Smart Animal Fencing and Emergency Predator Alert and Detection System (SAFEPADS)

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Abstract — **Smart Animal Fencing and Emergency Predator Alert and Detection System (SAFEPADS), is a multifaceted smart pet harness that aims to promote the health, safety, and happiness of pets. It offers users a comprehensive suite of features that monitor environmental conditions vital to their pets' well-being. SAFEPADS incorporates an environmental temperature and moisture sensor, Global Positioning System (GPS) location and geofencing system, and vibration training mechanism into a single, cost-effective product. SAFEPADS also includes an indoor location and fencing system as well as a predator detection and deterrent system, two features that are not currently included in competitor smart pet collars. Users can interface with SAFEPADS via a companion software application via WiFi. This paper will discuss the goals, objectives, key components, and design of SAFEPADS.**

Index Terms — **Geofencing, Global Positioning System, image processing, lens system, optoelectronics, WiFi.**

I. INTRODUCTION

Many individuals are pet owners who deeply care about the safety and happiness of their beloved animals. However, owing to busy schedules or other responsibilities, pet owners may not be able to continuously supervise their pets. This absence increases potential risks to their pets' well-being and instills concerns among pet owners regarding their animals' safety.

A technological solution has emerged to address these concerns: smart pet collars. Smart pet collars are devices worn by pets that offer a range of features that monitor environmental conditions crucial to their well-being and provide valuable insights into their health and happiness. Many products already exist in the smart pet collar market, offering various combinations of features desired by pet owners. These features include Global Positioning System (GPS) location and geofencing capabilities, manual vibration activation for training assistance, activity/sleep tracking, environmental temperature/humidity monitoring, wireless data transmission, and companion software applications.

Furthermore, SAFEPADS's sponsor outlined some features that would appeal to pet owners but are missing within pre-existing smart collars. One such feature is a mechanism to defend against or deter predators. Current wearable devices intended to defend pets from predators mainly utilize spiky protrusions that inflict pain upon attacking predators to deter them. Another feature missing in the current smart collar market is the capacity to track the locations of pets indoors and restrict their access to certain areas. Smaller pets often hide in tight spaces, leaving them lost to their owners, and pets also may explore areas that could potentially put them in harm's way. Current solutions to these concerns, such as standalone invisible fence systems, security cameras, and Bluetooth key finders, each have unique drawbacks and lack the convenience of integration with a previously purchased smart collar.

The SAFEPADS team aimed to combine many desirable competitor features into a unified, convenient product while also addressing the aforementioned market gaps. Additionally, the SAFEPADS team opted to create a pet harness rather than a pet collar to distribute the weight of hardware more ergonomically on the wearer. SAFEPADS incorporates the following subsystems, the inclusion of each delineated as one of this project's goals: temperature/humidity sensor, outdoor location/geofencing system, indoor location/fencing system, vibration mechanism (geofencing, indoor fencing, and user-triggered), and an automated predator deterrent system. SAFEPADS, as per the project goals, is also able to send and receive data wirelessly to a companion software application which users can interact with.

II. OBJECTIVES AND ENGINEERING SPECIFICATIONS

To meet the aforementioned project goals, a set of high-level project objectives were defined for SAFEPADS that related the initial project goals to concrete design steps. These project goals and corresponding objectives are outlined in the following table:

TABLE 1

PROJECT GOALS AND CORRESPONDING OBJECTIVES

Goal	Corresponding Objectives
Implement a vibration feedback system.	Embed a small solenoid or a DC motor in SAFEPADS that is controlled by the system's microcontroller.
Design and implement outdoor location and geofencing systems.	Implement GPS system to continuously determine SAFEPAD's location; develop software enabling users to select coordinates to establish a geofence boundary; ensure that upon SAFEPADS exiting the geofence boundary, users receive notifications and/or activate the vibration mechanism.
Design and implement indoor location and fencing system.	Design an optical system consisting of a transmitter mounted on SAFEPADS and a freestanding receiver.
Design and implement predator detection system.	Design a wide field-of-view camera system mounted on SAFEPADs; integrate the camera system with image processing software that determines if there are possible threats around the pet; implement strobe light activation based on software determination.
Design and implement predator deterrent systems.	Design an LED strobe light within a collimating lens housing that can flash brightly to frighten predators when activated by software.
Send and receive collar data; enable the user to view collar information and interact with SAFEPADS.	Design and implement a Windows application that can transmit and receive information from SAFEPADS.

Furthermore, meeting the following set of quantitative engineering specifications was determined to be crucial to the success of SAFEPADS:

- The system's battery life shall be at least one hour.
- Wireless upload speeds shall not exceed 10 minutes for general information and should not exceed 45 seconds for emergency notifications.
- Temperature reading shall be accurate within 2° C and relative humidity reading shall be accurate within 10%.
- The GPS/geofencing system shall update at least once every 30 seconds.
- The camera system shall have a total radial field of view of 300° and a total azimuthal field of view of 300°.
- The indoor location/fencing system shall have a 90° field of view in one direction and shall be at least 90% accurate from a working distance of 1 meter.
- The strobe light shall flash for one minute upon activation of the predator deterrent system.

VI. HARDWARE COMPONENT SELECTION AND DESIGN DETAILS

SAFEPADS includes various hardware subsystems, each necessitating design considerations and component selection. The project's hardware block diagram, shown in Figure 1, provides an overview of SAFEPADS' high-level hardware design, and the following sections delve into detailed explanations of the hardware within each subsystem.

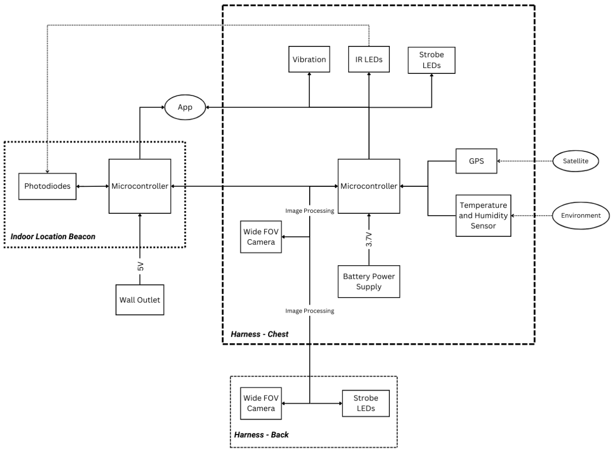


Fig. 1. Overall hardware block diagram

A. Microcontroller

Choosing the ideal microcontroller for our smart pet harness project was a pivotal decision that significantly impacted the design of the rest of the system. Our multifaceted harness demanded a microcontroller that could effectively process sensor data, execute geofencing algorithms, monitor the predator detection and efficiently activate the strobe light defense system. These functions, as well as a handful of others, all needed to be controlled with minimal power draw and high-speed response times. We also needed to consider the ease of programming, community support, and cost effectiveness, when making our decision. It was also necessary to consider the small size our board would have to be and to try to choose a microcontroller that would take up the least amount of space.

When considering all of these aspects, we decided to go with the ESP32-WROOM-32E since it was capable of the above and also had WiFi and Bluetooth functionalities built into the board, enabling faster and reliable data transmission to the application. It had the processing capabilities required for our purposes without the large footprint of some of the other options, and was easy to program and reprogram when necessary.

Some extra circuits had to be added to the board to allow for reprogramming after the chip had been soldered to the PCB. The overall footprint that the reprogramming circuits added to the board were negligible, and were worth the concession in order to avoid having to rework the solder and potentially damage the chip in the process.

B. Power Supply Subsystem

The desired goal of the power supply subsystem is to supply an appropriate voltage to all of the device's components from a rechargeable battery while also allowing the battery to be charged. Additionally, since the device is battery operated the power supply subsystem had an additional goal of needing to have a high energy efficiency. Furthermore, since the device needs to fit on a pet collar it was important to choose a solution that minimizes size.

Since the device is battery operated and thus must operate on a limited power supply, it was important to pick a battery with a high energy density. Many different types of rechargeable batteries were considered but ultimately lithium based rechargeable batteries were selected. Lithium batteries were selected due to having energy densities that were significantly higher than all other types of batteries considered. Additionally, lithium batteries availability in various types of shapes was a great benefit due to it needing to be able to fit inside a pet collar. The result of this decision is a battery that can last a long time while still maintaining a small size.

A power management integrated circuit was included in the power supply subsystem design in order to allow the recharging of the device. A power management integrated circuit is important since it allows the battery to recharge at a constant current which will provide predictable recharging times for the device. Additionally, a power management integrated circuit helps prevent overcharging the battery by having a voltage where it stops charging the device. The power management integrated circuit selected was the MCP73833T-AMI/UN. This charging integrated circuit charges lithium batteries up to 4.2V and can charge at a rate of 1A. Since the battery selected has a capacity of 2000 mAh this charging integrated circuit will be able to charge the battery to nearly full in approximately two hours. Additionally, this integrated circuit has a relatively simple design and small size allowing it to easily be implemented onto our device.

In order to ensure that all the charging current goes to the battery, a p-type mosfet transistor had to be included. This ensures that while charging the rest of the circuit is disconnected allowing all the charging current to go into the battery. When the charger is disconnected, the battery is once again connected to the device allowing the battery to supply power to the entirety of the system.

In order to supply the appropriate voltage to all components of the device from the battery, a voltage regulator is needed. A switching voltage regulator was selected over a linear voltage regulator due to it providing a greater energy efficiency which will extend the operational length of the battery. Since all the components operate at 3.3V, the TPS564257DRLR switching voltage regulator was selected. This voltage regulator allows for a programmable output which was selected to be 3.3V and provides a small ripple current which will be important for ensuring that the GPS can be functionally utilized. Additionally, it supports up to four amperes of output current which will guarantee that all components can be supplied with their necessary current requirements. By connecting the output of this voltage regulator to all components, all components are able to receive their appropriate amount of power.

After we began connecting everything on the boards to power, we realized that the power draw from all of the components at once nearly exceeded the battery’s limits; upon this discovery, we decided to add transistors before most of the components to be used as a digital switch [1], so the parts could have their individual current draws without it affecting the microcontroller or the power supply.

C. Temperature and Humidity Sensor

The temperature and humidity sensor serves the purpose of allowing pet owners to be notified if pets are in an environment of abnormal heat or cold for an extended period of time. In order to accomplish an accurate monitoring of temperature, many different temperature and humidity sensors were analyzed and the SHT31 was selected. The SHT31 offers a temperature within ±0.2℃ and a relative humidity within ±2%. Additionally, the SHT31 has a low current consumption and comes at a small size allowing it to take up little space on the collar and promote a long battery life. The SHT31 sensor communicates to our microcontroller using inter-integrated circuit communication and thus has connections to the serial clock and serial data lines on the microcontroller. This allows it to easily send data to our microcontroller by communicating with its I2C address of 0x44. Through the use of the SHT31, the collar is able to adequately monitor the temperature of the pet's environment.

D. GPS and Geofencing System

The global positioning system of the system is intended to provide accurate location updates of the pet and enable geofencing for the pet. In order to accomplish this, many GPS integrated circuits were analyzed and the PA1616S was selected. The PA1616S GPS features a low current consumption of 20mA as well as an accuracy within ±3 meters. This allows for accurate location updates while the device is outdoors. The GPS transmits this data using the universal asynchronous receiver/transmitter as its communication protocol of choice. Due to this, the transmitting pins of the GPS are connected to the receiver pins on the microcontroller and the receiver pins of the GPS are connected to the transmitting pins on the microcontroller allowing the two devices to communicate data between each other. The GPS module is able to determine its location 10 times per second when it is in view of a satellite but is currently set up to read its location in wider intervals of about 1 location per 7.5 seconds.

D. Indoor Location/Fencing System

The indoor location/fencing system consists of an optical transmitter-receiver pair that detects when SAFEPADS has passed the point of installation. The transmitter is an infrared LED affixed to either side of SAFEPADS while the receiver contains a ball lens, filter, and photodiode panel, as shown in Figure 2.

The receiver also contains a PCB and embedded ESP32 microcontroller. It was decided for the receiver to be freestanding rather than the transmitter since the necessary optics for the receiver are larger than the transmitter light source, and the size of SAFEPADS is constrained to prioritize the wearer's comfort. The receiver should be installed by the user at the desired indoor fence boundary (e.g. a doorway) at the height of SAFEPADS while worn by the animal so the system is approximately aligned. One passage of SAFEPADS by the receiver's point of installation is registered by the system as SAFEPADS entering the room, at which time vibration feedback may be administered. A subsequent passage by the receiver's point-of-installation is registered SAFEPADS exiting the room.

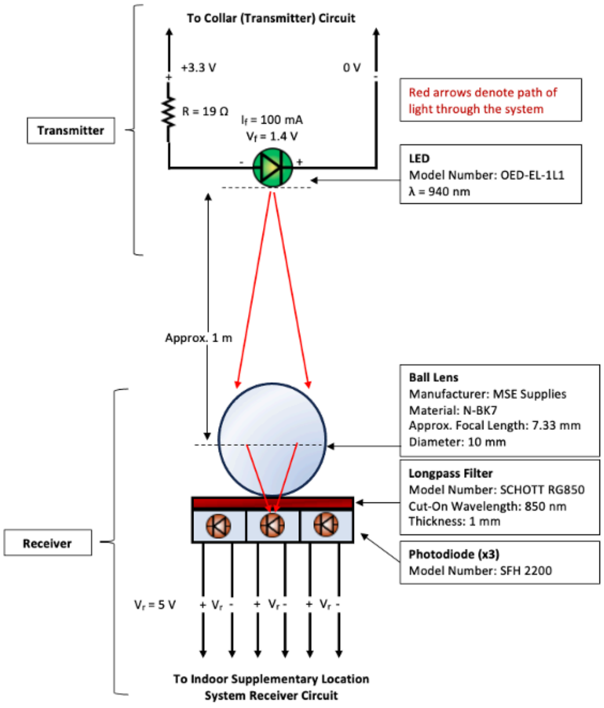


Fig. 2. Optical schematic of indoor location/fencing system

For the system to function, the wavelength of the transmitter light source must be outside the range that typical household lighting emits (400-700 nm) and must not disturb domestic animals (possibly up to 900 nm) [2, 3]. Considering this information, a source with a peak emission wavelength of 940 nm was selected, as well as a corresponding 850 nm long-pass filter to lessen the impact of environmental noise. An LED source was chosen over a laser diode due to its superior eye-safety profile. An LED with a 60° divergence angle (OED-EL-1L2) was selected to ensure the system would be robust against misalignment compared to a source producing a smaller spot.

Also necessary was selecting a photodetector compatible with this project. Photodiodes were chosen, as they possess a fast response time, and when reverse-biased, they respond linearly to incident optical power (as opposed to the logarithmic response of photoresistors). A component with a large active area of 7.02 mm^2 (SFH2200) was selected since this large active area would contribute to the receiver's wide field of view.

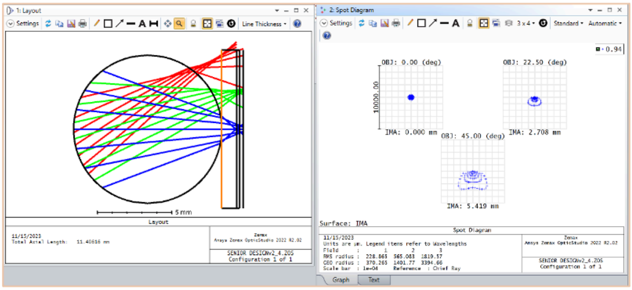
To achieve the desired 90° field of view using only one of the selected photodiodes (with an active area side length of 2.65 mm) as the photodetector, the receiver lens system would have to have a maximum focal length of 1.33 mm, as calculated using Equation 1. In Equation 1, "AFOV" denotes the lens system's angular field of view, "H" denotes the length of the active sensor area, and "f" denotes the lens system's effective focal length.

$$AFOV \;=\; 2 \times arctan(\frac{H}{2f}) \qquad (1)$$

This focal length is unachievable given the thickness of the filter and photodiode packaging. Ergo, a panel of three photodiodes placed next to each other was used, taking data from each photodiode. This arrangement yields an acceptable maximum focal length of 5.325 mm. The impact of blind spots resulting from space taken by the photodiode packaging in this setup is minimal since the LEDs emit a relatively large spot and light consistently reaches the photodiodes when SAFEPADS passes the receiver completely. After testing using one row of photodiodes, another row was placed normal to the first to further increase the system's field-of-view and accommodate pets of different sizes utilizing the same receiver.

A ball lens was selected to focus incoming light onto the receiver since it has been used historically to achieve a wide field of view at a short focal length without the bulk and cost associated with multi-element fisheye lens systems. While using this lens alone yields an image with significant aberrations, it is acceptable since the receiver is not intended as an imaging system. Instead, this lens acts to condense incoming light onto the photodiodes.

To find the best size and placement of the ball lens, the receiver system was simulated in Zemax OpticStudio. After inputting the specifications for the photodiode packaging and filter into OpticStudio, an N-BK7 sphere of variable radius and placement was placed. Ray fields with a 940 nm wavelength and incident angles of 0°, 22.5°, and 45° were placed to simulate incident rays within the desired field of view (45° on each side, for a total of 90°). To optimize the system, a Merit Function was constructed within OpticStudio's Optimization Wizard. The minimum glass thickness for the lens was set to 2 mm — lenses with any smaller diameter would be challenging to implement. The "Local Real Ray Y-Coordinate" and "Operand Less Than" operands were used within the Merit Function spreadsheet to constrain rays incident on the image plane to the sensor area. The optimization was run to yield a ball lens with a diameter of approximately 10 mm placed against the filter, seen in Figure 3.



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11/15/2023
Total Axial Length:    11.40616 mm
Zemax
Ansys Zemax OpticStudio 2022 R2.02
SENIOR DESIGNv2_4.ZOS
Configuration 1 of 1
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11/15/2023
Units are µm. Legend items refer to Wavelengths
Field      :      1        2        3
RMS radius :   228.865  565.083  1819.57
GEO radius :   370.265  1401.77  3394.66
Scale bar  : 1e+04      Reference  : Chief Ray
Zemax
Ansys Zemax OpticStudio 2022 R2.02
SENIOR DESIGNv2_4.ZOS
Configuration 1 of 1
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Fig. 3. Simulation of receiver lens including system cross-section (left) and spot diagram (right). Note that the blue, green, and red rays propagate from left to right in the system cross-section image.

Adding a negative meniscus or biconcave lens to better confine light to the sensor plane was considered and successfully simulated. However, given the additional size and cost of this component and adequate testing results with just the ball lens in place, it was chosen not to add this lens to the system.

The electrical design of the indoor location/fencing system is as follows: When light is incident upon the photodiodes, the generated current will be supplied to an inverting amplifier to provide a readable voltage. The output of the inverting amplifier is connected to one of the analog-to-digital converter pins on the receiver's microcontroller. The numerical output of the analog-to-digital converter is analyzed to determine if it is larger than a predetermined threshold value. If the generated number is sufficiently large, the software will register that a pet has entered or exited the area where the beacon is installed.

E. Predator Detection and Deterrent System

The predator detection and deterrent system is a two part system that will work in conjunction with each other. The predator detection system will consist of two cameras and software that is capable of identifying any predators. The software functions and details are further explained in the software section of this paper, as this section will cover the optical design involved in these systems. The predator detection system focused on maximizing the field of view of the lens systems, so that the total field of view between these systems is around 300°. The camera system is made up of two OV2640 camera boards with a custom made lens system that are fixed onto the camera. These lens systems were put onto the camera using 3D printed lens mounts made in Solidworks. The two cameras will be placed on opposite ends on the collar, one will reside under the neck of the animals and the other will reside on the back of the animals. The positions of these cameras will make a total field of view of 300° possible. The lens systems were made using a lens from a lens kit and the lens from the OV2640 camera board. This was done by deconstructing a lens set with an initial field of view of 160° and testing different combinations of lenses until a discernible image was formed with a great increase in field of view. One lens was placed close to the lens already on the camera board and another lens was placed 1.7 centimeters from the bottom lens. This created the sharpest image. The field of view was found to be 148.5 degrees. This was done by finding the focal length of the lens system once it was put on the camera. The focal length was found to be around 1.7 centimeters. This was done using the equation for the effective focal length seen below.

$$\frac{1}{EFL} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

The focal lengths of the lenses from the lens kit were found by shining a point source through the lens and finding where the point came to a focus. The focal length of the lens on the camera was listed in the camera specs.

The sensor size was found using the following equation:

$$sensor\ size\ =\ array\ size\ x\ pixel\ size$$

The array size was 1600 x 1200 and the pixel size was 2.2 x 2.2 micrometers. These values were multiplied together, respectively and the sensor size was found to be 0.00352 x 0.00264. These values represented the vertical and horizontal size. The diagonal sensor size (D) was needed and this was found using pythagorean theorem. The field of view was then found using the following equation:

$$FOV\ =\ \frac{2 \times tan^{-1}(D)}{2 \times EFL}$$

The second camera had a different custom lens design. This was done using the same procedures as the first one but using different lenses. The lenses used for this design were from a lens set with an initial field of view of 140 degrees and a lens set with an initial field of view of 60 degrees. These two lens sets were deconstructed and various lenses from each were used to create this lens design. The field of view was calculated the same way as previously discussed. The focal length for this system was found to be around 1.4 centimeters. Since the camera remained the same the sensor size stayed consistent with the previous calculation. The field of view was found to be 155 degrees, which created a total field of view, between each camera, of about 300 degrees. Based on the positions of the cameras the two fields of view can simply be added together because they are placed on two opposite ends of the collar. This concludes the optical design for the predator detection system.

The predator deterrent system consists of two sets of five SMD LEDS. A collimating lens is then placed on top of these LEDS. The collimating lens was put above the LEDS using a 3D printed lens mount made on Solidworks. The power output of each set is about 10 milliwatts, when the collimating lens was placed above the LEDS. This was found by applying a voltage to the LEDS and then using a power meter to find the power. This power output produced a luminescence that was bright enough to ward off or startle any predators approaching the pet. A schematic of this system can be seen below in Figure 4.

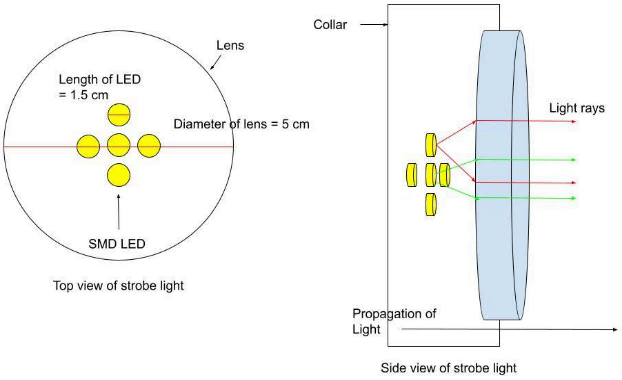

Fig. 4. Optical schematic of strobe light showing the set up of the SMD LEDs and how the collimating lens will be situated on the system.

The LEDs will be fastened on the collar so that the LEDs are situated on the back of the animal to avoid any light from being shined on the pet's face, and inhibit their abilities.

The predator detection and deterrent systems will work in conjunction with each through communication with the application. When a predator is viewed with the camera an alert will be sent to the owner's phone and the owner can then choose to turn on the strobe light and deter any predators from the pet.

F. Vibration Motor

There are a few different types of components that can be used to create a vibration for the correction component in the harness. One of the most common types of vibrating electro-mechanical components is aptly named vibration motors, or vibro-motors. These are the types of vibrations found in smartphones, video game controllers, and other electronics that require haptic feedback. They're generally affordable and versatile, which would make them a good fit for our project. They're designed with a weight attached to the shaft of the motor which causes a vibration when the motor spins. They come in both coin and linear types.

Another type of vibration component is the piezoelectric transducer. These use the piezoelectric effect, which is the phenomenon that a mechanical pressure can create electrical charges in specific materials, to create vibrations. These are often used in buzzers and for the same type of haptic feedback devices as listed previously.

The next electromechanical component to be considered is a solenoid. There are multiple different types, the most common ones being a rotary solenoid and a linear solenoid. They generally have a metal plunger that is resting inside a coil, and when an electrical current is applied to the coil, it generates a magnetic field that pulls or pushes the plunger based on the field direction. Due to Sara's previous experience using solenoids, we originally wanted to use one for our collar, however we've decided that the plunger would create too many potential problems and a different type of vibration would be better suited for our project anyway. The small size of the solenoids that would fit inside the casing of our collar would also likely not be enough mechanical force to be effectively felt by the animal, thus rendering the vibration useless.

More specific types of vibration motors are linear resonant actuators (LRAs) and eccentric rotating mass (ERMs) motors. They're less common in consumer electronics but are becoming more popular due to their precise and more realistic haptic feedback. LRAs consist of a mass attached to a spring and a voice coil. When an electrical signal is applied to the coil, the mass is moved back and forth at its resonant frequency. This is what creates the vibration. ERMs have an unbalanced mass attached to a rotating shaft which creates vibrations when the motor spins. LRAs and ERMs are both compact in size and would make a good fit inside the smart pet collar as there are no external parts that could get dislodged or affect other circuitry. They also can be adjusted in intensity by increasing or decreasing the applied voltage to make the vibration more or less intense, respectively.

Since the ERM vibration motors were the smallest overall while being simple to implement and powerful enough to be felt through the board and the material of the harness, we decided to go with one. Specifically, the Adafruit 1201 Vibration ERM Motor. It was already owned by Sara so we were able to save on costs for this component, and it was able to provide a more intense force than we were anticipating which was good as we were able to create multiple levels of intensity for different training purposes.

V. Software Design Details

A. Onboard Software

The software on the collar is coded using Arduino's IDE and is responsible for gathering data and transmitting it to the app for processing. This data includes live video, GPS location, temperature, and humidity. The collar sends this data over wifi to the app, which then communicates back to the collar in order to trigger specific functions, such as the strobe light defense and vibration motors. This communication works through the user's home network. Every few seconds, the collar sends a POST and GET request to the network. In these requests, the collar sends all of the previously mentioned information, which is then processed by the app. Based on the received information, the app will decide which triggers need to be activated, such as the strobe lights and vibration. Finally, the GET request reads all the triggers from the network, and the collar activates any features associated with the triggers. Through this system, the collar achieves semi-live updates.

B. User Application

The SAFEPADS Collar comes with a companion application that runs most of the processing-intensive features of the collar, particularly the predator detection and internet connectivity. The application is coded using various Python libraries. A general overview of the application can be seen in Figure 4.

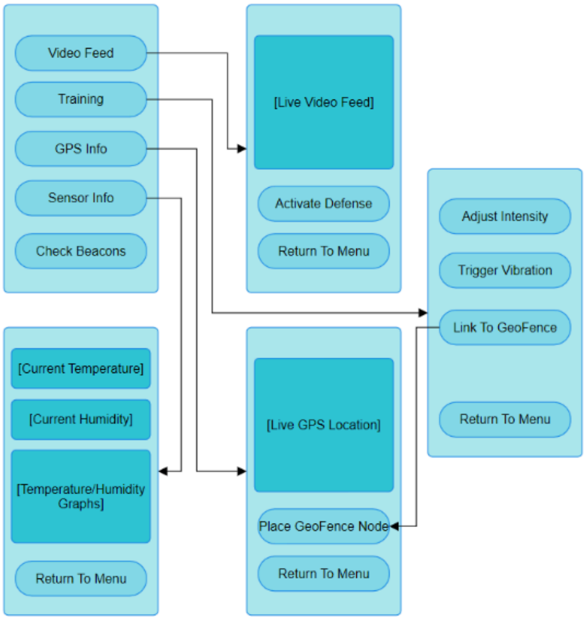

Fig. 4. GUI Design Diagram

The predator detection system utilizes Python's OpenCV library. This library comes with many tools for manipulation and processing images and video. Using the video feed from the collar, the application utilizes COCO's database to detect objects or animals within the frame. Once OpenCV's computer vision model is over 45% confident in the detection, it will send a signal to the collar to activate the strobe light defense. After the threat is no longer detected by the camera, the signal is sent to stop the strobe lights.

For the GPS system, the application receives live coordinates from the GPS module over wifi. Using the tkintermapview library, the application is able to display the pet's live location, as well as any geofences set up by the user. When the pet's location is read to be inside a geofence, the collar will vibrate to inform the pet it has entered a restricted area. Additionally, the user is able to decide whether a given geofence is an "inclusive zone" or an "exclusion zone", which controls whether the collar vibrates when the pet is outside or inside the geofence.

The app is also how the user will view any extra information gathered by the collar, such as humidity and temperature. Through a display, the user is able to see the pet's current humidity and temperature. The user can also use this feature to set up maximum temperature/humidity values, in order to be notified if their pet is experiencing dangerous conditions.

The training functions of the collar can be accessed through the app as well. The user is able to use the app to change the intensity of the vibration motors on the collar, as well as manually trigger them to assist with pet training. They are also able to link this training function to geofenced areas, automatically triggering the vibrations if the pet wanders into a restricted area.

The final job of the app is to display the status of the auxiliary beacon system. If the pet is currently indoors, the app allows the user to check if a beacon can currently see the pet, and if so, which one. This is done by connecting the beacons to the collar and the app using the user's home wifi network.

C. Beacon Software

The auxiliary beacons are an optional system meant to help users find their pets indoors. Using infrared LEDs that are on either side of the collar, the beacons are able to detect whenever a pet enters the room they are installed in. When this happens, the beacons send a signal to the app which is then displayed to the user, telling them which beacon can see the pet. Since the beacons are run with the same MCUs as the collar, the software was also created using Arduino's IDE.

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Rana Scherer is a senior at the University of Central Florida. She will be graduating with a Bachelor's degree in Photonic Engineering and a minor in Mathematics.

Sara Wijas is a senior at the University of Central Florida pursuing a degree in Electrical Engineering with minors in Cognitive Sciences and Intelligent Robotic Systems. She is taking an engineering job at Epic Universe after graduation.

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