Squirrel

Design Document

Team 3

Client: Bob Thompson

Adviser: Gary Tuttle

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Executive Summary

Development Standards & Practices Used

- Using a hybrid agile process
  - Weekly “stand-up” meetings
  - Dynamic sprints
  - Code reviews before merging
  - Use git for version control

Summary of Requirements

- The product must scare away squirrels
- The product must not damage the house or injure the clients pet
- The product must be able to withstand bad weather conditions
- There should be some way to monitor the status of the device
- The device must be able to attach to the deck without damaging it
- The device should be relatively low in cost

Applicable Course from Iowa State University Curriculum

- Cpre 185
- Cpre 288
- Cpre 458
- Cpre 575
- EE 333
- SE 185
- LD ST 322
- Com S 227
- Com S 228
- Com S 309

New Skills/Knowledge acquired that was not taught in courses

- Developing and designing a mechanical system to move the device
- Building and testing prototypes
- Evaluation and selection of parts needed to build the device
- Working on teams with people that specialize in an area different from our own.
- Identifying and providing for the needs of a client
- Developing a test plan

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1 Introduction

1.1 Acknowledgement

Thanks to Bob Thompson for providing the project idea, and Gary Tuttle for technical knowledge and advice.

1.2 Problem and Project Statement

Bob Thompson has squirrels that come and chew on his deck. Bob needs to get rid of the squirrels because the damage that they are doing to the deck and house is expensive to repair. The squirrels are smart enough to ignore loud noises and Bob's dog barking at them. Therefore, we need to find some way to autonomously scare the squirrels off of Bob's deck in a nondestructive way. The device that we create must be able to withstand the outdoors and potentially poor weather conditions. It must also only target squirrels, Bob has a pet dog and it is important that the launcher does not shoot at him.

To solve Bob's problem we propose using a small turret system that targets the squirrels and shoots them with ping pong balls. The ping pong balls will be attached to a fishing line so that we can reel them back in once they have been launched. We plan to use a sensor network and a computer vision system to identify and then target the squirrels with the launcher.

1.3 Operational Environment

One of our biggest challenges for this project is making the turret able to withstand the weather. Since it will be exposed to the elements on Bob's deck we need to design it in a way that if there is a storm or bad weather the turret will not be damaged. We will also need some form of monitoring system so that if our design fails to withstand some weather we can update Bob that part of the turret has malfunctioned.

1.4 Requirements

- The product must launch a projectile towards squirrels to scare them off the deck. The targeting system has to identify squirrels specifically so that it won't shoot at people or other animals.
- This projectile must not damage the deck, or injure the clients pet. There are windows along the house that can be easily broken and there will be traffic on the deck from other animals and people. In case the projectile misses the squirrel, there must be zero risk that the projectile will cause harm to the property or any other animal.
- The product must be able to withstand bad weather conditions. Wind should not prevent the product from rotating as normal and rain must not prevent the targeting system from identifying squirrels.
- There should be some way to monitor the status of the device. Should a device stop working for some reason, it must have a way to alert the client. Device malfunctions could include: projectile is damaged or not reloading, a camera or sensor is broken, a camera or sensor is covered by something, or the device cannot turn/rotate.

- The device must be able to attach to the deck without damaging it. The wood on the deck should not be screwed or nailed into, and the device should detach without peeling off the paint or finish.
- The device should be relatively low in cost. All three devices should be produced within the base budget provided for the class.

1.5 Intended Users and Uses

While our product is designed for Bob's situation it could potentially be used in any situation where the user wants to scare away squirrels. The only adjustments that would need to be made for each user would be the attachment the secures the launcher so that it does not move or fall over.

1.6 Assumptions and Limitations

Assumptions:

- Three identical machines, each with a shooting range of around 25', will be sufficient to cover the area of the deck.
- Firing a ping pong ball toward the squirrel will be enough to deter it from damaging the deck.
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Limitations:

- Machine must have a reasonable cost.
- Has to operate for long periods of time without maintenance.
- Must stay operable in strong winds and rainy conditions.

1.7 Expected End Product and Deliverables

The goal of our project is to produce a functional squirrel deterrent turret by December of 2020. Given the success of the first unit, as well as time and budget constraints; we may decide to build up to 2 more units to improve coverage of the property. The sentry device can be broken down into the following 5 subsystems: power, vision, targeting, launching, and UI.

The power system is responsible for stepping down AC power from an outlet to DC voltages that will be used to power the raspberry pi, servos, sensors, and launcher.

The circuit in Figure 4 is our initial idea for ADC power conversion.The voltage rectifier turns the AC to a rectified wave which then is smoothed out by capacitors and a switch-mode power supply controller. This possibly will need an LC filter, but the voltage regulator would finally step the power to the load to the most appropriate voltage the load needs. We will have an approximation once we start ordering servos, launcher electronics, computer hardware, and any other variables.

The vision system is responsible for controlling the sensors and identifying the squirrels. The photo database and networking aspects used in the machine vision process are also included in this section.

The targeting system is responsible for rotating the center pipe, which is used to sweep the area with the camera and line up the shot for the launching system.

The launching system is responsible for firing and recoiling the projectile. The projectile will be launched with a spring, slingshot, or a flywheel design. The projectile will be recoiled with a servo that winds back a fishing line attached to the ball, to pull it back to its starting position.

The UI is an additional proposed idea that would display system status over an LCD screen. The LCD could be used to display error information useful for debugging or repairs, as well as information on the number of squirrels tracked over a given time.

2. Specifications and Analysis

2.1 Proposed Approach

Our proposed approach is to create 3 identical machines with AI capabilities to identify squirrels. Upon identification, it will shoot a ping pong ball at it to scare it away. The ping pong ball will then be reeled back using a string that will be attached. The machines will communicate with a UI and report any errors to the machines.

So far, we have brainstormed ideas of how we would like the machines to look and function (see section 2.4). We have also started designing circuits and making a list of hardware and software requirements (e.i. See section 1.5 and 1.7).

2.2 Design Analysis

So far, we've designed an initial circuit schematic for power, basic mechanical architecture, and have started making decisions on what the hard requirements are in terms of the possible environmental damages that the system would most likely have to endure.

We have yet to begin implementation of our design. As we progress through this semester and next we will update this section with what we learn about the effectiveness of our design.

Strengths of our current plan include:

- Minimal power usage due to cameras only being turned on if the always-on motion sensors detect movement.

- User-friendly UI to report errors and bugs
- Camera protection and self-cleaning
- Batteries not constantly needing replacement
- Not needing to move negates navigational issues.
- Retractable ping pong ball that doesn't require extensive retrieval measures

Weaknesses of our current plan include:

- Long-term durability against environmental damages
- Power will require an ugly electric cable connecting to the house's power outlet
- Wifi connection required

2.3 Development Process

We will be using an Agile development process with weekly stand-ups and three week long sprints. We have chosen an Agile process because it's flexible and gives us room to learn with each iteration and set appropriate goals/deliverables. Since we aren't very familiar with working on a project like this and working with people from different areas of study, an agile process will let us focus on small deliverables and make sure everyone has something to work on. Weekly stand ups should be sufficient to keep everyone updated; more frequent stand ups would be hard to coordinate between all six group members, but may be necessary the week of an important deadline. We also decided on three week sprints because it forces us to break the project down into smaller, manageable pieces while still giving us enough time to work on important functionality.

We have also decided against a Test Driven Development process due to the fact that a lot of the code we'll be working on is unfamiliar to us and involves a lot of configuration. This means we'll be reading through documentation and then doing a lot of experimenting. Once we have communication set up we'll add unit and integration tests.

2.4 Conceptual Sketch

The system below is a sentry device designed to identify and agitate squirrels. The primary component box holds a sensory array, power convertor, a gimbal, the base of the geared center pipe, and a raspberry pi. The power convertor is used to step the AC voltage from a wall outlet down to the DC voltages needed to power the electrical components within the box. The sensor array is used to detect motion within the range of the sentry. The raspberry pi is used to control all of the other devices in the system.

At the top of the geared center pipe, lies another box which holds the targeting camera as well as the launching and retrieving mechanisms. The center pipe acts as an insulated path for wires between the boxes, as well as rotational axis for the launcher box. The boxes are used to keep components safe from weather and FOD. When movement is detected by the sensory array, the raspberry pi will activate the camera and gimbal to sweep the area for squirrels using machine vision. The camera is attached to the launcher so that it will line up with the projectile trajectory. Once fired, a servo is used to reel back the projectile and place it into the launch position.

The base of the primary box rests on a clamp. The Clamp is used to fix the sentry unit to the deck railing. Velcro straps will also be wrapped through braces on the primary box and the clamp to keep the system secure.

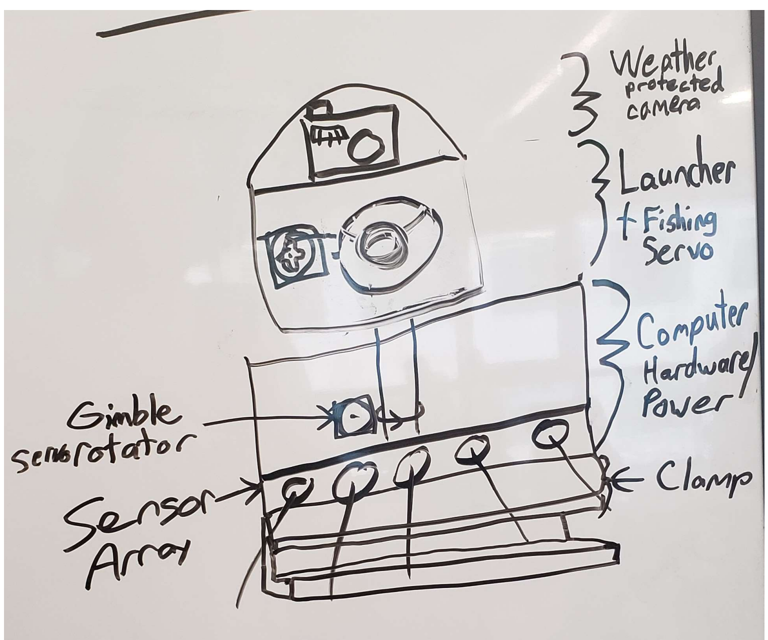


Figure 1: Squirrel Sentry - Front View

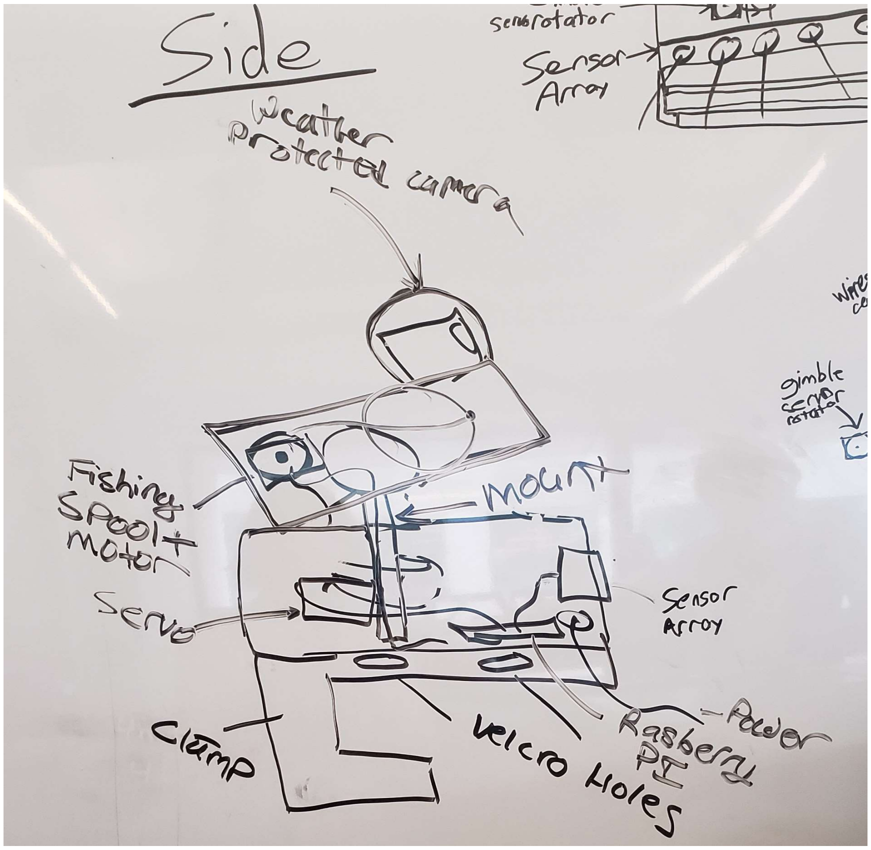


Figure 2: Squirrel Sentry - Side View

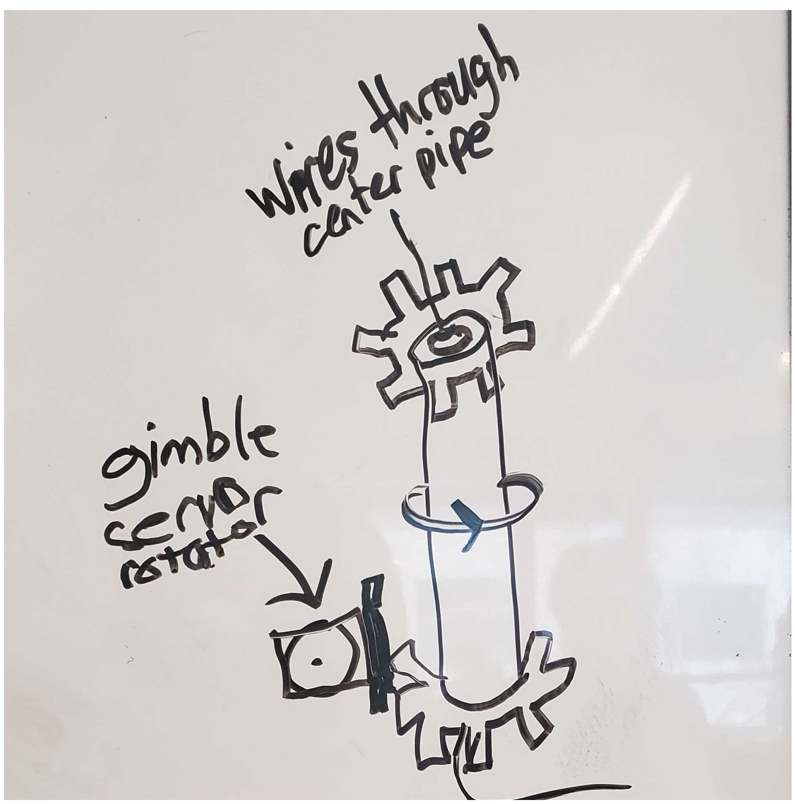


Figure 3: Rotating hollow shaft

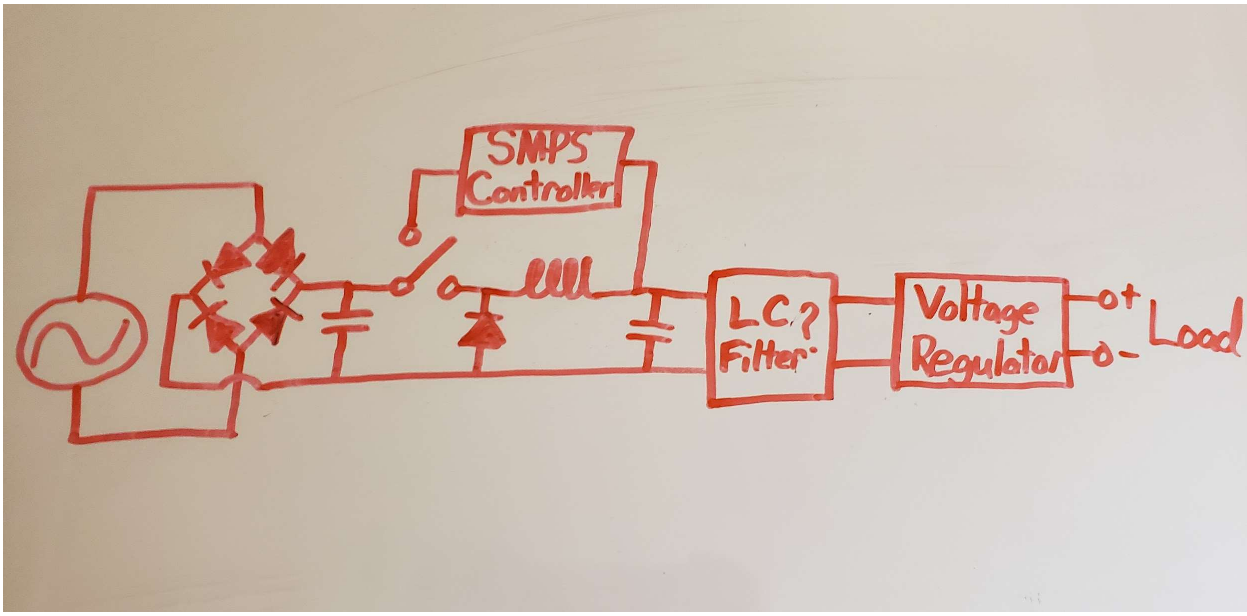


Figure 4: Initial ADC power converter circuit

3. Statement of Work

3.1 Previous Work And Literature

We intend to model the computer vision piece of our project after a similar project that was done by Peter Quinn [1]. Peter uses a product called Jevois, a camera system with a small microprocessor attached that is optimized to use deep neural networks (DNN) for object localization and classification. Peter takes the on board YOLO (you only look once) classifier and uses transfer learning to fine tune it to identify the squirrels in his garden. Transfer learning is a technique where you take a previously trained DNN and continue its training using a small data set specific to your use case. Using transfer learning Peter was able to tune the network with only a few images of squirrels in his yard and get satisfactory detection.

Using Peter's method is advantageous to us. It allows us to offload the processing of the network to the Jevois camera, and we will not need to worry about the processing requirements for the main arduino processor that we intend to use. It also gives us a path to develop the vision network without needing to design it ourselves. While this project gives us a jump start on the vision system for our project it is not the perfect solution. The Jevois camera is very slow when using the YOLO network. An alternative that will boost our speeds for this network would be to use the Jetson nano, a full computer for embedded applications that has an onboard GPU module for DNNs. Another issue is that we will need to set up a system to collect images to train our network. In order to use transfer learning we will need to capture images of the squirrels on Bob's deck. This means that we will need to set up a system specifically for collecting data.

3.2 Technology Considerations

For the main controller we needed to choose between a raspberry pi, an arduino, and a Jetson nano. These controllers are very popular. This means that if we run into issues when building the sensor network and connecting the vision system there will be a lot of online resources to assist us in solving the issue. The benefit to using the raspberry pi over the arduino would be its built in wifi capabilities and that it is a full computer which makes it easier to implement the higher level computer vision pieces of the project. The Jetson nano has these same benefits but also has an onboard GPU. If we use the Jevois camera we do not need the GPU module of the Jetson and the raspberry pi would be the best option.

The computer vision system has two options. One is the Jevois camera, and the other is the Jetson nano. The Jevois camera gives us the option to decuple the image processing and detection from the main control system, but at the cost of a significant performance drop. Our research indicates that using our network on this camera would result in a frame rate of ½ fps while Jetson can manage around 3-4 fps. Both of these systems would be the largest single cost of the project with the jetson being around $100 + $30 camera and the Jevois + pi combo being $60 + $55. So the cost is similar between the two and will not be a factor at small volumes.

The launching system has three options. A flywheel, a spring loaded gun, and pneumatics. Pneumatics are a good option because they involve no exterior moving parts for launching. However, looking online it was determined that the pneumatic system for launching would be too expensive around $200. The other two options are a flywheel and a spring loaded gun. The spring loaded gun would come fully built however it would be difficult to reload with our reel system. The fly wheel would be easier to reload, but we will have to assemble it ourselves from the vex parts..

We are looking at using vex kit parts for the motor systems and the gear systems as well as building the flywheel. These parts can be ordered in small volume at relatively low cost and are designed to be easy to use. One major downside is that we will have to write our own drivers since the motor modules are not designed to be used with the main controllers that we want to use.

3.3 Task Decomposition

Targeting System

1. Find or build a gearing system for turning the main axle connected to the launcher.
2. Find or build a motor system to control and turn gears.
3. Define feedback loop and develop program for turning system to specific location.

Vision System

1. Find sensors for motion detection.
2. Develop a loop to turn on the camera when motion is detected.
3. Collect images of squirrels on Bob's deck.
4. Fine tune YOLO network.
5. Load a custom network onto the Jevios / Jetson system.
6. Feed location of detected squirrels from camera to main controller.
7. Develop controls for a targeting and launching system to fire at squirrels.

Launching System

1. Find or build a ping pong ball launcher. Modify it to connect to the targeting system.
2. Find a fishing line and spool to reel in the ping pong ball after it has been launched.
3. Find and build a motor system to reel in the ping pong ball.
4. Define and program control loop for launching and reeling in the ping pong ball.

Power System

1. Finding appropriate ADC Converter for walled power connection
2. Initial draft of circuit design for delivering safe power load

UI (extra)

1. Complete the previous four tasks with priority over this task.
2. Develop a status system that can be used over the internet for debugging purposes as well as real time status of the device when it is running.
3. Develop an LCD display to show general status information about the device.

3.4 Possible Risks And Risk Management

Our main risk is the mechanical system used to control movement and firing of the ping pong balls. As EE/CprE/SE students we have not had any training on developing or building these systems.

Our second risk is the training and deployment of the YOLO network. From past experience we know that this is very complex and will take a long time to do.

Our third risk is creating a reeling system that tangles easily and often when the ping-pong ball is launched. We need to think of ways to prevent tangles with things on the deck like chairs, tables, etc.

Something about COVID here ...

3.5 Project Proposed Milestones and Evaluation Criteria

Milestones

1. Create full bill of materials
2. Order all Parts
3. Finalize design document
4. Targeting system prototype
5. Launching system prototype
6. Vision system prototype
7. Power system prototype
8. Train Vision system
9. Integrate launching and targeting
10. Integrate vision
11. Fully integrate system
12. Pass system test

Milestones 1 through 7 detail our goals for the first semester. Milestones 8 to 12 cover the goals for the second semester. See project timeline for more details.

3.6 Project Tracking Procedures

We will track our progress using the issues page on gitlab

3.7 Expected Results and Validation

Targeting System - System will turn the launcher left and right to a specified location of the programmer.

Launching System - System will launch and reel in ping pong ball when the command is given by the programmer

Vision System - System is able to detect motion. This detection will trigger the main camera to turn on. The main camera will send object detection information back to the main controller.

Main Control - The main control system will take in the information from the sensors and send it to the UI. When the main camera sends a detection signal the main control will use the targeting and launching systems to fire in the general location of the detected object.

Power System - All systems will be left undamage through regular use.

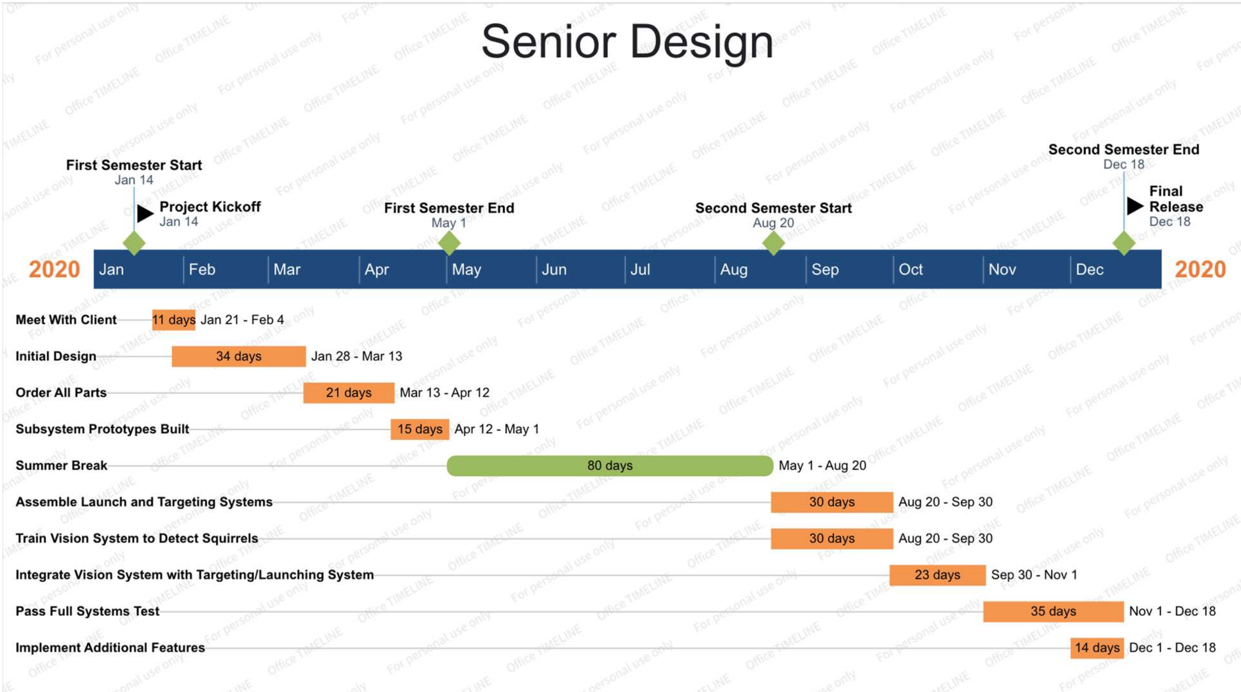
4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

At the end of the spring semester we will have assembled prototypes for each of the subsystems. To meet this goal, we plan to create the full bill of materials and complete parts 3 and 4 of the design document by the end of march. In the first two weeks of April, we will order the parts necessary for the vision system and finalize the design document. In the 3rd week of april, we will finish ordering all the system parts. Over the summer we will continue to improve our subsystem prototypes and plan for the next semester.

In the second semester we will begin by spliting the group into two sections. The first section will work on integrating the launching and targeting systems, while the second section trains the vision system to detect squirrels. After the first 6 weeks of class, we will continue working together to integrate the vision system into the main project. In the final 5 weeks of the class, we will work towards passing the full system test. In the final 2 weeks we may begin testing the device on-site at the client's property.

After these tests are completed, we will begin implementing some additional quality of life features given timing and budget constraints. These features include wifi communication and an LCD display panel that will be used to report analytics on the squirrels as well as device diagnostics.



4.2 Feasibility Assessment

For our project we believe that it is feasible to complete the targeting and launching systems. We also anticipate that the motion detection piece of the computer vision system will be completed. We anticipate a lot of difficulty in the Squirrel detection piece of the computer vision system as the technology that we are using is only four years old. This means that there are very few out of the box solutions for this piece of the system and it will take a lot of work.

4.3 Personnel Effort Requirements

We plan to complete this portion along using our project timeline that will be prepared for the next submission of the design document. See the Gnatt chart in section 4.1

4.4 Other Resource Requirements

We have just begun looking into prefabricated solutions for the launching, targeting, and power systems. We will need sensors for motion detection. We will use the Jevios camera and an arduino or raspberry pi for the main control system.

4.5 Financial Requirements

Have not yet discussed this. The product should be relatively inexpensive since we will need to buy a lot of parts to build the turret.

5. Testing and Implementation

5.1 Interface Specifications

We have spent the last few weeks working towards part selection. We will have a meeting in the coming weeks to make the testing plan.

5.2 Hardware and software

5.3 Functional Testing

5.4 Non-Functional Testing

5.5 Process

5.6 Results

6. Closing Material

6.1 Conclusion

We have completed our initial design. We plan to meet with our advisor to get feedback on it and then plan to split up and take on our four main issues. The targeting system, the launching system, the vision system, and the power system. We also intend to meet in the next few weeks to develop our project timeline, and our testing plan.

6.2 References

[1] P. Quinn, *Squirrel Deterrent*, Hackaday.io, April 28, 2018. Accessed on: February 23, 2020, [Online]. Available: https://hackaday.io/project/156926-squirrel-deterrent/details

6.3 Appendices