Smart Squirrel Proof Bird Feeder

Design Document

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1 Introduction

1.1 Objective and Background

Squirrels are the “enemy” of backyard birders. Even though squirrels are cute, bird lovers detest them to appear in their gardens. They do not just want to share the bird food, but they can take all of it. Their amazing athletic ability, voracious appetite and ability to chew through almost everything makes them unstoppable in the backyard. According to the National Pest Management Association, squirrels are considered pests. They are threats to the electrical wires and telephone lines outdoors. They can also invade houses for food and warm shelters [1]. Bird feeders are one of the main food sources that attract squirrels to visit people’s backyard. The main goal of this project is to keep squirrels away from bird feeders and provide a peaceful and enjoyable environment in the backyards for the birders.

To solve this problem, we plan to build a smart bird feeder with a camera compatible with a web application. The camera will first distinguish bird by machine learning algorithm with pre-studied pictures. Other sensors such as pressure sensors are also used to support the bird feeder to distinguish squirrels. After the identification, the feeder machine will either automatically load a reasonable amount of bird food based on its weight or prevent squirrels from stealing bird food. The feeders also have a repelling system to decrease squirrels’ interests to steal food. Researcher Jackson and his fellows from University of Toledo, Ohio, claimed in their study that their study objects, two fox squirrels have a hearing range between 113 Hz to 49 kHz at a level of 60 dB sound-pressure level [2]. Ultrasonic also works as an alarm call among squirrels by another study in University of Manitoba, Canada [3]. By comparison, human and birds have a similar hearing range. Both are most sensitive from 1 kHz to 4 kHz. Therefore, ultrasonic does not have any effect on birds. In addition, when the food is almost eaten up, the feeder will notify people to refill the food on the app. To please the backyard birders, we can also create an additional feature of taking birds’ pictures when birds are eating in front of the bird feeder.

Our solution is an innovation to the existing products, combining the smart squirrel bird feeder and innovation of squirrel proof techniques. The current squirrel repellent bird feeders passively prevent squirrels from taking the bird food, and squirrels are smart enough to beat the feeders. According to the YouTuber Mark Rober, squirrels managed to overcome all the squirrel proof bird feeders he tested [4]. There are some effective squirrel proof bird feeders which have several limitations. Our smart squirrel proof bird feeders is designed to actively provide food for only birds. The feeder also provides smart features such as taking pictures and notifying users.

1.2 Visual Aid

Figure 1: Visual Aid of the Smart Squirrel Proof Bird Feeder

1.3 High-level Requirements List

- The bird feeder must perform real time (less than $500ms$) object detection to distinguish squirrels and birds and also track each bird.
- The feeder machine must load approximately $10g$ bird food to each bird.
- The repel system must be able to expel squirrels when the food is loaded for the birds. The time that squirrels try to approach to the feeder should be at least 50% less.

2 Design

2.1 Block Diagram

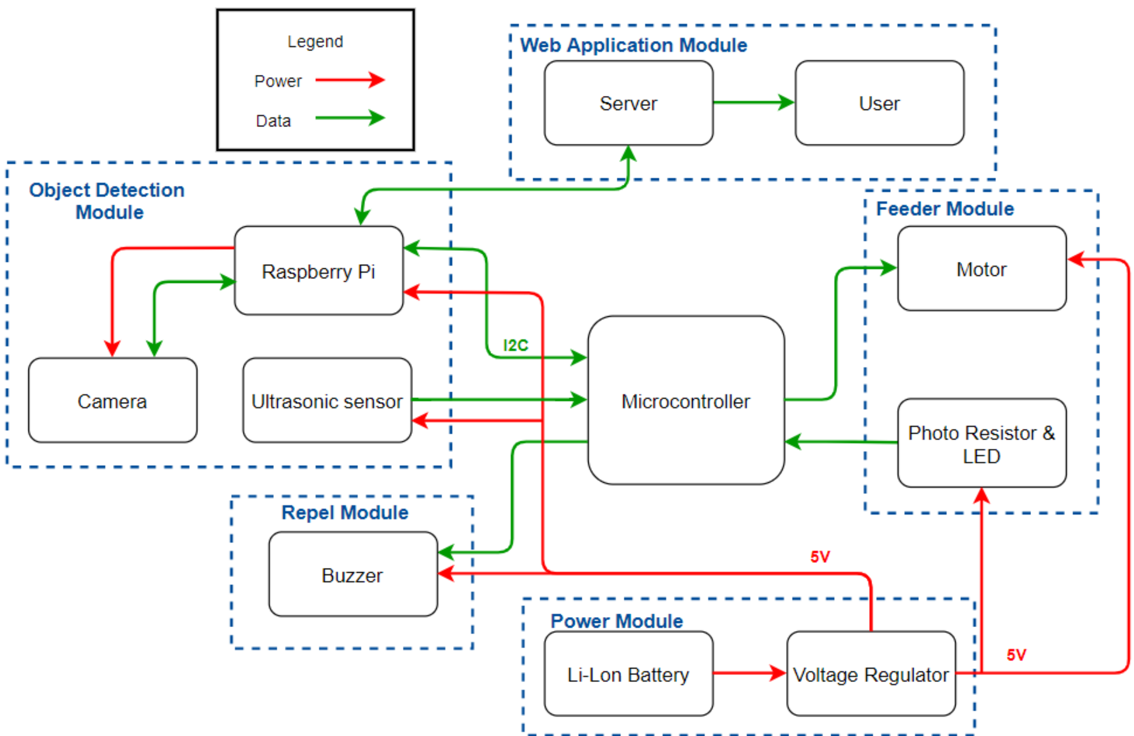

Figure 2: Bird Feeder Block Diagram

2.2 Physical Design

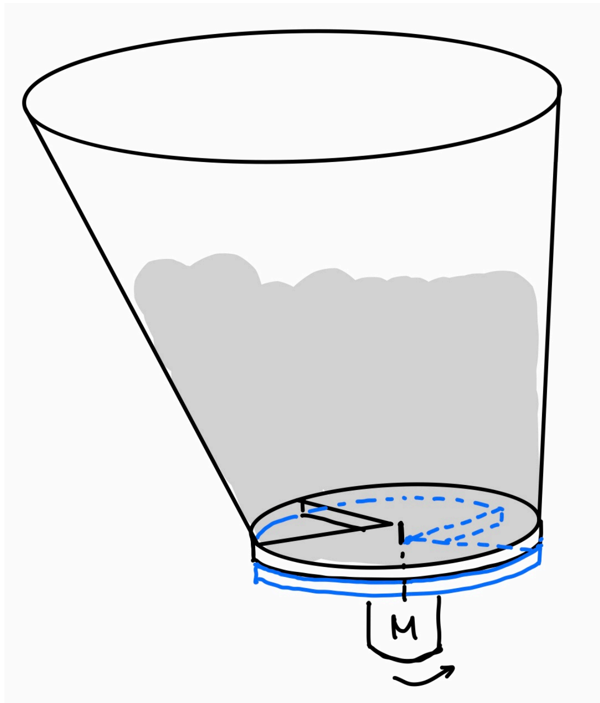

Figure 3: Bird Feeder Physical Design

As shown in Figure 3, the mechanical machine in feeder module will be designed as a upside down circular truncated cone, so that it will be able to have a large food storage as well as a small opening to control the dose of the food. As clearly drawn on the graph, there will be a controllable motor that can rotate the base of the cone, so that the food can be released at desired occasions. The rotation base consist of two plate with same size of opening whereas one is fixed and one is driven by the motor. So, when food need to be loaded, the motor will rotate and the openings will align with each other, hence the food will drop. Otherwise, when the food is not desired, the motor will rotate to a place where the opening are not aligned and so the food will be blocked.

2.3 Repel Subsystem

The repel Subsystem is implemented with a ultrasonic annunciator to generate ultrasound above $20kHz$ to repel squirrels, as squirrels are able to hear ultrasound and ultrasound works as alarm call amount squirrels.

2.3.1 Ultrasonic Generator

The ultrasonic annunciator is connected to the microcontroller. The annunciator is capable to produce a frequency range from $5Hz$ to $50kHz$ with a $5V$ input power. To generate ultrasound, the microcontroller will need to send corresponding frequency signal to the annunciator. The annunciator can produce $40kHz$ ultrasound at a level of $103dB$ sound-pressure level [5].

Requirement	**Verification**
1. The ultrasonic generator should generate ultrasound via a microcontroller at a frequency level of $40kHz$ $\pm 2kHz$ and a sound-pressure level of $100dB$ $\pm 5dB$ to repel squirrels. 2. The ultrasonic generator can generate ultrasound with a frequency range of $20kHz$ - $50kHz$.	1. Connect the output signal from the microcontroller to the ultrasonic annunciator to an oscilloscope. The signal should oscillate at a frequency of $40kHz$ $\pm 500Hz$. 2. To test if the sound frequency of the ultrasonic annunciator has reached the desired range, we need utilize the spectrum analyzer to measure its frequency range.

2.4 Object Detection Subsystem

Object Detection Subsystem is for identifying whether a bird or a squirrel is requesting bird food in front of the bird feeder. The object detection subsystem contains a camera, a trained model and a ultrasonic sensor. The system should output a signal to the feeder subsystem for loading bird food.

2.4.1 Camera

The camera captures the front side of the bird feeder so the single-board computer can process object detection algorithm to identify squirrels and birds. The camera also capture pictures for the users.

Requirement	**Verification**
1. The camera placed within 5cm to the objects should output image or video that covers the full front side of the feeder (approximately $250cm^2$).	1. Take pictures by the camera with a $16cm$ by $16cm$ referenced object placed $5cm$ away from the camera, ensure the camera can capture the whole object.

2.4.2 Ultrasonic sensor

The ultrasonic sensor is connect to the microcontroller. The ultrasonic sensor should be able to detect if there is an object in front of bird feeder or not. The ultrasonic sensor would keep running after starting the bird feeder. If there is an object, the microcontroller will request the single-board computer to wake up and process object detection.

Requirement	**Verification**
1. The ultrasonic sensors should able to detect objects in a similar area range as the camera ($16cm$ by $16cm$)	1. Place a referenced object in front of the ultrasonic sensor, moving a bird picture around the referenced area should cause the return distance value to change.

2.4.3 Single-board Computer

Raspberry pi will be used as the single-board computer to conduct object detection. Raspberry pi receive the streaming from the camera and distinguish squirrels and birds in real time. Raspberry pi need to communicate with the microcontroller for loading-food signal. The communication will happen via UART protocol. Raspberry pi also works as WiFi module to upload pictures and send notification of lack of bird food to the web application.

Requirement	**Verification**
1. Raspberry pi must be able to communicate with microcontroller via serial communication. 2. Raspberry pi must be able to connect WiFi and upload pictures to the web application.	1. Input signals from Raspberry pi and microcontroller, the output should appear immediately and correctly. 2. Place a picture of the bird, a picture of that picture should appear on the web application with the date and time information.

2.4.4 Trained Model

Tensorflow Lite will be used to implement the deep learning models. Identifying squirrels and birds is rather a lightweight job, so Tensorflow Lite should be enough and runs faster than Tensorflow framework.

Requirement	Verification
1. The object detection should happen in real time, at least in $500ms$.	1&2a. Test the algorithm by importing bunch of test images, time average processing time and compute the mAP. The average testing time should less than $500ms$ and the mAP should higher than 90%.
2. The object detection model have a mAP (mean average precision) higher than 90%.	1&2b. Put the same test images in front of the camera. The signal for indicating whether this is a squirrel or bird should appear without noticeable delay and the mAP should be higher than 90%.

2.5 Web Application Subsystem

The web application subsystem connects users with the bird feeder. The web application will notice the user to refill the bird feeder when the bird food is only 10% left in the feeder. And the Web application also involve with a database to store the history information with picture of birds.

2.5.1 Web Application

The web application works as a user interface of the bird feeder. The birds' pictures would store in the database and the notice of lack of bird food would also appear on the web app. Users can search for the history information of the bird feeder with pictures of birds and refilling date.

Requirement	Verification
1. Web application must notice users when there is a shortage(less than 10%) in the bird food.	1. Input a signal of food shortage, the notification should appear on the web application.
2. User should be able to view the history of bird feeder.	2. Click on the history tab, there is a list of history of bird feeder, including pictures of birds with date and time and the refilling date.

2.6 Feeder Subsystem

The feeder module will take input signal from object detection module via the microcontroller and decide to either load food or not through mechanical switches. The amount bird foods that is loading to the birds should be approximately $10g$. The small amount of bird food would limit the times that squirrels try to rob bird foods.

2.6.1 Motor

The mechanical switch is driven by the motor to load bird foods for birds. The motor is directly controlled by the microcontroller. By limiting the time and speed of the motor, the amount of food loaded can be controlled.

Requirement	**Verification**
1. The feeder will load food after receiving the signal transmitted back from the image processing result.	1. Implement the identify-feed process with bird picture/model to test the accuracy.
2. The feeder will load approximately 10g bird food each time.	2. Measure the amount of food that the feeder will load each time. Make sure the error is less than 10%.

2.6.2 Photo Resistor & LED

Photo resistor and LED will be placed on the inner side wall of the feeder. The photo resistor will be able to detect if the feeder need reload food and send the signal back to notify the user via web application module.

Requirement	**Verification**
1. The user will get notification if there is a shortage (less than 10%) in the bird food.	1. Test with different food amount for the accuracy of food shortage detection with photo resistor and LED. If the bird food is below the 10% mark, it should trigger the food-shortage signal.

2.7 Power Subsystem

2.7.1 Power Supply

AC/DC adaptor will be used to power the microcontroller and camera connected. There will be a 9V battery converted to 5V, which will power all the Modules. TS780572 will be used to convert 9V battery to 5V.

Requirement	Verification
1. The batteries must be able to store enough charge to provide at leaset 50mA at 5V for 1 hour.	1A. Attach a 5 Ω resistor as a load. Measure the current through resistor with an oscilloscope. Discharge the battery for one hour.

2.7.2 Voltage Regulator

Requirement	Verification
1. The voltage regulator must provide 5V±5% at 50mA.	1.Attach 5Ω resistor as a load. Supply the regulator with 9V DC. Measure and ensure the output voltage remains between 4.75V and 5.25V using the oscilloscope

2.8 Control Subsystem

2.8.1 Microcontroller

The microcontroller will be connected to the ultrasonic sensor, ultrasonic annunciator, motor, photo resistor and Raspberry Pi. ATmega328p will be used as the microcontroller. It needs to send high frequency signal to the ultrasonic annunciator to generate ultrasound for repelling squirrels. The microcontroller also receives the feedback from all the sensors and the signal from Raspberry Pi to control the motor to load bird food when the Raspberry Pi and ultrasonic sensor indicate there is a bird.

Requirement	Verification
1. The microcontroller must be able to communicate with Raspberry Pi.	1. Input signals from Raspberry pi and microcontroller, the output should appear immediately and correctly.
2. The microcontroller should send out high frequency signal ($40kHz$ $\pm 5\%$) to ultrasonic annunciator.	2.Connect the output signal from the microcontroller to the ultrasonic annunciator to an oscilloscope. The signal should oscillate at a frequency of $40kHz$ $\pm 5\%$.
3. The microcontroller should control the motor to run for $1s$ to load $10g$ $\pm 5\%$ bird food.	3. Input a signal for the microcontroller to load bird food, the loaded bird food should weight $10g$ $\pm 5\%$.

2.9 Circuit Schematics

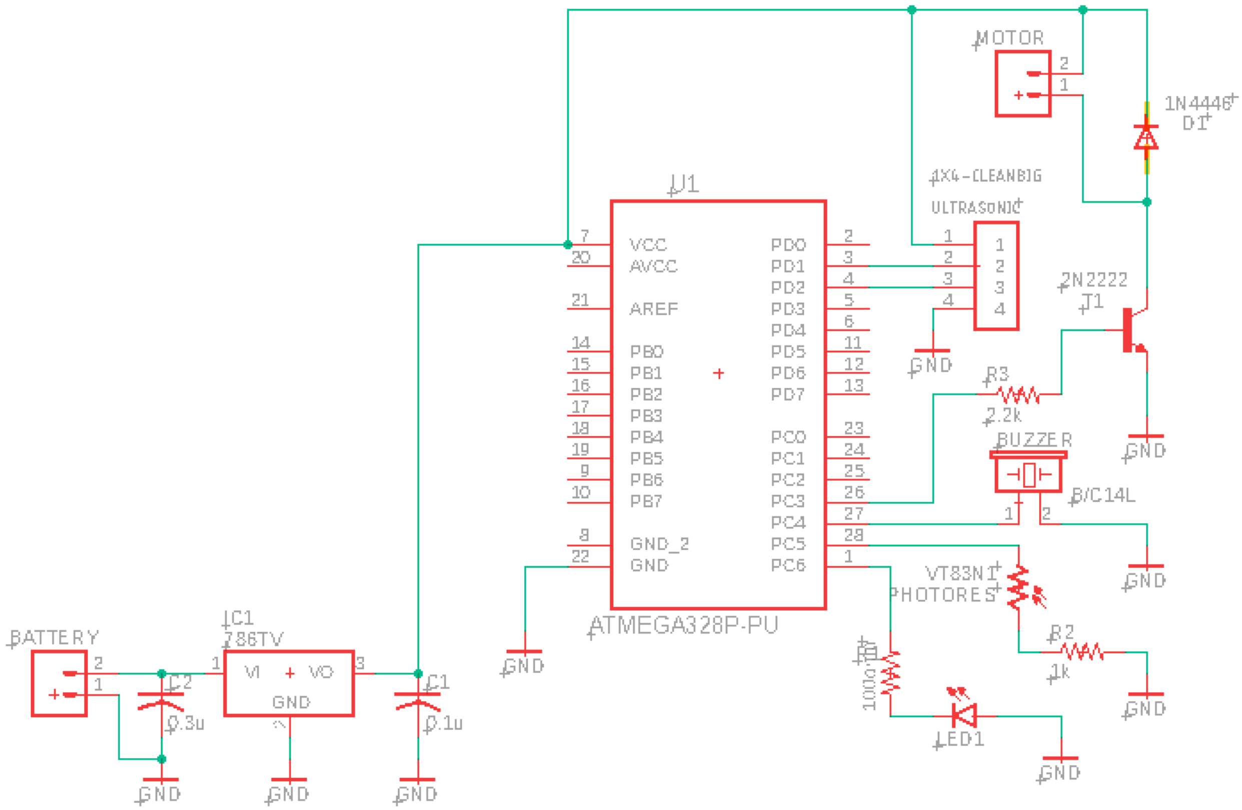

Figure 4: Circuit Schematics for Repel, Detect, Feeder and Power Modules

2.10 Flow Chart

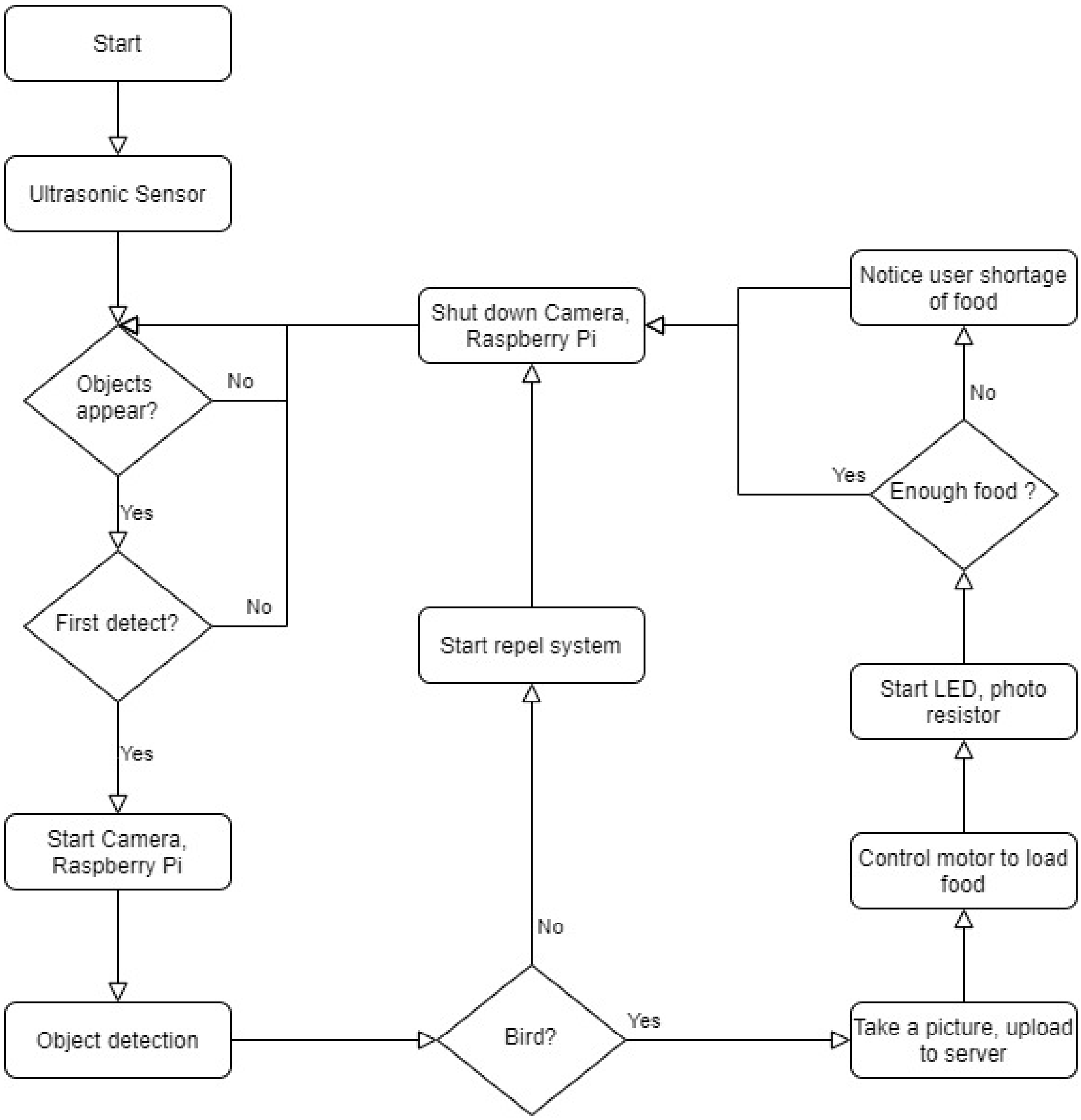

Figure 5: Flow Chart

As shown in the Figure 5, when the system starts, the ultrasonic sensor would run all the time to detect if there is an object in front of the feeder. If the ultrasonic sensor detect an object, we only want to do object detection once to reduce the power consumption. In this way, we also control the time to load food for one bird. Thus, the Raspberry Pi and camera will only start at the beginning of an object detection. After processing the image, the model will identify the object. A squirrel will cause the repel system to start. If the object is a bird, the picture will be uploaded to the database by Raspberry Pi and in the mean time, microcontorller will control the motor to load food for the bird. At the end of procedure, the photo resistor will check if there is enough food in the container. The food shortage signal will send to the web application and notice the user by Raspberry Pi. Raspberry Pi and camera will shut down to save power.

2.11 Tolerance Analysis

One important tolerance of the project is the power consumption. The consumption of the main components are shown in the table below. The battery type of the project is AA with 2400 mAh capacity. After rough calculation, the circuit will approximately draw at least 725 mA current from the battery, which indicates that the feeder machine will work about 3.3 hours before it runs out of power. However, the motor and Raspberry Pi will not work full time according to the flow chart shown above, the actual power consumption will be less and the usage time will increase. To further decide the actual potential power consumption, extra measurement is needed with lab equipment.

Component	**Capacity**
Battery	2400mAh

Component	**Working Voltage**	**Current**	**Total Current Drawn**
Ultrasonic Sensor	DC 5V	15 mA	15mA
Motor	DC 5V	∼200 mA	200mA
Buzzer	DC 5V	∼10 mA	10mA
Raspberry Pi	5V	500mA∼1.2A	500mA∼1.2A
Total			725mA∼1425A

3 Cost and Schedule

3.1 Cost

3.1.1 Labor

The total estimated time for the project is approximately 360 man hours. Also, assuming the development salary is around $\$40/hour$. The total labor cost for the project will be:

Name	Hourly Rate	Total Hours	Total
Linfei Jing	$40	120	$12,000
Christine Li	$40	120	$12,000
Yitian Xue	$40	120	$12,000
Total			$36,000

3.1.2 Parts

Part	Quantity	Cost
ARDUINO UNO R3 [A000066]	1	$23
Buzzer [W-08A]	1	$2.32
ULTRASONIC SENSOR [3942]	1	$3.95
STANDARD MOTOR 9100 RPM	1	$1.95
PHOTO RESISTOR GM5539	1	$0.95
LIGHT EMITTING DIODE [5mm]	1	$0.5
Resistors [A-0003-C07]	10	$5.95
RASPBERRY PI 4 MODEL B 4GB SDRAM	1	$55
Total		$93.32

Sum of the cost for this project will be around **$36,093.32**.

3.2 Schedule

Week	Linfei	Christine	Yitian
3/8	Test with subsystems on Arduino board and design the PCB board layout	Begin working with Arduino IDE to test subsystems using Arduino	Begin working with Arduino IDE
3/15	Revise and finalize the PCB board design	Finalize the PCB Schematic from the test result	Begin working on object detection and Tensorflow
3/22	Further improve & test PCB/Solder and work on feeder module	Adjust PCB design if necessary and start fabricating physical device in Feeder module	Implement object detection model on the RPi, assisting with feeder module
3/29	Revise PCB and test the object detection module with code from Yitian	Working on communication protocol between microcontroller and RPi	Set up WiFi feature of the RPi
4/5	Revise project functionality and construct database connected for web app module	Connect PCB with other components and start testing	Design web application and construct database
4/12	Assemble RPi Camera with the feeder box in the design and prepare for the mock demo	Assemble all the components and test the overall functionality	Assemble all the component for the mock demo
4/19	Mock demo	Mock demo	Mock demo
4/26	Demonstration	Demonstration	Demonstration
5/3	Presentation	Presentation	Presentation

4 Ethics and Safety

There are several concerns regarding the safety and ethics in the project which need further consideration. For the safety concerns, improper ways of using and storing batteries can cause fire or explosion hazard. The damage may can occur when the temperatures are too high (e.g., above 130°F) or too low (below freezing 32°F [6]). The bird feeder, as an outdoor electrical device, could be damaged by the moisture in extreme weather which can lead to short-circuits. We are responsible for notifying the users of the potential consequences and send out the instruction and correct implementation for this product, in compliance with IEEE Code of Ethics [7].

For ethical issues, we will focus on implementing the security for the web application module to ensure the privacy of users. We will keep the data confidential and reliable by avoiding illegal transmission of the data and clarifying the retention and disposal periods for the information [8].

References

[1] N. P. M. Association. (2021, Feb) Squirrels 101. Accessed February 2020. [Online]. Available: https://www.pestworld.org/news-hub/pest-articles/squirrels-101/

[2] H. H. Jackson LL and H. RS, "Audiogram of the fox squirrel (sciurus niger)," *J Comp Psychol*, Mar 1997, accessed February 2020.

[3] D. R. Wilson and J. F. Hare, "Ground squirrel uses ultrasonic alarms," *Nature*, Jul 2004, accessed February 2020.

[4] M. Rober. (2020, May) Building the perfect squirrel proof bird feeder. Accessed February 2020. [Online]. Available: https://www.youtube.com/watch?v=hFZFjoX2cGg&t=187s

[5] L. Tang. (2019, Nov) Product specification (w-03a). [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/Myntahl%20DBA%20East%20Elect/W-03A.pdf

[6] Osha.gov. (2019, Jun) Preventing fire and/or explosion injury from small and wearable lithium battery powered devices. Accessed February 2020. [Online]. Available: https://www.osha.gov/dts/shib/shib011819.html

[7] ieee.org. (2016) Ieee code of ethics. Accessed February 2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

[8] acm.org. (2018) Acm code of ethics and professional conduct. Accessed February 2020. [Online]. Available: https://www.acm.org/code-of-ethics