Rodent Deterrent and Classification System

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Introduction

Problem

Every summer and fall, thousands of backyards, lawns, golf courses and open grass fields suffer from rodents and birds digging the ground searching for earthworms, soil-dwelling insects, and insect larvae. This leaves behind large patches of loose turf and ruins the grass. Not only is this a huge problem for the grass farming industry but is also a nuisance for every backyard owner, ruining the aesthetics and plants grown on the lawn. The current deterrent methods are technologically naive including just a motion sensor, lights and loud sounds which cause loud noises at night, fail to prevent lawn digging, and leave the user unaware of the type of rodent affecting their lawn.

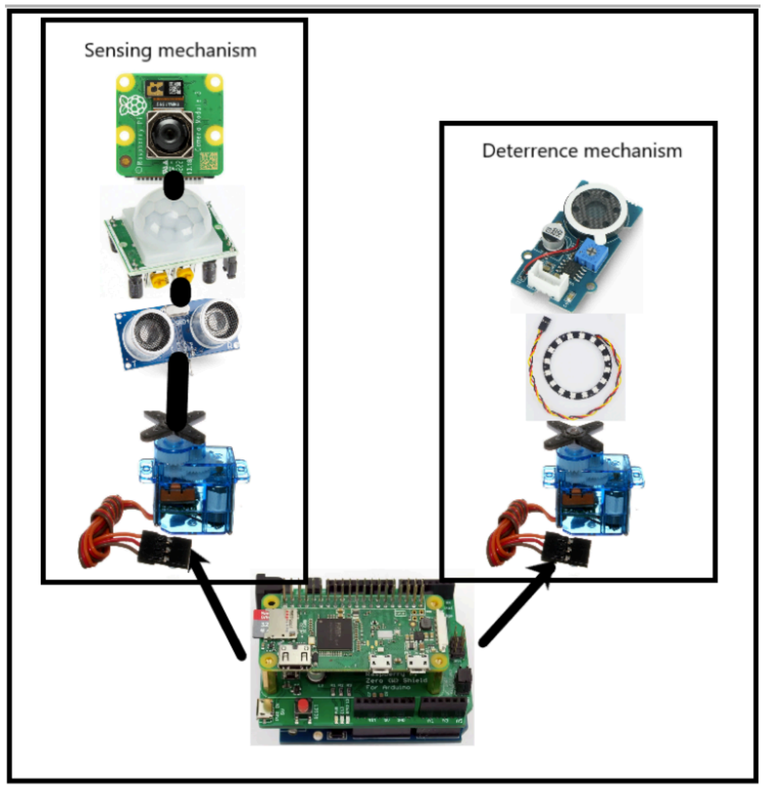
Solution

We propose a rodent detection and deterrent system which comprises many parts. Using infrared and ultrasonic sensors on a rotating servo, we would detect any rodent outside of the usual landscape of the lawn the device is placed in. The PI camera system would simultaneously work to take a clean shot of the rodent/bird and store it in the file system. If recognized to be a ground digging rodent, for the actual deterrent, our colored lights and localized speaker beeps go in the direction of the rodent rather than in a single direction like previously commercialized methods. This ensures rodent deterrence and also informs the user the type of animals responsible for digging their lawn.

High Level Requirements

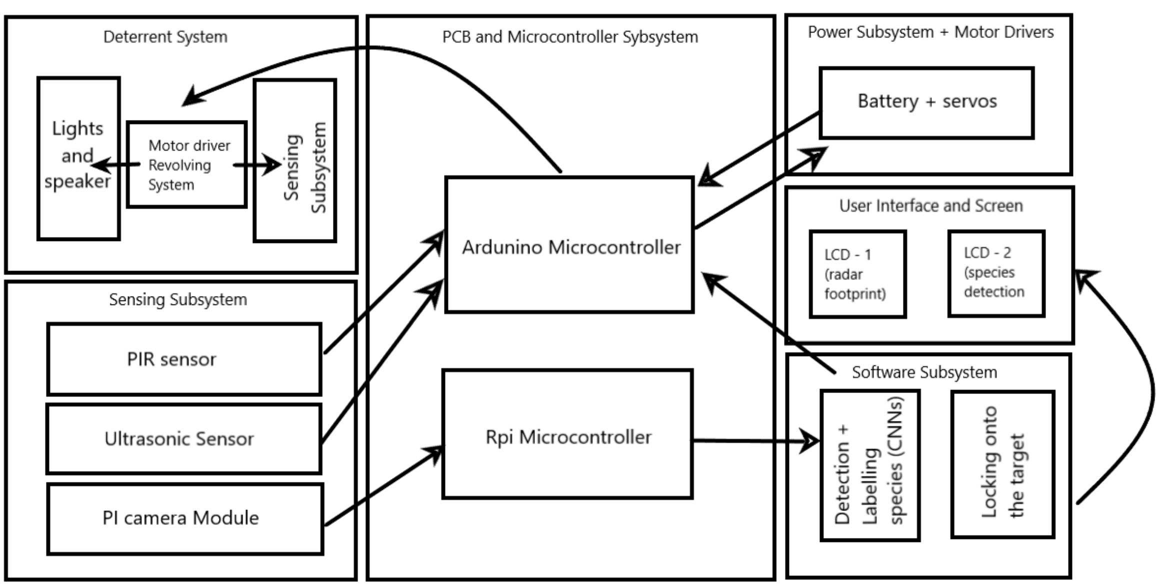
1. The system must be able to successfully and accurately detect rodents with > 90% success rate and also avoid false detections based on other movements in the environment (eg. person walking, dog running).
2. Components should have high durability and battery capacity to ensure a long lasting solution (battery life of up to a month).
3. Sensors should be capable of detecting at a relatively long range while also being able to scan a large field of view (360° field of view and 10m radius).

Visual Aid



(Visual Aid for product)

Design



(System Design Pipeline)

Subsystem Overview and Requirements

1. Sensor Subsystem

The sensor subsystem is the core of our project. It will feature an array of sensors that we will congregate to ensure that we can accurately track the rodent. Furthermore, the need for multiple sensors acts as a failsafe, to ensure that we can still perform the task should any of the other sensors be inhibited in doing their job. The data from these sensors will be essential to the success of our software subsystem.

a. **Ultrasonic Sensor**
   i. ***Requirement 1:*** *The sensor should be able to detect objects in a radius of 10 meters.*

b. **Pi Camera Module**
   i. ***Requirement 1:*** *Camera module has a native resolution of 5 MP and can take 2592 x 1944 pixel images. It also supports video at 1080p at 30fps and 720p at 60fps.*
   ii. ***Requirement 2:*** *It is easily compatible with the RPi microcontroller over ribbon connector.*

c. **PIR sensor**
   i. ***Requirement 1:*** *The PIR sensor has a sensitivity range up to 20 feet (6 meters) 110° x 70° detection range*

2. Deterrent Subsystem

The deterrent subsystem receives signals from the sensory and microcontroller subsystem. When the sensory subsystem detects a rodent, the sensory subsystem and the microcontroller subsystem sends appropriate signals, activating the deterrent system.

a. **Lights**
   i. When the deterrent system detects a rodent, the speaker should produce lights that repels the rodent.
   ii. ***Requirement 1:*** *The light should be bright enough to be seen in daylight, but not too bright to be considered a light hazard for rodents.*

b. **Speaker**
   i. When the deterrent system detects a rodent, the speaker should produce sounds that repels the rodent.
   ii. ***Requirement 1:*** *The volume of the sound should be loud enough to repel rodents, but not too loud to be a noise hazard.*

3. Microcontroller + Communication Subsystem

Choosing the right microprocessor and communication protocols is essential to the success of the project as it would dictate processing all the information with lowest possible latency and integrating the sensors with the deterrence system.

a. Arduino ESP32 and Raspberry Pi Pico

   i. ***Requirement 1:*** *Both have the standard UART, SPI and I2C communication which can connect to all the sensors and actuators used in the project and they also support USB 3.0 and other protocols that enable fast transfer of information.*

4. Software Subsystem

The software subsystem's success is essential to our whole project succeeding. The software subsystem will work side by side with our sensors to ensure that the tracking of the rodents is accurate and effective. The software will perform analysis on the live feed of the camera sensors as a means of detecting and tracking the rodent. This system will run on the compute resources of the Arduino.

a. Detection and Labeling

Given the visual data, the software should accurately detect and label the specified image in real time.

   i. ***Requirement 1****: A strong and in depth dataset to test the detection and labeling*
   ii. ***Requirement 2****: A flushed image recognition code that can function in real time (does not have too much compute requirements to function)*
   iii. ***Requirement 3****: Software should be able to detect when its view is blocked*

b. Tracking

Given a visual feed, we want to ensure that we can track movement that occurs. This is essential for the detection and labeling to succeed.

   i. ***Requirement 1****: Collects data of where the object is in space (will be essential for providing this to sensors so they can move accordingly)*
   ii. ***Requirement 2****: Maintains tracking even with changes in sensor data*
   iii. ***Requirement 3****: Should not require heavy computing power (should be able to be done even using an Arduino's compute resources)*

c. Signaling

The software should be able to compile data and collect data such that it has constant communication with the sensors (needs to effectively subscribe and post data).

i. ***Requirement 1**: Software needs to compile data in a readable manner for sensors to change*
ii. ***Requirement 2**: Software needs to decode sensor data to effectively perform detection and tracking*

5. Power Subsystem

The power subsystem is responsible for generating, storing, regulating, distributing, and managing electrical power to ensure the proper functioning of onboard systems and instruments. This system includes a 12V battery, a 12V-5V converter, and voltage regulators.

a. ***Requirement 1:** The power is set to ensure overcurrent protection, overvoltage protection, and thermal management to prevent damage to electrical components and ensure safe operation.*
b. ***Requirement 2:** The battery capacity ensures a lifetime of a month.*

6. Mechanical Subsystem

The mechanical subsystem involves any of our parts that requires any movement. In the scope of this project, this includes all the rotors and servos that will move our device so that it is able to scan the entire area. Ensuring these mechanical components work are important, as we want to ensure we can scan the entire field of view.

a. Rotors
   i. ***Requirement 1:** The camera, sensors, speakers, lights should all be firmly attached to the rotor*
   ii. ***Requirement 2:** The rotor should rotate at a speed at which the sensor subsystem can detect rodents and constantly update information about its surroundings.*
   iii. ***Requirement 3:** Servos need to have high durability such that it can perform rotations consistently and be able to be activated multiple times.*

Tolerance Analysis

Variations due to environmental factors can lead to slightly lower detection accuracy for the infrared and ultrasonic sensors. Moreover, the PIR sensor has a limited range of 7 meters which may be sufficient for the average user, but it only supports a range of 100°. To resolve this issue, multiple sensors are attached on the rotating servos for a 360° view. Alongside the PIR sensor, we have two other sensors: an ultrasonic sensor and a camera. The two sensors work together to eliminate their limitations. Another issue is calibrating the ultrasonic sensor to ignore the ever changing landscape of a lawn. This can be overcome with the communication of the two sensors' backend to provide a more complete picture of the environment. The microcontrollers and servos may have the issue of finding adequate wattage and current to provide to the whole system without having short working times. Since the product uses two microcontrollers and a constantly running sensory board, we may have to try to limit the battery usage by finding innovative ways of placing the three sensors covering most areas without having the servo to be on for the duration of operation. Small solar panels and chargeable battery packs might be considered depending on the performance and longevity of the battery. The pi camera module could suffer from poor lighting conditions, but this can be mitigated by the lights included in the design which can be turned on with signal from other sensors. On the software side of the project, CNNs might have to be finetuned for less optimal lighting conditions for zero shot detection when necessary giving the least amount of false positives. Smaller models would also have to be in place to ensure data transfer and deterrence systems to work with negligible latency.

Ethics and Safety

Ethics:

It's crucial that we adhere to ethical guidelines throughout the duration of this project. One particularly prominent ethical consideration is the potential for causing harm (Code 1.2 in the ACM Code of Ethics and Professional Conduct). Within the scope of our project, a primary concern is the welfare of the animals we're trying to prevent entering areas where our system is placed. Our group is committed to upholding this code by prioritizing the well-being of these animals above all else.

As a team, we've recognized that our approach involves influencing the behavior of these species to help them recognize restricted areas (where our system will be deployed). For this reason, to prevent any ethical breaches, we are using indirect methods, such as audio and visual cues, as a means of solving the core problem. We believe this strategy not only safeguards the animals but also mitigates the necessity for harsher measures like pest control, particularly in situations where it is unwarranted.

Safety:

Safety is of the utmost concern to our group. We want to ensure that the application of our device will be safe for both the users and the animals we are targeting with our device. Our first safety concern is with regards to the animals and is related to the use of lights and sounds within our system. We want to ensure that this deterrent system is effective, but also not harmful to them. Therefore, our light system will be implemented such that the intensity will not be damaging to the animal, and the sound system will be run at high frequencies, but not high enough that it will cause damage to the ears of the animals.

Our second safety concern will be the moving parts of our invention. The device will be moving in a 360° fashion, and this will require several moving parts. Therefore, we want to ensure that our design is safe and make sure nothing can get clamped and affect these moving parts. Lastly, is the safety regarding lithium batteries the project will require. Lithium batteries are notorious for igniting, especially in heated settings. Given that our device will be placed outside, we want to make sure that our batteries are sealed in a safe encasing, such that it does not have direct exposure to sunlight.

References

1. https://youtu.be/ahhb5EjHleY?si=lWJFFg86J490MpB7 [Arduino Radar and Turret]
2. https://youtu.be/f2TUxoaKIsA [[DEMO] Headshot Tracking || OpenCV | Arduino]
3. https://youtu.be/VJ4o3T3aBho [5 Best Ultrasonic Pest Repellers in 2023: That Actually WORK!]