24-671 Special Topics: Electromechanical Systems Design
Safeguard Against Pests Robot
Mid-Semester Report: Problem Identification and Design Requirements
October 13th, 2023
Team #4
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Executive Summary

Problem Description:

Our project aims to address the growing concern of people regarding pest control, particularly insect infestation in outdoor environments like home gardens, such as lantern flies. Traditional pest control methods are often not very effective, environmentally friendly, or easy to use. To solve these problems, we are creating an autonomous robot that can identify and eliminate pests in a more targeted, efficient, and eco-friendly way. Our innovative solution will provide a better and safer way to deal with pest problems.

Key Product Features:

Our robots possess several key features that make them ideal for pest control activities. These include the ability to operate autonomously, precise identification of pests, targeted spraying, customizable liquid storage, low liquid level warning, and environmentally friendly design. The robots are designed to work independently, reducing the need for constant human intervention in pest control operations. We utilize advanced techniques such as convolutional neural networks (CNN) to accurately identify and locate target pests while avoiding misidentification of non-target objects. The robots spray liquid directly at the identified pests, eliminating them with precision and minimizing the use of chemicals. The liquid storage system allows users to select the appropriate liquid for the type of pest being targeted, making the robots highly customizable. Additionally, the robot is equipped with a low liquid warning system that alerts users when the liquid levels are low. Our products are designed with environmental awareness in mind, ensuring safe and eco-friendly pest control that does not harm non-target organisms.

Final Prototype Functionality:

The finalized prototype encompasses the key features of the proposed product, which include accurate identification of pests, liquid shooting, low liquid level alarms, and autonomous operation. A CNN-based object classification system is utilized in the prototype to effectively identify target pests and ensure pest identification accuracy. The prototype also demonstrates the ability to shoot liquid at pests through precise and variable range control, thus minimizing collateral damage. It includes a liquid storage system that can detect liquid levels and notify users of low liquid levels through alarms. Although some manual intervention may be required for testing, the prototype already has basic autonomous functionality, showing the potential for fully autonomous operation.

Problem Definition

Problem Description

Pest infestation, particularly in outdoor environments such as home gardens, is a persistent and challenging problem for homeowners and agricultural communities. Traditional methods of pest control typically involve the use of insecticides, traps, or manual intervention. However, these methods have some limitations that affect their effectiveness, environmental impact, and user-friendliness.

Traditional pest control methods, such as using insecticides and traps, often lack accuracy in terms of their effectiveness. They can harm non-target species, damage ecosystems, and lead to a decrease in the overall effectiveness of pest control. The need for repetitive manual work, such as resetting traps or reapplying insecticides, further weakens their practicality.

The use of chemical pesticides has caused serious environmental problems in terms of their impact. These chemicals can have adverse effects on non-target insects, wildlife, and even human health.

The widespread use of chemical pesticides causes pollution, pollutes water sources, and disrupts the natural balance of ecosystems.

Traditional pest control methods require regular maintenance, physical labor, and professional knowledge to be effective, making them less user-friendly. This brings time-consuming and often frustrating experiences to homeowners and gardeners. The limited scope and accuracy of these methods also hinders their ability to solve pest problems comprehensively.

The Pest Control Robot project is committed to alleviating these problems by proposing innovative autonomous pest control solutions. The project aims to develop a robot that can autonomously identify and eliminate pests in a more precise, environmentally friendly, and user-friendly manner. By combining advanced technologies such as object classification, precise positioning, and autonomous operation, this project aims to completely change the way pests are controlled in outdoor environments, making them more effective, environmentally responsible, and available to a wider user base.

Market Competition

Mosquito Control Robot:

Figure 1: Mosquito Control Bot

This robot focuses on removing mosquitos through a trapping mechanism. With its 4 wheel configuration, the robot travels around a predetermined route and makes occasional stops. During these stops the robot begins to emit CO2 gas through catalytic propane reactions. An air flow system is placed near the CO2 source to capture mosquitoes. Both the gas tank capacity and battery determine the max operation length. Operation is Autonomous but is managed through a tablet or wireless controller. Although it is able to remove many mosquitos despite its range limitation, the method it uses is environmentally harmful. Our product will use an environmentally friendly approach.

Autonomous Pest Control Robot:

Figure 2: Pest Control Robot

This robot is intended to spray pesticide along large farms (multiple robots in each farm. The robot travels to specific areas with wheel and track components. The artificial intelligence aspect of the project is underdeveloped, but in concept the robot would need to track pesticide use and communicate with other robots to avoid overspray. The sprayer is designed to apply pesticide with more concentrated targets compared to traditional spraying. Although this product could potentially be used for home garden use, the computing specifications needed to track pesticide use are unnecessary for our problem environment. Instead of spraying in specific areas to prevent future bug infestation, our product will target bugs when they are spotted.

Laser Cockroach Deterrent:

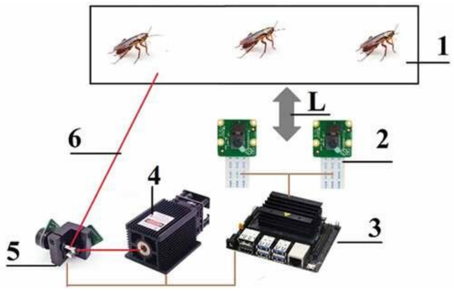


Figure 3: Laser Cockroach Deterrent

This prototype uses galvanometer mirrors and neural networks to point a laser at cockroaches. The system relies on stereovision (2-camera configuration) to detect cockroaches, calculate distance, and calculate angle. Mirrors move accordingly based on these calculations and the laser turns on. The laser is turned on and off based on further camera feedback. The speed of the identification is the biggest limiting factor, mostly due to the limiting camera hardware for the small device. Our product intends to replicate the stereovision configuration used in this product. However, our product will be larger and can accommodate more powerful electronics and computations.

Assumptions and Constraints

Assumption	**Constraint**
Lantern Flies are all types of pests	Timeline limitations
Pest movement speed is not too fast	The project may have budget constraints
Pests become dead after being sprayed once	Actual pests vs. controlled testing environments

Table 1: Assumptions and Constraints

Our project is based on three assumptions and three limitations. The first assumption is that we need to focus only on eliminating Lantern Flies as we have to narrow down the scope and depth of our research due to time constraints. The second assumption is that we cannot afford high frame rate cameras, and thus we assume that the movement speed of pests will not be too fast. If an insect moves too fast, it cannot be captured on camera. The third assumption is that pests are set to die after being sprayed once, and therefore, we do not need to continue monitoring insects that have already been sprayed with insecticides. These assumptions also highlight the limitations of the actual environment.

Stakeholders and Customer Needs

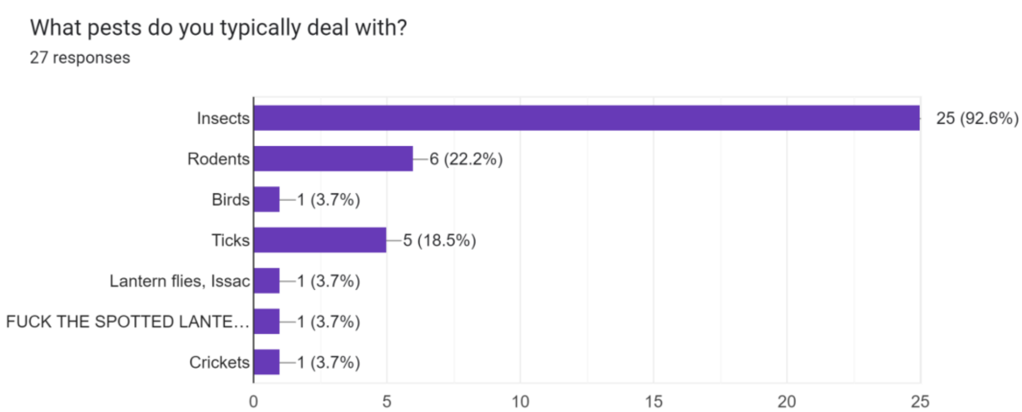
Stakeholder Identification

Stakeholder identification plays a crucial role in pest control robot projects. It ensures that the robot's design and functionality meet the needs and expectations of all direct or indirect participants. The main stakeholders of this project are homeowners and gardeners who face pest infestations, local communities that prioritize environmental sustainability, and potential investors who are interested in innovative pest control solutions. Additionally, environmental agencies, health organizations, and regulatory agencies are also key stakeholders since they are concerned about the impact of traditional pest control methods on the environment and health. Academic institutions and researchers are also important stakeholders as they can benefit from the technological advancements and insights into autonomous pest control systems that the project offers. Identifying and engaging with these stakeholders is crucial for shaping a robot that not only meets end users' needs but also adheres to ethical, environmental, and legal considerations.

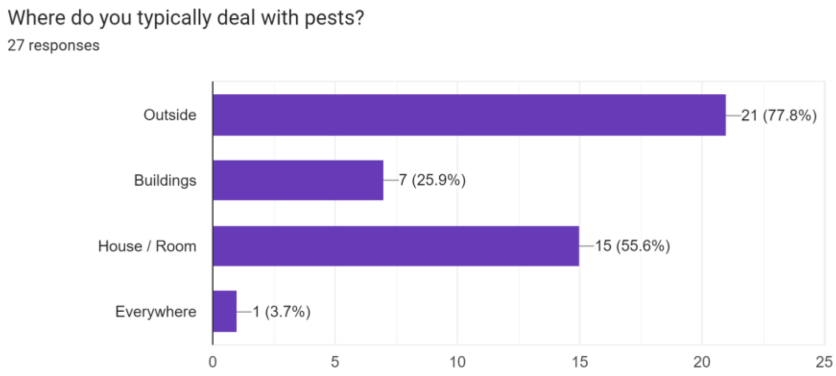
Customer Needs

For external outreach of our product, we created a survey. The survey helped determine the problem environment, the most popular pest control methods, their strengths and limitations, and the public attitude towards pest control. Our survey respondents were gathered by inviting friends, relatives, and other students to complete the survey. Our results indicate:

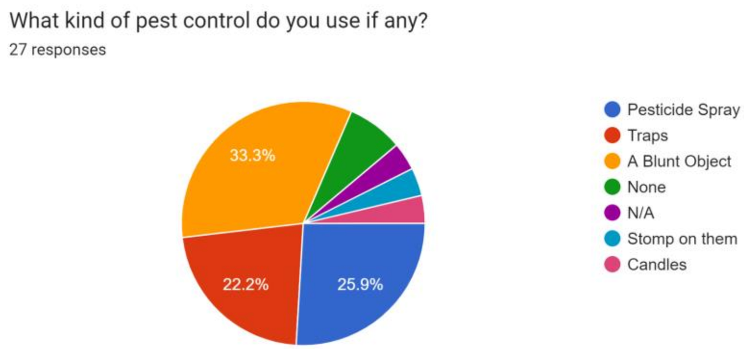
- Problem Environment
    - Most of our respondents deal with insects, reaffirming our decision to design our robot to track and shoot lantern flies



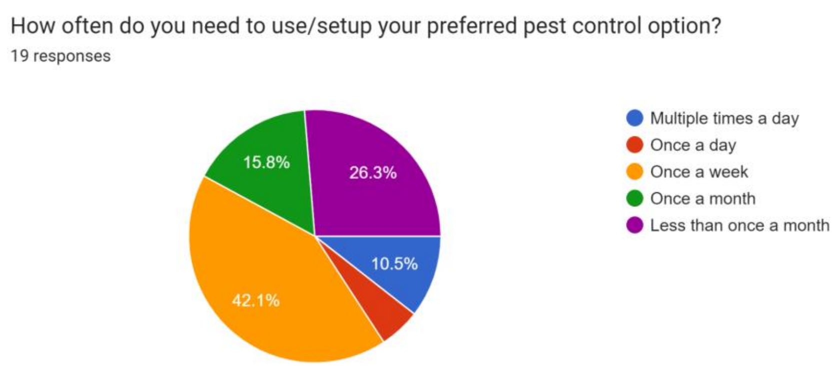
    - Most pest issues occur in outdoor environments, reaffirming our decision to design our robot for a home garden environment



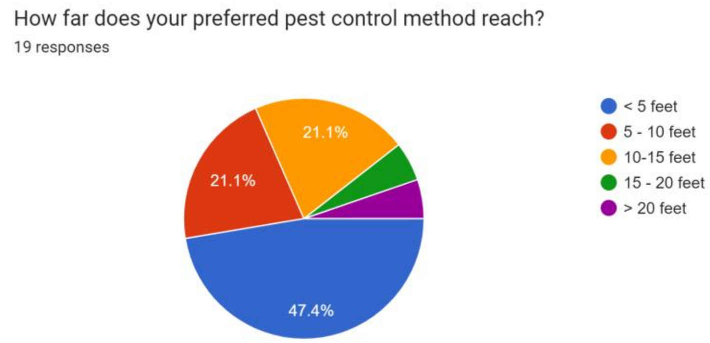
- Conventional Methods
  - Most respondents use a blunt object, traps, and pesticide spray



  - Limitation 1: Very short range (generally less than 5 feet)



  - Limitation 2: less than 75% accuracy for 65% of respondents



- Limitation 3: Requires repeated manual work/setup, most used pest control methods once a month or greater

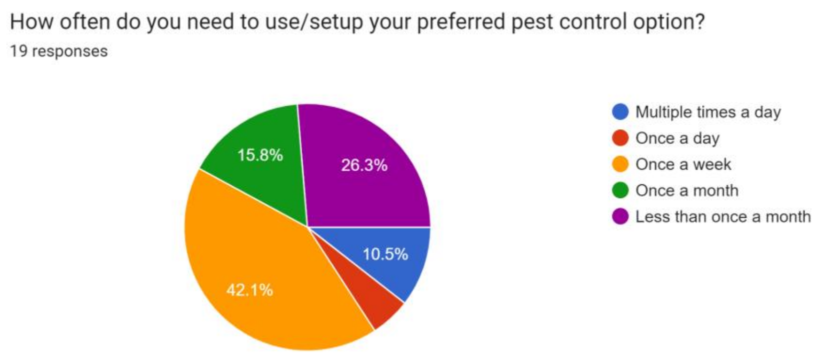
What are the disadvantages to your current pest control option ?

They keep on coming

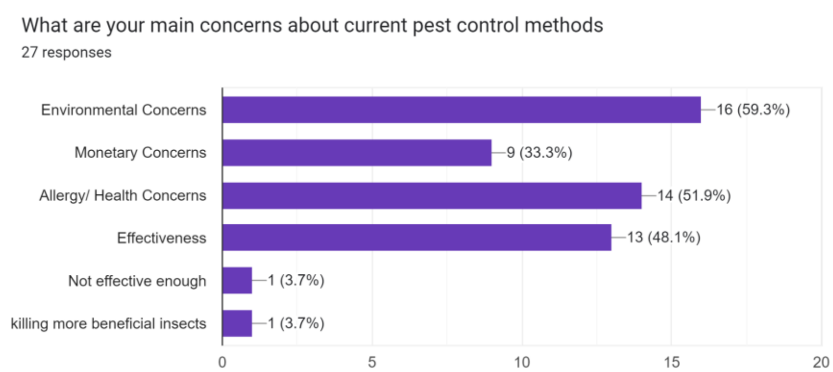
Needs effort to keep going.

Requires active use.

Requires manual spraying



- Public Attitude to Pest Control
    - Environmental concern is the largest priority, followed by health concerns and effectiveness



Based on the survey results, our four main customer needs were generated. Needs #1 and #2 are the main differences between our proposed solution to conventional solutions. We categorized #1 and #2 as basic needs because they differentiate our product from conventional solutions and reflect the most popular customer concerns. #3 and #4 are ranked as performance needs that would improve customer satisfaction which is not possible with the conventional methods.

Number	Need	Priority
1	The robot operates for long periods autonomously	B
2	The robot is environmentally friendly	B
3	The robot has high accuracy	P
4	Has large effective range	P

Table 2: Customer Needs Table

Target Specifications

Based on our customer needs and survey results, the target specifications below were organized. For competitive comparisons, blunt objects and pesticide spray were used as they were the most used in our survey.

Liquid storage, liquid per insect, and battery life all determine how long the robot can operate autonomously. We aim to set the replenishment rate for the liquid and battery to be equal, but we believe it is easier to replenish liquid and can afford for that rate to be higher. Liquid per insect, and battery life determine how environmentally friendly our robot is since we want to reduce energy and water consumption. Finally, range and accuracy needs are converted to specific metric values.

Comparison for the first two metrics was not possible due to the huge difference in the method used. To obtain marginal and ideal values for metrics 1 and 2, we paired comparisons with metric 3. For example, since battery life has a marginal value of .5 to reduce manual setup, values for storage and per insect volume are chosen so that no replenishment is needed until half a month. Ideal values for metrics 3, 4, and 5 were chosen not only by the main two comparisons but also by the comparison of other products and the survey. The ideal range was chosen by comparing the range of water guns. The ideal battery life and accuracy took into account all survey responses. Liquid storage, liquid per insect, and battery life are our most important metrics since they relate to our basic needs. Accuracy and range are still important for performance needs, but marginal values are more lenient.

Metric #	Need #	Metric	Unit	Importance (1-5)	Comp A	Comp B	Marginal	Ideal
1 (Min)	1	Liquid Storage	L	4	0	0	1	2
2 (Max)	1, 2	Liquid per Insect	mL	4	0	0	35	25

3 (Min)	1, 2	Battery Life	month	5	.25	.25	.5	1
4 (Min)	3	Accuracy Rate	%	3	90	75	75	90
5 (Min)	4	Shooting Range	ft	3	2	3	5	10

Table 3: Target Specifications

Concept Generation

Functional Decomposition:

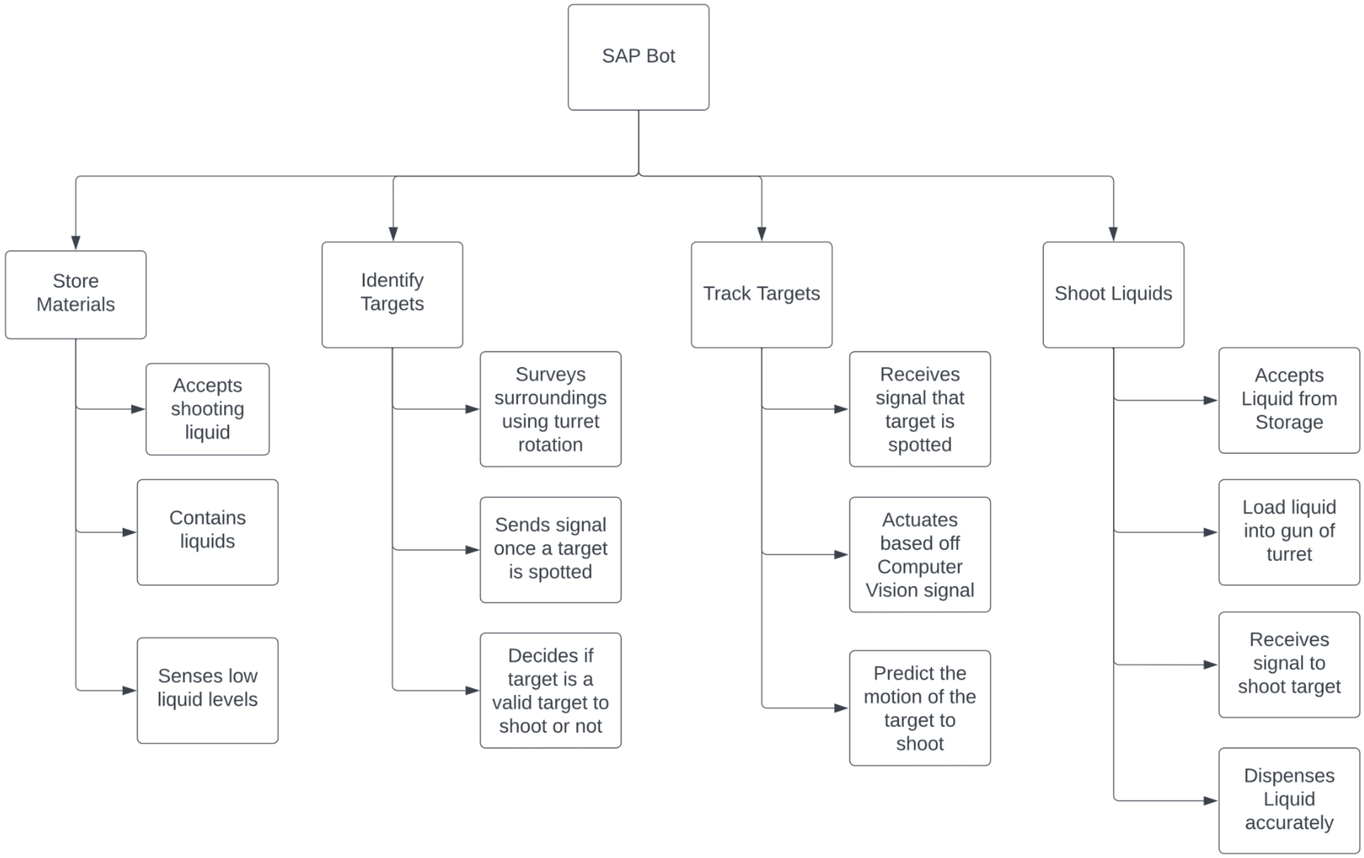


Figure 4:
Functional Decomposition tree showing four of the main subsystems of our design. Below each of the subsystems, we can see some of the main functions for each of them.

Store Materials:

This subsystem is responsible for storing the materials we need for the operation of the design. The main material we are concerned about is the shooting liquid. This subsystem should allow the user to fill a container with the shooting liquid of their choice, and this container should store it until it needs to be dispensed. Another main function of this subsystem is sensing the liquid level. The subsystem should be able to sense when the liquid level is low in the container and should notify the user through a visual signal.

Identify Targets:

This subsystem is responsible for identifying possible targets to shoot at in the near surroundings and confirming that it is a target we need to shoot at. This will take care of constant 360-degree surveillance of the surroundings by rotating the camera around until a potential lantern fly is spotted in the frame. When a target is seen, the subsystem should decide whether or not this object is actually a target we need to shoot at, as it is possible that other pests or animals can be in the frame. Once it is confirmed that the target is valid to shoot at, a signal of its current location should be sent to the Track Targets subsystem to aim at the target correctly.

Track Targets:

This subsystem is responsible for tracking the valid target's location and aiming the shooting mechanism directly at the target. This subsystem will receive the location of a seen valid target, and this subsystem will start rotation of the shooting mechanism to aim it in line with the target. The subsystem should detect if this target has moved by the time the mechanism is in line with the signaled location, if it has, the subsystem will send signals of its real-time location to follow the target's new location. This subsystem will also send a signal to the shooting liquid subsystem once the target is not moving and the mechanism is aiming at the target to shoot liquid at it.

Shooting Liquids:

This subsystem is responsible for actually shooting the liquid at the target. Once the signal has been received that the shooting mechanism is currently aiming at a valid target, this subsystem should dispense some amount of shooting liquid at a high enough flow rate to kill the target. This subsystem should only use liquid that is stored in the liquid container from the Store Materials subsystem. Ideally, this subsystem should determine if we have killed the target or not, by detecting any movement by the target once it is shot. If it can be confirmed that the target is not moving, we can ignore this particular target when surveying the surroundings for more potential targets.

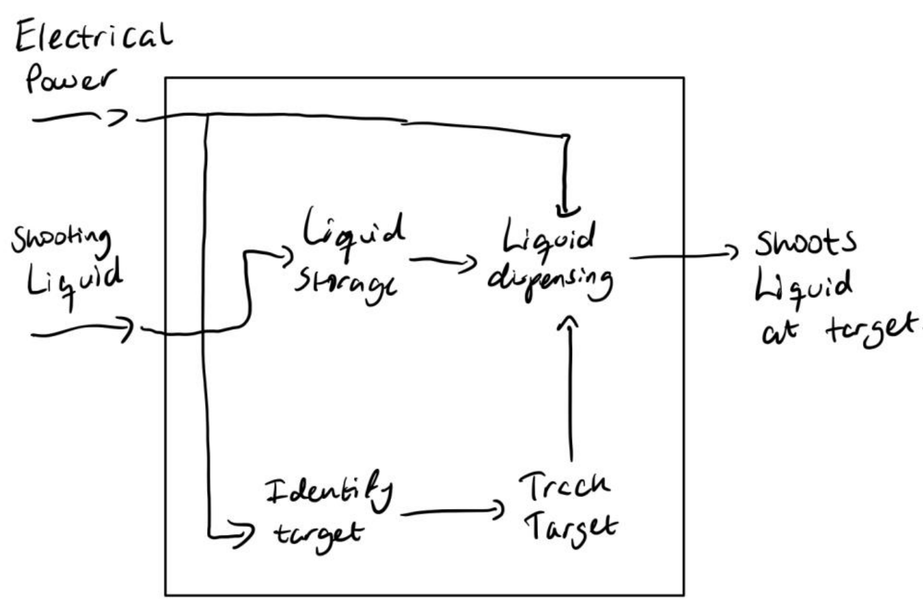


Figure 5:

The black box diagram of our design shows how each subsystem will interact with each other to produce successful outputs and results. Inputs would be electrical power supplied to the system and the actual shooting liquid to be dispensed. A successful output would be dispensing liquid at a valid target in the surroundings.

<u>Sub-System Concepts:</u>

Identify Targets (Object Classification):

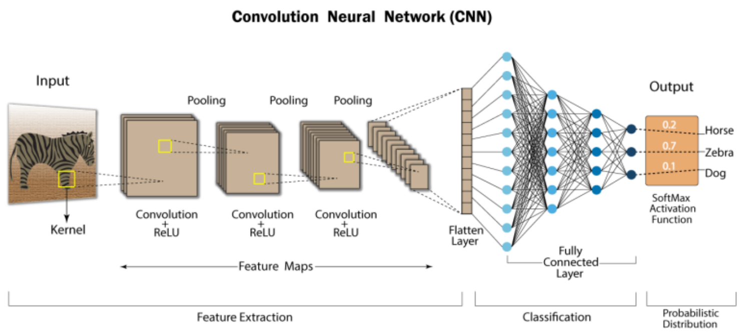


Figure 6:
Convolutional Neural Network Concept

In terms of identifying the lantern flies, we came up with four concepts to complete this task. The first one was using a convolutional neural network to act as a classifier for the objects found within the camera scene, where the objects would be found via an object recognition algorithm. In terms of the object recognition algorithm, we will most likely be using openCV for the recognition and segmentation.

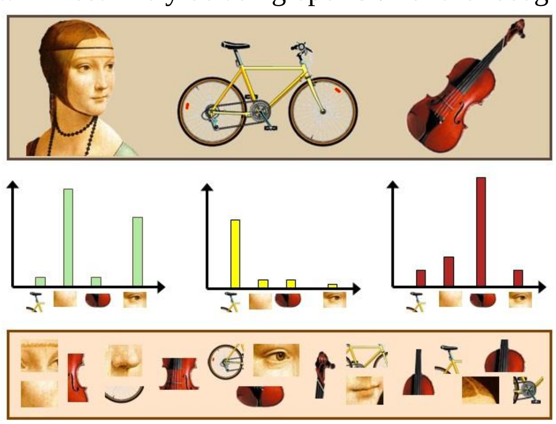


Figure 7:
Bag of Words Approach

We also thought about using a Bag of Words Approach with K-Nearest-Neighbours classification. This would require us to identify relevant features within the camera scene and then create a histogram of these features, thus creating the bag of words. Once these features are extracted we can use K-Nearest Neighbours to classify whether the features within an image correspond to the object we are trying to classify. Overall, this approach is comparable to the convolutional neural network in terms of classification ability, however since we are only worried about identifying lantern flies this approach would be unnecessary since it’s used to identify multiple objects. We also identified simple template matching and color matching as potential concepts. These concepts are further explained in the appendix.

Track Targets:

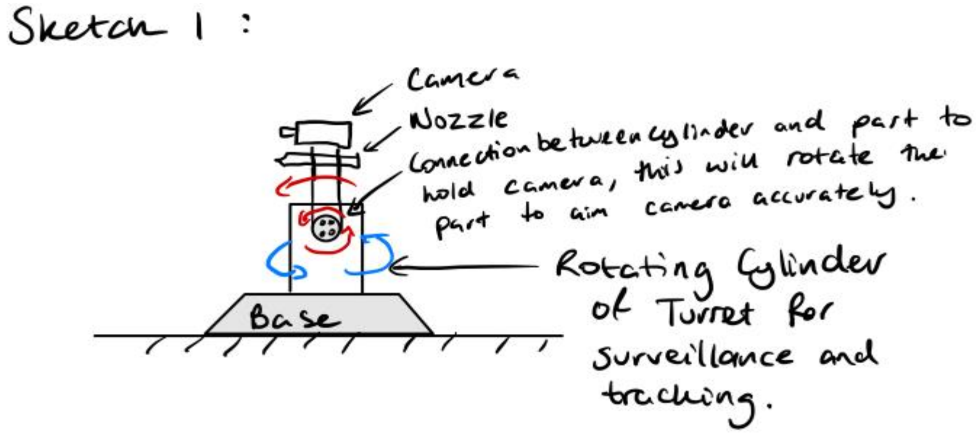


Figure 8:
First sketch of a concept for the Track Targets subsystem.

This sketch shows an initial concept for achieving all the main functions of the track targets subsystem. The rotating cylinder in the sketch allows us to have 360-degree surveillance of the surroundings, and this cylinder is what would contain the liquid as well. Connected to this same cylinder would be an attachment that controls the pitch of the camera and nozzle (shooting mechanism). This attachment allows the subsystem to accurately aim at the target when a location is given as a signal. Once the nozzle is aimed at the target, a signal is sent to dispense liquid at the target.

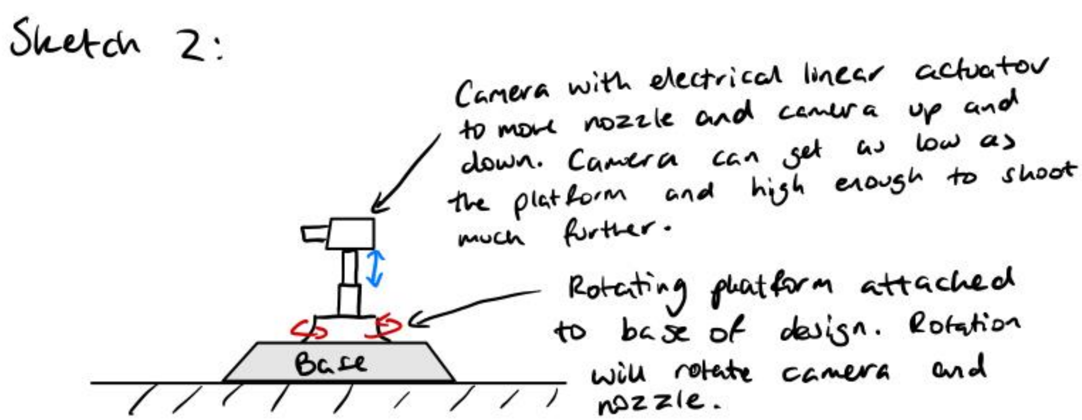


Figure 9:
Second sketch of a concept for the Track Targets subsystem

This sketch shows another concept that we generated for this subsystem. This concept consists of a different rotating mechanism, as there is just a rotating base that holds onto the camera and nozzle, rather than having the whole cylinder rotate. This rotating base will allow for the 360 degree surveillance as we want for this subsystem. For this concept however, there is no pitch, rather we have a linear actuator that moves the camera and nozzle vertically to aim and shoot at the target. This mechanism for aiming should achieve similar results for aiming and accuracy. This is because we can vary the horizontal distance the liquid goes by varying the vertical height of the nozzle.

Shooting at Targets:

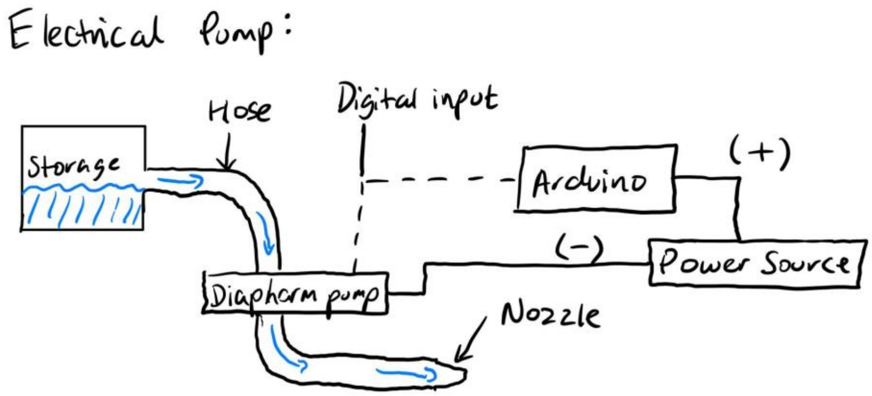


Figure 10

This sketch shows the electric pump configuration. For this concept, an electric diaphragm pump would displace the water in the storage container straight to the nozzle. The pump would have electrical connections attached to the power source and the arduino, with the arduino digital input completing the circuit when instructed. Hose connections would need to be provided to connect the storage to the pump and the pump to the nozzle. Because of hose connection flexibility in path and length, the placement of the physical components can vary based on other needs.

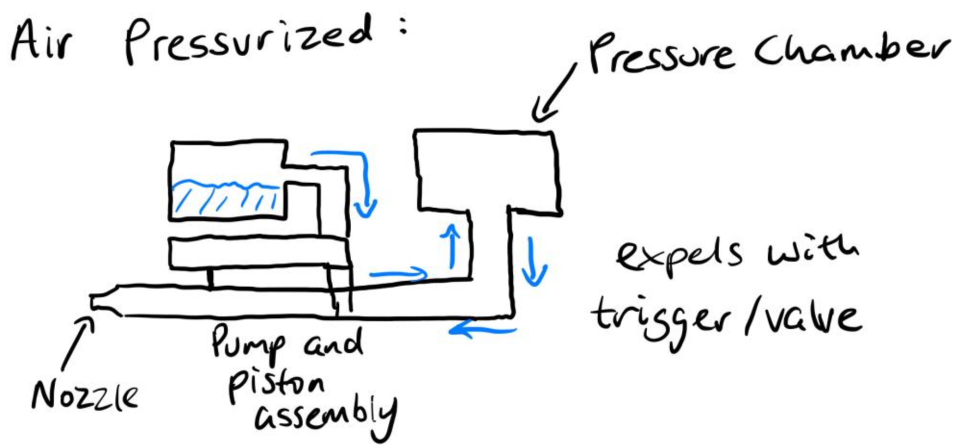


Figure 11

This sketch shows the air pressurized concept, which is heavily inspired by traditional super soakers. Through linear actuation of a pump and piston assembly, the water in the storage is moved to the pressure chamber that already has air. As pumping continues, the chamber's pressure increases. When the valve is opened, all the water in the chamber is expelled at a high speed based on the pressure. The location of the chamber and storage does have some flexibility with the use of one way valves. The ability for the chamber to hold high pressures is a determining factor for how fast the water can be expelled. Arduino digital inputs can be used to move the pump.

Storage of Materials:

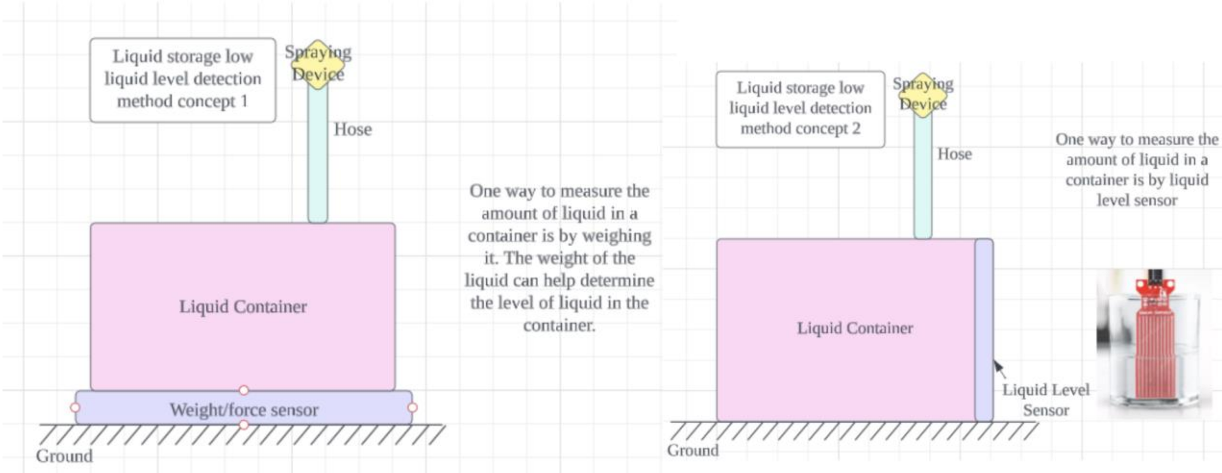


Figure 12:
Liquid Level Detection Method Concept (Concept 1 uses a force sensor on the left, while Concept 2 on the right uses a liquid-level sensor.)

The Figure above illustrates two different methods for measuring liquid levels in a container. Concept 1 involves using a force sensor to measure the relationship between changes in gravity force and changes in liquid level caused by the container during use. This allows us to infer the liquid level in the container by measuring the gravity force of the container itself.

Concept 2, on the other hand, is more straightforward. By installing a liquid level sensor in the container, we can directly measure the level of liquid inside the container.

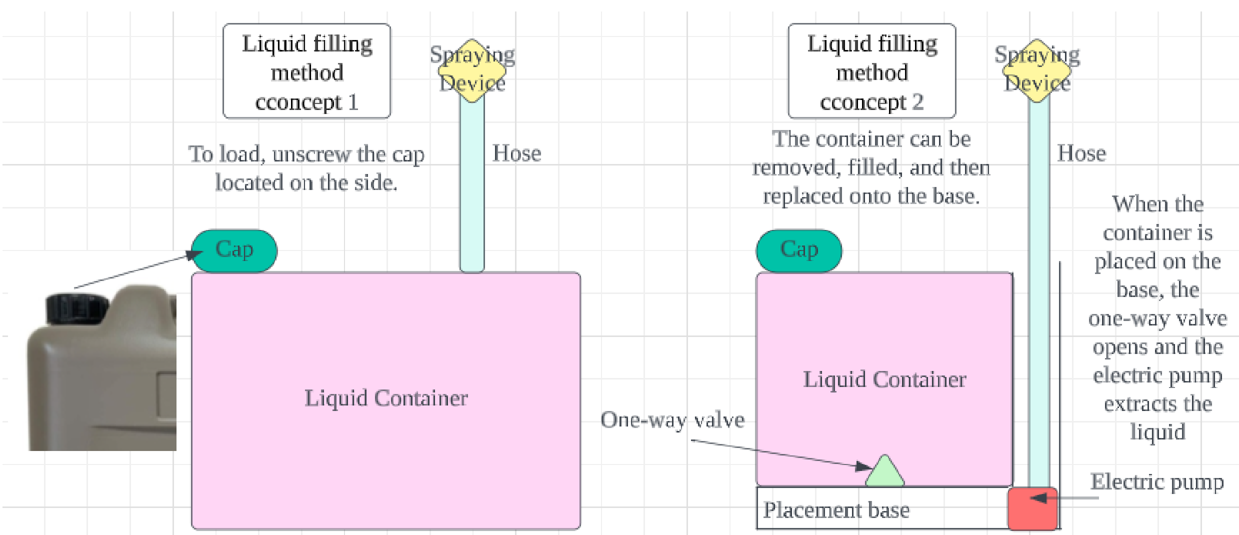


Figure 13:
Liquid Filling Method Concept (Concept 1 uses a simple on the left, while Concept 2 on the right uses a

one way valve.)

The figure above demonstrates two distinct methods of filling containers. In concept 1, the liquid container is fixed to the ground, and a simple screw cap is located above the container. Refilling the container is as easy as unscrewing the cap and pouring the liquid directly into the container.

Concept 2 is slightly more complex than concept 1. In this case, the liquid container can be removed individually, and just like in concept 1, there is a simple screw cap at the top of the container to open and fill. Once the filling process is complete, the container should be placed back on its base. The protrusion on the base will open the one-way valve at the bottom of the container, and the liquid will flow to the electric pump through gravity, completing the entire filling process.

Concept Selection

After deciding on our top concepts for each subsystem, we created whole system concepts. The following table below shows the different whole system concepts we created and the individual sub-system concepts that compose them.

Table 5: Concept Grouping

System Concept #	Liquid Level Detection	Liquid Filling and Pressurization	Identify Targets	Track Targets	Shoot Liquids
1	Weight/Force Sensor	Simple Cap	Neural Network	Rotating Cylinder and Tilt	Electric Pump
2	Liquid Level Sensor	One Way Valve	Neural Network	Rotating Cylinder and Linear Actuation	Air Pressurized
3	Weight/Force Sensor	Simple Cap	Neural Network	Height Controlled Linear Actuation and Rotating Platform	Piston Pump
4	Weight/Force Sensor	Simple Cap	Bag of Words	Rotating Cylinder and Tilt	Electric Pump
5	Liquid Level Sensor	One Way Valve	Bag of Words	Rotating Cylinder and Linear Actuation	Air Pressurized
6	Weight/Force Sensor	Simple Cap	Bag of Words	Height Controlled Linear Actuation and Rotating Platform	Piston Pump
7	Weight/Force Sensor	Simple Cap	Color Matching	Rotating Cylinder and Tilt	Electric Pump
8	Liquid Level Sensor	One Way Valve	Color Matching	Rotating Cylinder and Linear Actuation	Air Pressurized

From these system concepts, we used a screening matrix to find our top five system concepts based on our identified selection criteria. The following matrix below shows our concept selection screening matrix, with the highlighted concepts being our chosen concepts. We used the Autonomous Pest Control Robot as our reference for the concept selection screening.

Table 6: Concept Selection Screening

Selection Criteria	Autonomous Pest Control Robot	1	2	3	4	5	6	7	8
Feasibility	0	1	1	0	1	-1	0	1	0
Precision	0	1	0	-1	1	1	-1	-1	-1
Minimal Complexity	0	0	0	0	-1	-1	0	1	0
Large Workspace	0	1	1	-1	1	1	-1	1	-1
Less Parts	0	0	-1	1	0	0	1	0	1
Totals	0	**3**	**1**	**-1**	**2**	**0**	**-1**	**2**	**-1**

As shown in the table, our selection criteria focused on ensuring that the robot would be within scope while also prioritizing the performance of the robot. For instance, to ensure that our robot would be within scope, we used minimal complexity, fewer parts, and feasibility as our selection criteria. Then, we included precision and a large workspace to ensure that our requirements, in terms of customer needs, would be met. This led us to select system concepts number 1,4,5 and 7.

We then took these concepts and used a scoring matrix to further help select our final system concept. The matrix below shows our selection matrix including the main scoring criteria we considered. We highlighted our final system concept in green and our secondary concept in yellow.

Table 7: Concept Selection Scoring

		System Number				
Scoring Criteria	**Weight**	1	2	4	5	7
Pest Identification	0.7	4	4	4	4	1
Easy to Refill	0.4	5	3	5	3	5
Can Be Used In the Dark	0.4	4	3	2	2	1
Precise and Accurate Shooting	0.7	5	4	5	4	5
Pest Detection Range	0.5	4	5	4	5	4
Pest Shooting Range	0.6	5	3	5	1	3
Total		**14.9**	**12.3**	**14.1**	**10.7**	**10.4**

For our final concept selection, we selected criteria that were directly related to our requirements and customer needs. For example, we included a pest shooting range and pest detection range criteria to ensure that our robot's workspace satisfied our requirement of being about 10 feet. The weights for the matrix were chosen based on the overall importance of the criteria to our project. We found that pest identification and precise and accurate shooting to be the most important criteria for our robot. Overall, after scoring each of the system design concepts we found that system number 1 to score the highest.

Storage material subsystem:

For our storage material subsystem, we decided to use concept 1 for both the liquid level detection method and the liquid filling method. We considered using concept 2 for the liquid level detection method, which is more direct and easier to implement, but it requires placing the sensor inside the container. This is challenging due to the container being relatively closed, making it difficult to position the sensor correctly within the container. Additionally, we must consider the wiring, routing, and waterproofing of the wiring in the container. Thus, the use of concept 1 for the liquid level monitoring method is more suitable.

Regarding the liquid filling method, we chose concept 1 because it is easier to implement than concept 2. While concept 2 is more convenient for users to fill, it has a relatively complex structure that requires us to consider the airtightness of the chassis. Completing concept 2 within the given time limit of the course may not be feasible, so we opted for concept 1.

Track target subsystem:

For our final choice of the track target subsystem, we decided to combine features from both sketches 1 and 2, however, the main ideas are from the first sketch. The combination of these sketches comes from using the rotating platform rather than the rotating cylinder, as it would be easier to have a rotation of the camera and this makes the design much less complex when achieving the same results. But for controlling the camera and nozzle directly, we moved forward with the concept from the first sketch, where we controlled the pitch, rather than moving vertically with a linear actuator. This is because we are given more freedom for the camera and nozzle when we can control the pitch, and accuracy and precision would be significantly better for the nozzle if we can change the pitch rather than the height. If we are varying the height, we would be using equations of projectile motion to hit a target, but this would need to be calculated in real time and then the nozzle must be configured to this certain height, just for it to not be very accurate. Instead, actually aiming directly at the target would be much more effective for our main functions. When looking at the selection matrix criteria, the combination of these concepts produces the greatest pest detection range and shooting range, which are very highly weighted criteria points for our prototype. This gave us plenty of evidence to conclude that we will be using this final concept for the subsystem.

Shooting subsystem:

For the shooting subsystem, we looked into scoring for accuracy/precision as well as feasibility and complexity . The electric pump configuration provides the most consistent shooting power, increasing accuracy and precision. Feasibility is also easier because the assembly is very simple and component locations are flexible. When looking at other concepts, the arduino requires linear actuation and it becomes an extra factor taken into account when testing if the proper power is being applied. Furthermore, large amounts of concentrated space is needed for the other concepts. While the total assembly for the electric pump concept is not small, the space taken is spread out into different components across the entire robot. These advantages were considered during scoring and we concluded that the electric pump configuration is the best concept for the subsystem.

Identify targets subsystem:

Considering that the robot will be used outside and in variable environments, we must ensure that our identification process can handle any vision challenge we encounter. For example, we must consider variable viewpoints when looking at the lantern fly, variable illumination due to the sun since the turret will be outside, and even any occlusion that may occur with other objects within our scene. These challenges would make it hard to identify lantern flies with simple algorithms such as template matching. Therefore, we would need to use a data-driven approach, such as some sort of machine learning / deep learning approach, in order to compensate for these potential challenges. Thus, this leaves us with the bag of words approach and convolutional neural network as our main concepts for the identification of lantern flies. Furthermore, if we consider the fact that our robot should be able to function at night, with possibly some illumination provided by a stationary light source, a convolutional neural network would be more effective than a bag of words approach. Feature extraction and clustering would be hard to do with footage taken at night since some features would be hidden thus increasing potential noise due to lack of illumination. This would render this approach unusable by our standards which is why system one, which uses a neural network, has a higher score than system four.

With our final system design chosen based on the matrix, we created our CAD model to reflect our chosen sub-system concepts and requirements. The following figure depicts our CAD model with each subsystem highlighted.

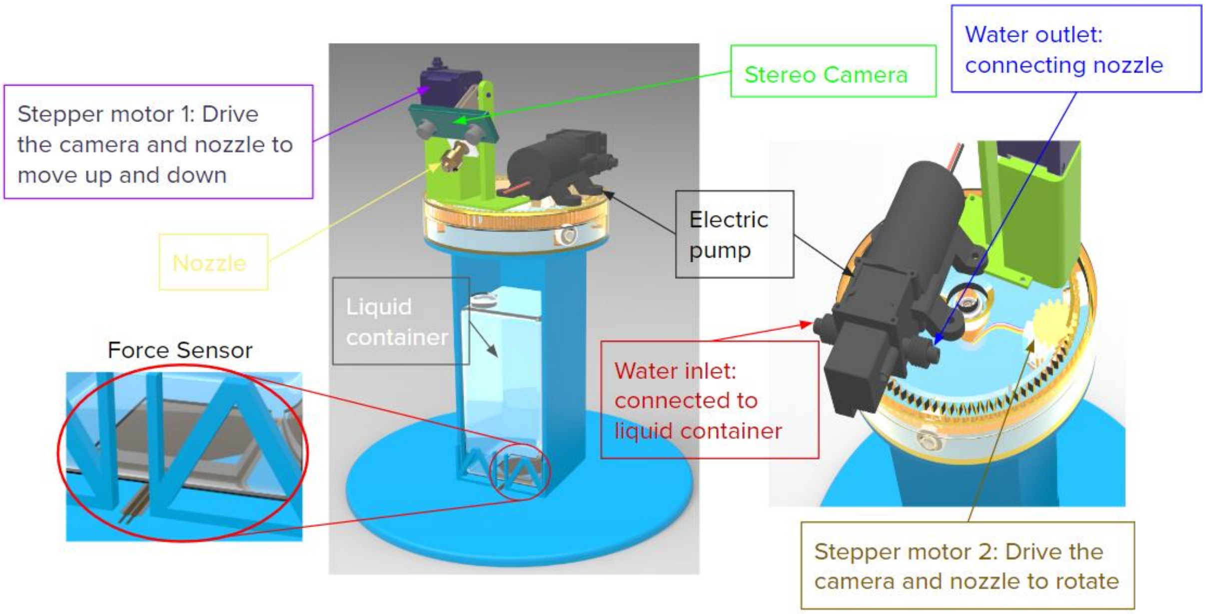


Figure 14:
CAD Model

Project Planning

<u>Gantt Chart:</u>

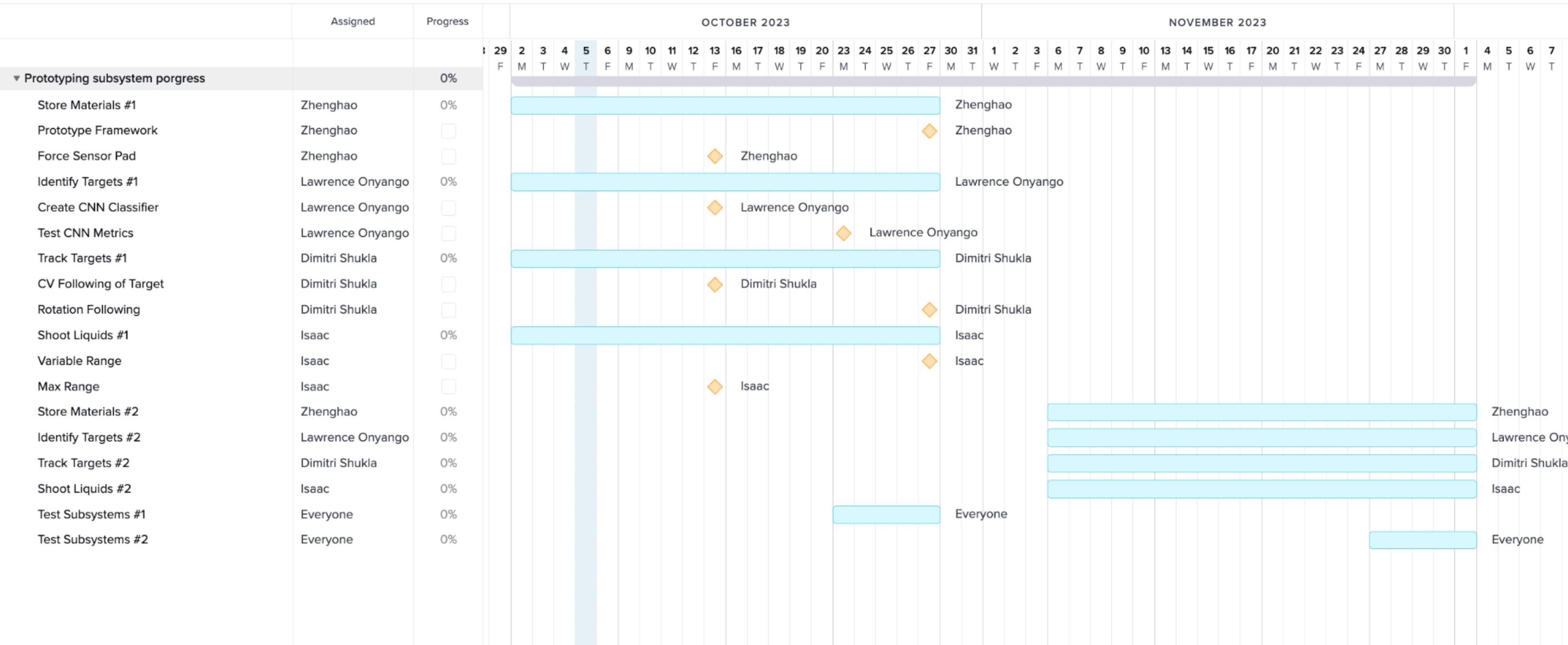


Figure 15:

Gantt Chart displaying the timeline of our prototyping progress.

This Gantt chart is how our team is tracking and estimating the progression of our prototype. We have placed milestones on the Gantt chart to enforce deadlines to complete the subsystem each of us are working on. You can see each of our names on each subsystem to see who is working on each subsystem. The milestones are to ensure that we are completing our work and progression at the right pace, in order to have a working prototype for the Mid-semester prototype demo day. We aim to finish prototyping each of our subsystems at the same time, this way we have a few days to put each of them together to have a complete first prototype of our design. Based on our milestone completions when we present our first prototype, we will make new milestones for the final prototyping progress.

For the Store Materials subsystem, Zhenghao will aim to integrate the force sensor pad to a liquid container and gather data to relate capacity to readings from the force sensor. This way the prototype is able to detect the liquid levels at any point in time. He also aims to make a complete framework to put all the other subsystems together, as this container will take up the majority of the space of the design, so everything else attaches to this subsystem as it is the main body of our design.

For the Identify Targets subsystem, Lawrence is in charge of making sure our CNN classifier is able to detect and verify lantern flies from a frame given to the program. Once this is complete, he will test and create several plots and charts to allow us to see where we can improve our software in detecting these targets. Essentially, Lawrence will be collecting data on how accurate the classifier is at locating and validating the wanted targets for a given image. It is very important for us to collect this sort of information, as we know if this subsystem needs a larger dataset, or needs to be refined with its algorithm in general. If we have a correctly working classifier, Lawrence can spend more time and effort on other subsystems for the final prototype.

For the Track Targets subsystem, Dimitri is responsible for hitting the milestones for this subsystem. He will make sure that the software can receive different input signals to cause rotation of the motors, to ensure rotation of the platform we will build. He is also responsible for making sure that the motors we will use produce enough torque to control the pitch of the camera and nozzle. Once this is confirmed, we are able to ensure that the physical components of this subsystem can work correctly. He will also need to make sure that the software from Lawrence's subsystem can interact with each other, as signals will be sent from this subsystem to initialize a target location.

For the Shooting Liquid subsystem, Isaac is responsible for configuring and prototyping this subsystem. He will make sure that this subsystem is able to shoot liquid at a variable range, and that the max range of the shooting mechanism is up to standard with our target specifications. Once he can confirm that it achieves these main functions, he will start to think about the integration of this subsystem into the others to create an initial and complete prototype for our design.

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Appendix

Concept Generation Cont.:

Sub-System Concepts Cont.:

Identify Targets (Object Classification):

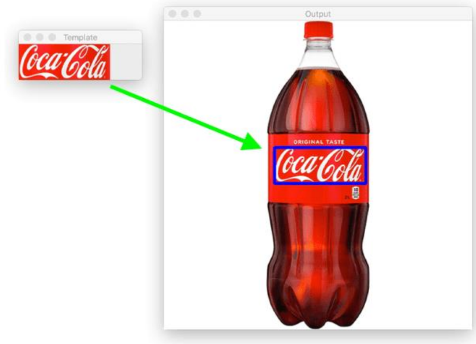

Figure 16:
Template Matching Approach

Our other object classification concept was to use a simple template matching algorithm to identify the lantern flies. For instance, we would take an image of a lantern fly and then go through the image we want to classify and simply compare the pixels. We can then measure the similarity between the template image and the object to be classified to identify whether the object matches the template image. Overall, this algorithm is simple to implement, however, it isn't as robust as our methods since it does not factor in any environment variables such as illumination and occlusion.

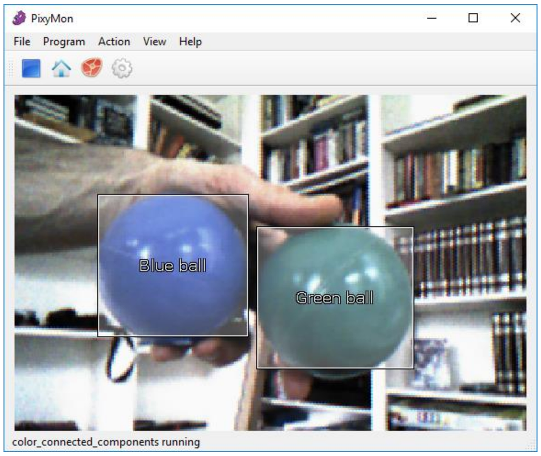

Figure 17:
Color-Matching Approach

Lastly, our last identification concept was to use Pixy2 to implement a simple color-matching algorithm to identify the lantern flies. The Pixy2 camera allows us to categorize certain color hues with objects and therefore perform object identification based on the color. Therefore, we would simply identify the main color and hue for lantern flies and then encode that color to mean a lantern fly. This concept would work for simple object classification, however since it only relies on color matching, it can easily lead to misidentification of objects with similar hues. For example, if someone's shoes match the lantern fly's color, it would be classified as a lantern fly and then shot at. As such, this concept is not as robust as the data-driven approaches we outlined for object classification.

Track Targets:

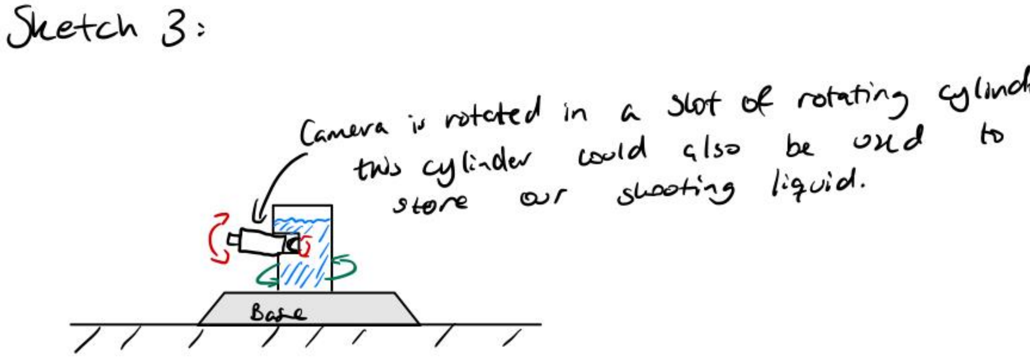

Figure 18:
Third Sketch for the Track Targets subsystem.

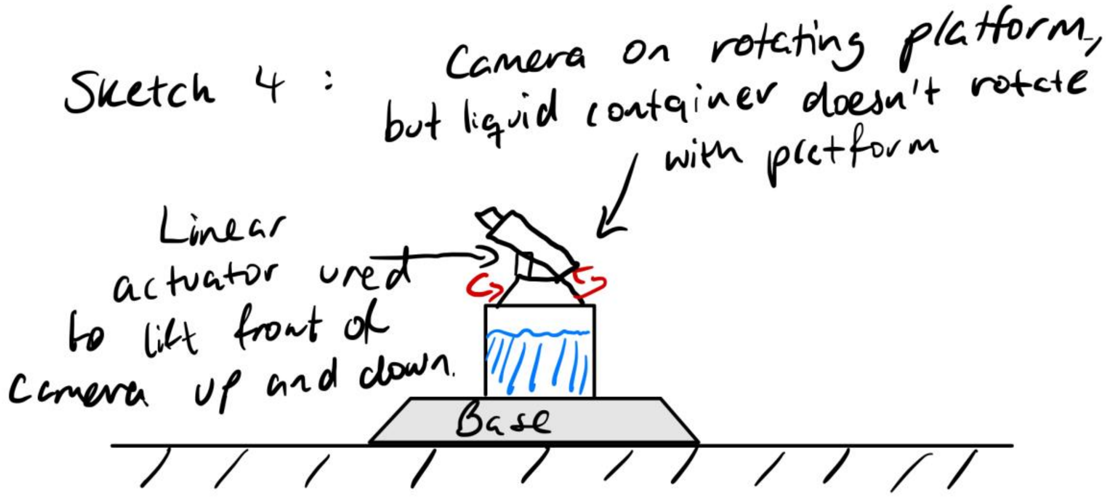

Figure 19:
Fourth sketch for the Track Targets subsystem.

Storage of Materials:

Figure 20:
Pressurization (If need) Method Concept.

In the upper part of the figure, there is a refillable tank made of stainless steel. The lower part of the figure shows a method of manually pressurizing the tank after filling it. The purpose of this concept is to enable the nozzle to spray out the liquid quickly and smoothly. However, we will not need to pressurize the container if the performance of the electric pump is satisfactory.

Shooting Liquids:

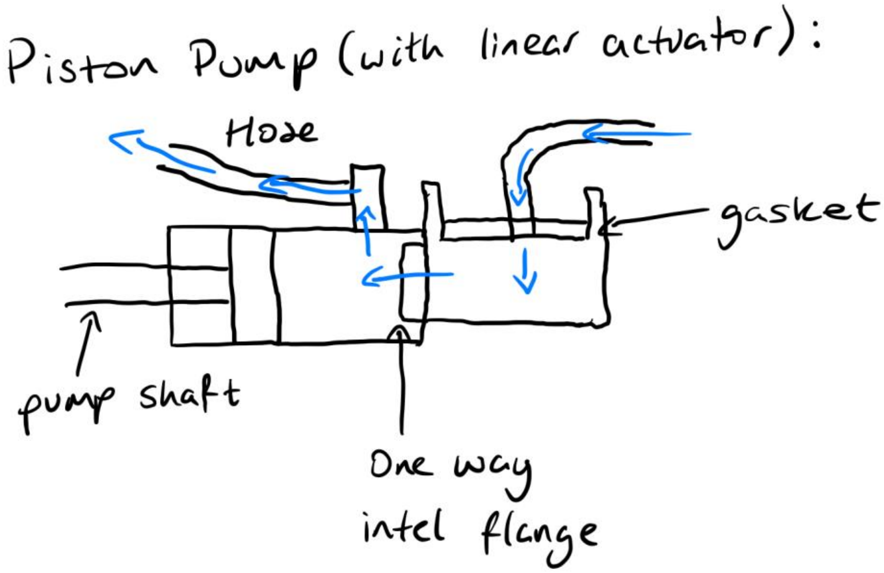

Figure 20:
Piston Pump (with linear actuator)

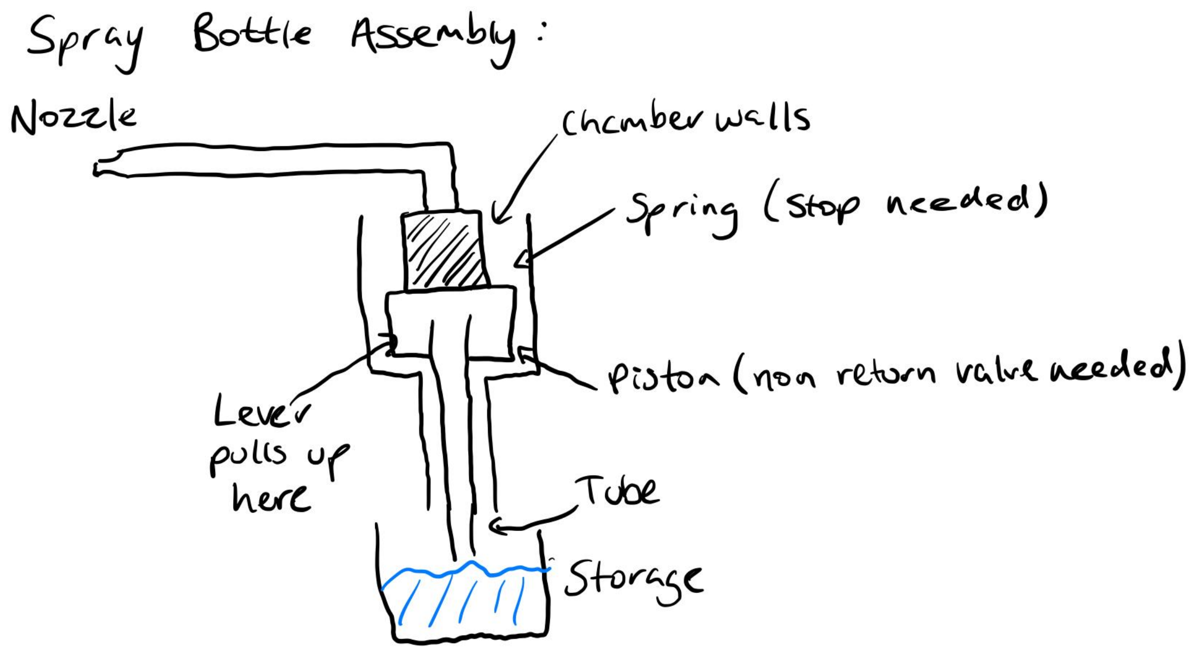

Figure 21:
Spray Bottle Assembly

Work Distribution

Team Member	Tasks Worked On
Lawrence Onyango	So far, I have worked on helping create and identify optimal object classification concepts. I also worked on concept selection, specifically the matrixes and selection criteria. I also helped identify market competition and defining our mission statement.
Isaac Olmos	I have worked on setting up the shooting concepts and prototype. I have also worked on establishing customer needs and target specifications. I also did general comparisons to market products and prototypes during research.
Dimitri Shukla	I have worked on researching for parts to buy for my subsystem and setting up the code and testing framework for the track targets subsystem. Once we have access to the parts and other electronics I will be able to upload my code to test different inputs of motor speed and angle displacements and observe how the motors will react to this. This will give us a better understanding on if these motors or plausible to use for yaw and pitch of the camera and nozzle.
Zhenghao Weng	I have completed several tasks in the development of the robot. Firstly, I designed the storage material subsystem, then created a 3D model of the entire robot. Additionally, I obtained approximate data on the robot, such as its size, container capacity, and the installation location and method of its components. Once all the prototype components are assembled, I will conduct force sensor tests to collect data and establish the relationship curve with the liquid level.