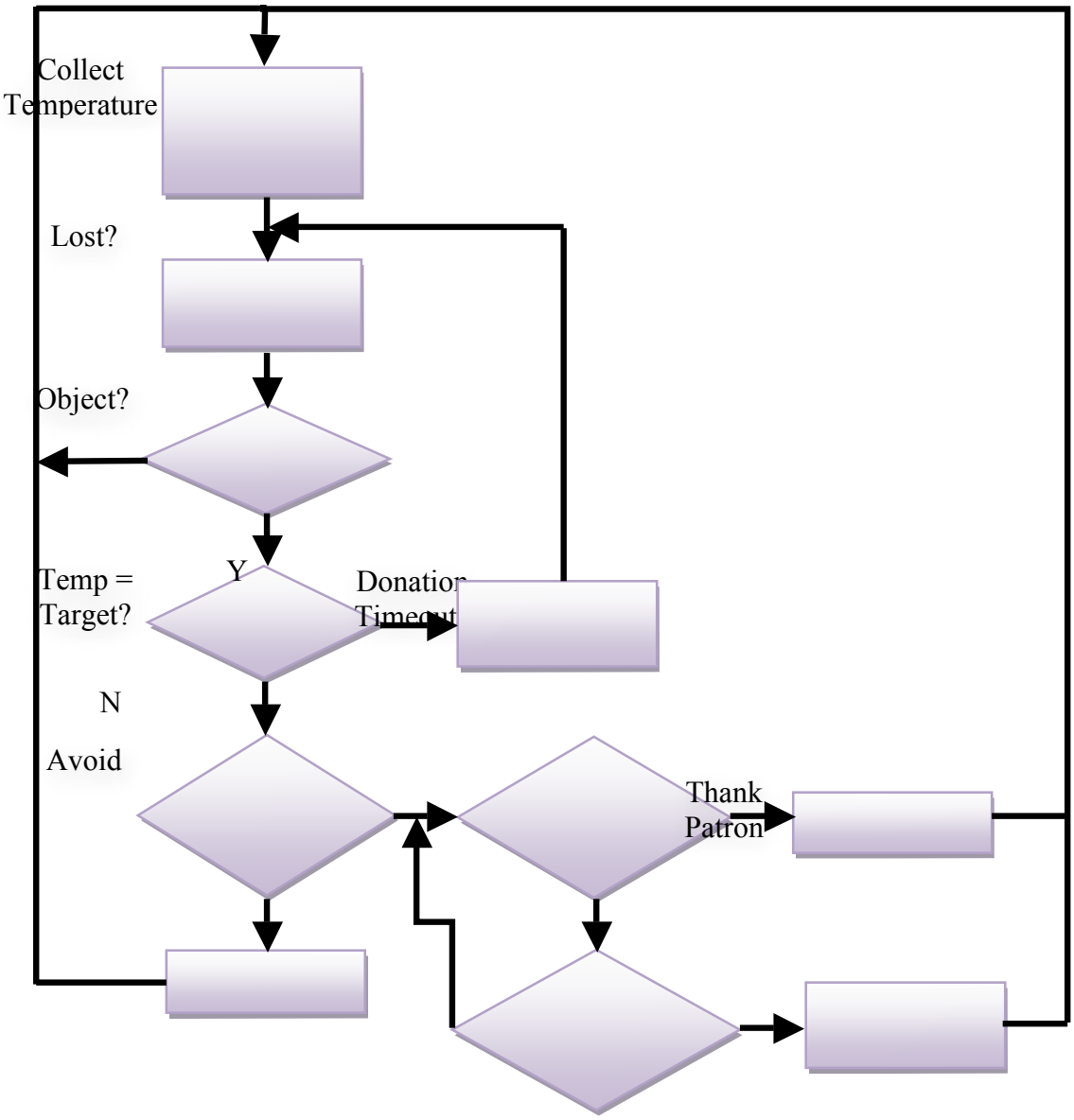


Figure 7: Behavioral Flowchart for Philanthrobot

9. Conclusion

Philanthrobot has achieved all of the goals and behaviors that I wanted to accomplish. He can successfully locate and track people based upon their body heat and then collect donations from them.
Depending on the distance from the IR thermometer and the temperature of the room, Philanthrobot is almost always successful in reaching his target.

Unfortunately, since I took IMDL in the fall semester people will be bundled up due to the colder weather. This makes it harder for Philanthrobot to detect body heat due to the surface temperature of the clothes being closer to the ambient temperature. But, when Philanthrobot loses track of the target you can always place your hands at his IR thermometer sensor's level or "roll up your jeans" and he will find you.

If I could start the project over with the knowledge that I gained this semester, I would make Philanthrobot's head smaller, buy more of the IR thermometers, and replace the IR proximity sensors with sonar. The weight of the head was a big problem before I modded the 485-HS servo to fit in the pan/tilt bracket and ended up costing me two extra servos. Since I am only using one IR thermometer sensor, it makes it more difficult to judge the location of the body heat source. I have to sweep the sensor back and forth to determine if the person has moved, but if I had an array of the sensors I would be able to compare data between them to determine the location more quickly and accurately. The point of Philanthrobot was to collect donations for charity, and most of this takes place outside. While the IR proximity sensors are cheaper, they aren't suitable for use outside in the sunlight without proper shielding, and sonar sensors would have made it easier to transfer my robot to outside use.

Overall, I am proud of the amount of work that I've accomplished in the semester and would gladly recommend anyone with an interest in robotics to sign up for IMDL.

10. Documentation

Arduino Mega 2560 Documentation
http://www.arduino.cc/en/Main/ArduinoBoardMega2560

Sharp Short Range IR Sensor Datasheet
http://www.sparkfun.com/datasheets/Sensors/Infrared/GP2D120XJ00F_SS.pdf

Photo Interrupter Datasheet
http://www.sparkfun.com/datasheets/Components/GP1A57HRJ00F.pdf

IR Thermometer MLX90614 Datasheet
http://www.futureelectronics.com/en/technologies/semiconductors/analog/sensors/temperature/Pages/1705169-MLX90614ESF-BCF.aspx

11. Appendices

Rather than have the code add an extra 40 pages at the end of the report, I will upload all of the code to Philanthrobot's project website:

http://philanthrobot.blogspot.com/