Pet Threat Detector: Proposal

ECE 445 Proposal

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1 Introduction

1.1 Objective

For many households around the world, pets are treated like family members. Many pets need to go outside to get exercise and are left unattended while they roam the yard. This can lead to pets finding themselves in a wide variety of dangerous situations. Some common examples of dangers that pets can encounter include finding a wild animal, becoming injured or wandering far from home. While owners eventually discover the danger their pet was in, this usually happens after the pet has been harmed. Many varieties of global position tracking for pets exist including microchips and Global Position Services (GPS) collars but these only notify the owner of where the pet is located and not of any other existing danger they might have encountered [1].

Rather than use a simple GPS tracker, we propose solving this issue with a comprehensive danger detection system for pets. To monitor the current state of danger that the animal is in, a variety of sensors and a camera will be attached to a harness that the animal will wear when going outside. When these sensors detect a change in the pet's behavior or current state, the owner will receive a notification on their mobile device through a software application. These notifications will include information about the potential type of danger that the pet is experiencing. Applying these sensors along with the traditional GPS tracking and mobile notification system will provide more comprehensive information on the pet and improve an owner's response time for handling the imminent threat to their pet's safety. Our solution can also be safely used with several pets to monitor each of their conditions simultaneously.

1.2 Background

Pet safety technology is a relatively new and unexplored field. The most prominent and commonly used electronic technology for pet safety are microchips using passive integrated transponders (PIT). This development was originally introduced in 1984 to study the migration patterns of fish. PIT devices are injected into the animal and contain a radio frequency identification (RFID) number to track which animal is which. Not very much has changed with this technology since its creation and it has most frequently been used as a method of identifying a lost animal that someone has found [2]. However, PIT microchips do not feature GPS technology and do not track the exact location of a pet. This feature is included for tracking collars. These devices use global positioning and an accelerometer to detect an animal's motion and current position. GPS tracking collars were invented in 2014 by Terrie Williams, Christopher WIlmers and Gabriel Elkaim to track large wild cats [3]. While these devices do monitor the animals' behavior using an accelerometer, the device is not made with the intention of detecting hazards to the animal. These devices have been refined and commercialized for pets as well with some even including cameras to record what the pet does on a day to day basis. Other devices are designed to track the location of hunting dogs so that the owner can locate their dog and game [4].

Per request of the ECE 445 professors, this project's problem is based off of a project completed in a previous year. The original solution to this problem was composed by Group 8 from the Fall 2019 semester and was titled "Pet Pest Protector." For this design, the group used a collar equipped with a Passive Infrared (PIR) motion sensor to detect the motion of other animals that may cause the pet harm [5]. While the device accomplishes the task of detecting danger from other animals or humans in close proximity to the pet, there are many other forms of danger that would go unnoticed by the PIR sensor. The American Veterinary and Medical Association notes that the average household in the United States has 1.6 dogs indicating that having more than one pet is not an abnormality [6]. However, the device proposed and built by Group 8 does not have a method for distinguishing between a friendly pet and a dangerous pest. To mitigate the problems present in the prior design, the revised design will focus on tracking the condition of the pet rather than the danger itself. To replace the function of the PIR sensor, the new design will use a heart rate monitor and accelerometer combination to track the pet's motion and heart rate. If the pet's heart rate exceeds a value set by the owner while the accelerometer detects a large amount of motion (possibly indicating that the pet is running from a threat) or no motion (because the pet might be frightened or injured), the owner will receive a notification via the mobile device application. Along with this notification, a picture taken with a small camera on the harness will be sent to the owner. This picture will help the owner indicate if the pet is in danger and, if so, the exact variety of danger the pet is in. Utilizing this photo capability will also mean that this device can be applied to multiple pets because if one pet's heart rate rises because of the other, the other pet will appear in the captured image. The new solution will also contain a GPS tracking system, in which the animal's coordinates can be viewed on the owner's mobile device at all times. This way, if the pet is in danger, the user can reach their pet as fast as possible, since they will know where to go. Another feature that the user can add through the application is a delimitation radius for the pet. When the pet moves outside of the radius set by the owner, the owner will get a warning notification that the pet may have run away. This solution can identify more potentially dangerous situations to the owner than the previous design and utilizes different technology for detecting the threat.

1.3 High-Level Requirements

- HLR-1: The Pet Threat Detector shall detect whether or not a pet is in danger using a variety of sensors with 90% accuracy or greater.
- HLR-2: The Pet Threat Detector shall send a notification to the owner's mobile device when the pet is in danger through the Communication Module with failure rate of 5% or lower.
- HLR-3: The Pet Threat Detector shall track the longitudinal and latitudinal coordinates of a pet within a 20 meter radius of its actual location and display these results to the owner as long as communication between the mobile device and harness is maintained.

2 Design

To complete the task of notifying a pet's owner quickly of any possible danger, the design will interface between two physical devices: a modified pet harness, which will be designed specifically for this application, as well as the user's mobile device. Harnesses are commonly used as a training mechanism and should not cause any discomfort during use while still providing a platform to include each of the desired features. The mobile device refers to any smartphone or tablet which can run the student developed software application.

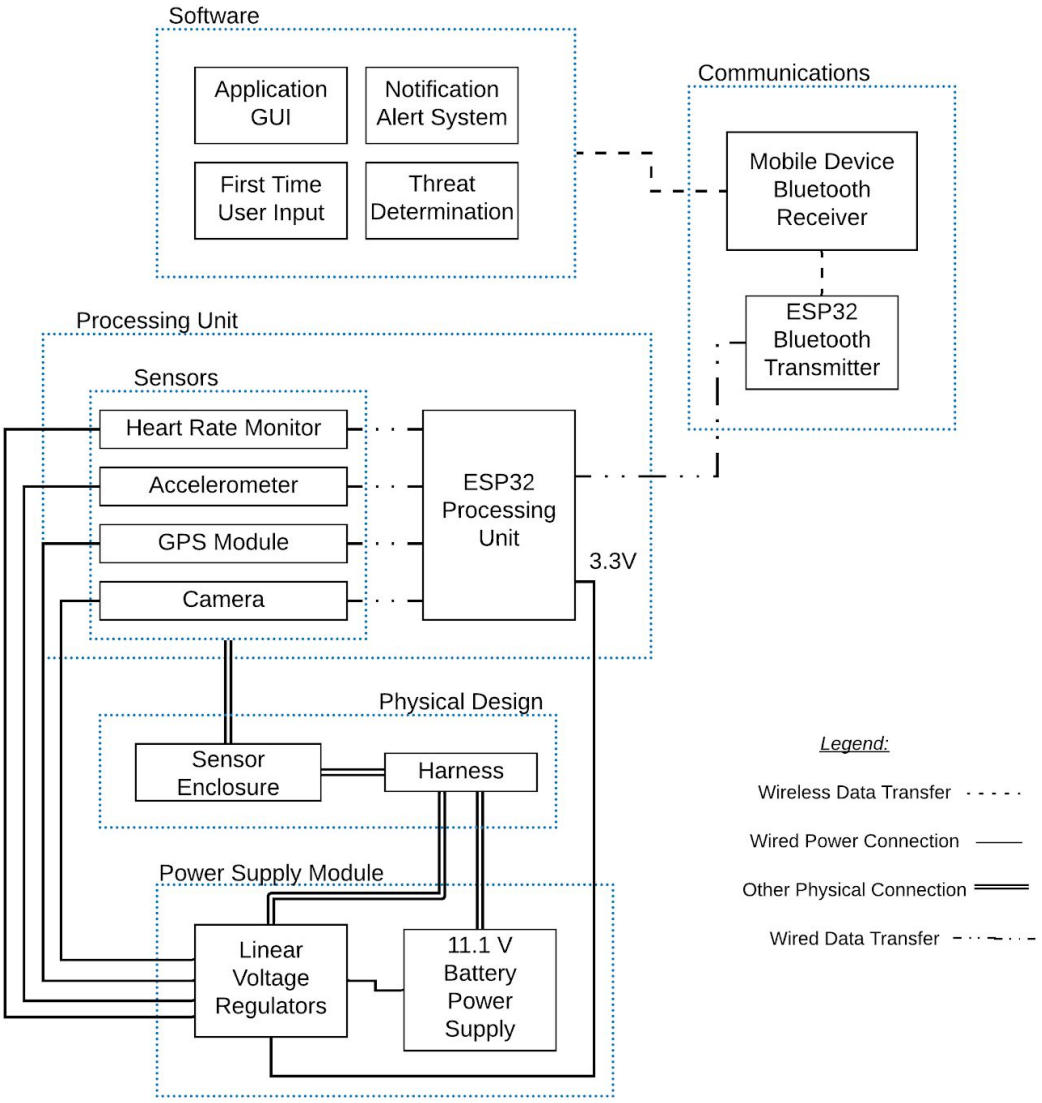

Figure 1 - Block Diagram of the Pet Threat Detector

Design organization is subdivided into five modules: a Power Supply Module, a Physical Design Module, a Processing Unit Module, a Communication Module and a Software Module. The primary task of the Power Supply Module is to ensure each component is supplied with the appropriate power required for operation. This includes the battery supply, power wire routing and a small network of linear voltage regulators. Mounting electronics on a pet presents numerous challenges which are diminished through the Physical Design Module. While this module does not include any electrical components, it is still an integral module for keeping the animal safe when the device is in use. All of the sensors for monitoring the pet's physical condition are contained within the Processing Unit Module as well as a microcontroller which collects the data to be sent through the Communication Module. The Processing Unit Module also contains an integrated software component developed on the Arduino IDE which will be used to interpret what data to send through the Communication Module. The software that the pet owner will interact with is contained in the Software Module. This includes an application which will be developed for Android devices for the user to calibrate the harness to their pet's needs and receive notifications about the condition of their pet.

2.1 Power Supply Module

In order to power the sensors and be paired with a mobile device, the harness will need a power supply. Considering that it will be worn by pets for potentially long periods of time, the power supply cannot add a considerable amount of weight to the harness, nor can it be harmful to the animal, i.e., the battery cannot be prone to be bitten and have its contents exposed. It is also desirable for it to be rechargeable for ease of use.

Lithium-polymer (LiPo) batteries fit these requirements. Its weight ranges from 170 to 250 grams [7], which is ideal for this application and its voltage rating per cell is of 3.7 V [8], which means it is possible to go to 11.1 V with 3 cells, which is ideal for the purposes of this project, and use voltage regulators to adjust it to each voltage level needed. Moreover, given that these batteries are widely used in electronics on the market, it would be easy for the user to get it replaced.

As previously mentioned, a small system of linear voltage regulators will be necessary to ensure that each device receives the appropriate power input. The required voltages for each device are dependent on the component chosen so the voltage regulator specifications and total battery voltage are yet to be determined. Lithium-polymer batteries under 250 grams exist that can supply voltages of 11.1 V [9] which should be sufficient for the system requirements.

In terms of safety, the battery will be contained within a lightweight but durable plastic enclosure screwed shut with small and secure screws, such that the pet is not able to open it by biting it, and still being covered by the harness fabric. There will also be a small hole on the side of this enclosure for charging the battery through a cable, with a movable flap that can cover this hole whenever the device is not charging.

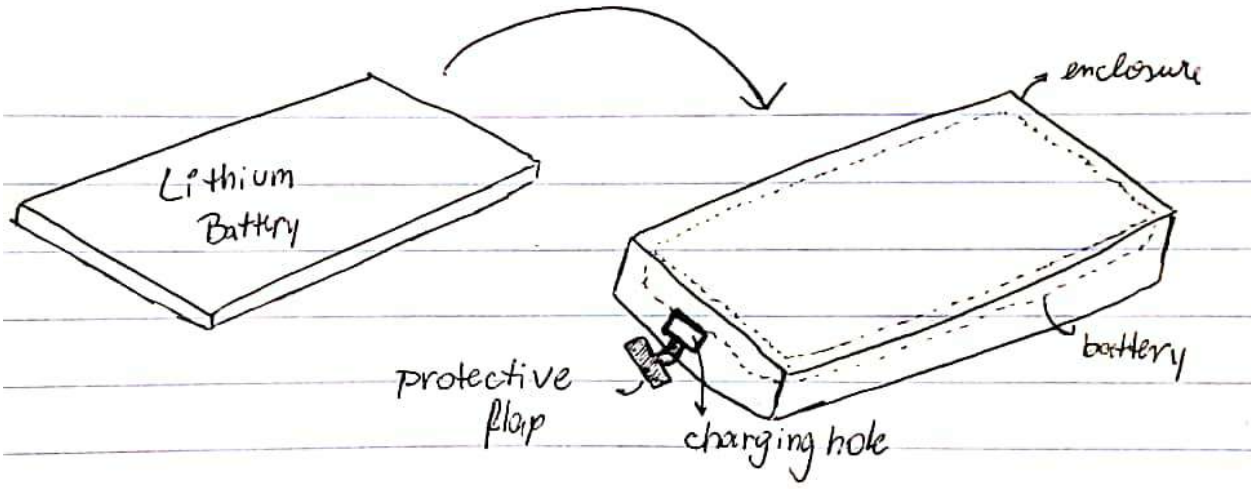

Figure 2 - Sketch of the battery and its enclosure

- PSM-1: The battery shall be safe from biting and rough handling.
- PSM-2: The power supply shall weigh no more than 300 grams.

2.2 Physical Design Module

While the physical design contains no electrical components, its design contributes important criteria for the focus of the product as a whole and influences choices for other components. Animals can have destructive tendencies, especially when young, so the physical design is an important component to this project. Additionally, pets are living beings that the owner's wish to protect by using this device so its design must minimize discomfort and maximize safety when in use.

2.2.1 Harness

Despite the original senior design project being based on a collar, it was determined that a harness is the most effective accessory to incorporate the other features of the product. Harnesses are larger in size and cover more of the pets body than a collar does. Unlike a collar based design, this allows room to spread the various devices around the harness to prevent the device from becoming too heavy for the animal in one particular area. Using a harness also prevents the pet from easily removing the device because it will be secured to the pet in more places than a single clip collar. The harness itself will be composed of a durable but lightweight fabric such that the pet's mobility is not restricted while also

being strong enough to avoid being ripped apart by the animal. Nylon and polyester are materials being considered for this design because of these qualities. Polyester is slightly stronger and everyday waterproof, making it the more likely material to be chosen for the harness [10]. This technology can be applied to an animal of any size but for the purposes of this demonstration, the harness and its requirements will be modelled as if the pet is a large dog.

Equally important to this device success as the pet's safety is its functionality. To take an accurate heart rate measurement, the optical sensor's pad must be positioned close to the animal's hind legs. For this reason, the collar must extend to this area of the animal. Existing harnesses have large areas of fabric which cover the pet's stomach which provides a region close enough to the target area to monitor the pet's heart rate. Additional layers of fabric will be enclosed over any wiring between devices on the harness to avoid interaction between the animal and the electronics. This also means electronics will be inaccessible after being installed in the collar and additional soldering may have to be done to avoid wires from slipping out during use.

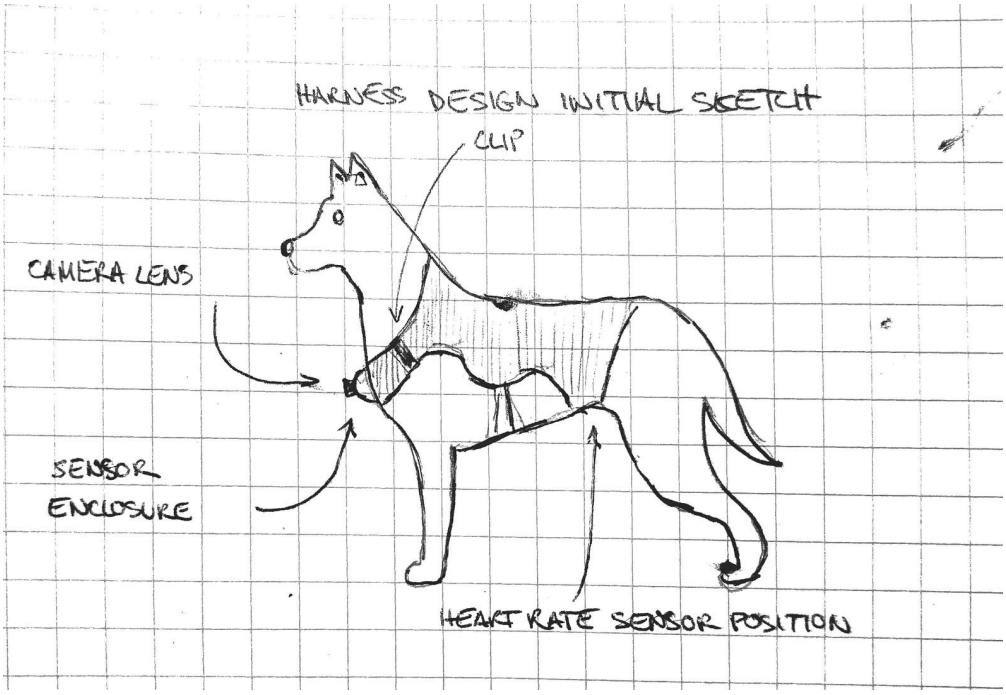

Figure 3 - Sketch of the harness design with all sensors and their positions

- PHD-1: The location of the heart rate monitor shall be positioned to detect an elevated heart rate within the tolerances outlined in PUM-3.
- PHD-2: The harness shall sufficiently cover all electrical components and wires with the exception of the heart rate monitoring pad such that they are inaccessible without the use of additional tools to cut the fabric.

- PHD-3: The harness shall safely support all of the electronics while remaining under a weight of 1200 grams.

2.2.2 Sensor Enclosure

Along with the ESP32 microcontroller, the most fragile components involved in the physical design are the sensors. These devices must avoid any interference from the pet to function correctly. A small electrical box like enclosure will be fastened near the chest of the pet. Inside of this enclosure will be the ESP32 microcontroller, the accelerometer, the GPS tracker as well as the camera that will be used to capture the image of the potential danger. This position does not restrict the pet's movement anymore than a normal harness and keeps the electronics out of harm's way. To ensure there is no electrical interference and to keep the weight of the device low, the enclosure will be made of a lightweight but durable plastic material. Each device will also be secured tightly within the enclosure to prevent the sensors from shifting during use and damaging each other or the microcontroller.

- PHD-4: The electronics inside the enclosure should not move from their initial positions further than 1 cm after 2 hours of use.

2.3 Processing Unit Module

This module takes care of data processing and routing on the harness. Since many signals are being processed and transmitted, a chip such as the ESP32, which includes Bluetooth capability [11], would be needed for the harness processing unit. Any processing and interpretation of data will be accomplished through the integrated software on this microcontroller, while the mobile device application will be mainly utilized for user interaction.

2.3.1 ESP32 Microcontroller

The processing unit on the harness will have data coming from the camera, GPS tracking, accelerometer, and heart rate monitor. These would be read and processed by the microcontroller on the ESP32 chip through its software component, which will be coded through the Arduino IDE. Depending on the combination of signals received, different signals will be sent to the smartphone via Bluetooth. Here, it needs to be taken into consideration that the GPS tracking is always on and sending information and the heart rate monitor will only take readings when the pet is standing still for accurate measurements. The latter observation means that, when the accelerometer sees near zero motion, the heart rate monitor takes a reading and, if it is elevated, the accelerometer identifies motion for the next 5 to 10 seconds, which leads to the identification of the type of danger. The types of notifications sent according to the sensor readings are shown in Table 1.

Table 1 - Notification types based on a combination of different signals

Accelerometer (before heart rate reading)	Heart Rate	Accelerometer (after heart rate reading)	Camera - is a picture taken?	Notification type
Still or small movements	Normal	Still or small movements	No	No notification sent
Still or small movements	Normal	A lot of movement	No	No notification sent - the pet might be running, in which case its heart rate will be elevated after a while and will trigger one of the other notifications
Still or small movements	Elevated	A lot of movement	Yes	Your pet has an elevated heart rate and is moving
Still or small movements	Elevated	Still or small movements	Yes	Your pet has an elevated heart rate and is not moving

- PUM-1: The ESP32 shall record the current heart rate when the detected motion is approximately zero.
- PUM-2: The ESP32 integrated software shall process a data packet composed of data collected from the sensors which will produce accurate results to be viewed on the application with a 90% success rate.

2.3.2 Heart Rate Sensor

In order for the ESP32 microcontroller to process the pet's vital conditions, the harness incorporates a variety of sensors. Several other methods of monitoring the pet's current condition were considered before deciding on the heart rate sensor and accelerometer combination. Along with the heart rate monitor, some of the other original ideas for this included measuring the pet's rate of respiration or performing a digital signal processing analysis on the pitch of a bark or other sound to determine if the pet was in pain. Each of these techniques presented its own challenges. Respiratory rate is a difficult parameter to measure with currently available sensors while maintaining a low cost. Using DSP analytical techniques to distinguish between a yelp that indicates discomfort and a normal sound would also be challenging without providing some kind of sample reference sound. Furthermore, a microphone

would also detect high frequency noise from other sources in the environment and the software would have to use complex DSP interpretation mechanisms to differentiate these sounds.

Similarly to these two approaches, the heart rate monitor solution provides several concerns. Notably, when a pet becomes excited by anything, its heart rate will rise whether the subject of its excitement is a threat or not. While it is nearly impossible to distinguish exactly why a pet's heart rate might rise from currently available technology, this problem is solved by using an additional camera module and software as discussed in Table 1. Another common issue in regards to heart rate monitoring is accurate detection through pets with thick coats of fur. This is mitigated through two solutions: using an optical heart rate sensor rather than motion or sound based sensor and by positioning the device as close to the heart as possible on the harness [12]. While many optical heart rate sensors are still being considered, the SEN-11574 seems to fulfill the requirements necessary and has been used to measure the heart rates of animals in other applications [12]. The device is at a relatively low cost when compared to similar models and is optimized for use with Arduino devices. At only five eighths of an inch in diameter, the device is small enough to safely and effectively secure onto a harness while only drawing a maximum of 4 mA of current [13]. While the most effective positioning for an accurate reading is not final, the sensor will be located on the harness near the pet's stomach and hind legs to obtain an accurate pulse reading in an area where as little fur blocks the optical detector. This area of the body is commonly used by veterinarians to check an animal's pulse [14].

- PUM-3: The heart rate monitor shall identify a heart rate as "elevated" when the pet's heart rate exceeds the value determined to be elevated through the application setup calibration with a tolerance of ±10% of the pet's actual elevated value.

2.3.3 Accelerometer

Another issue that arises with using a heart rate monitor is that heart rates are most accurately collected when an animal is standing still. An accelerometer is used to resolve this problem as well as provide additional information about the current state of the pet. If the accelerometer detects an acceleration close to zero meters per second, a heart rate detection will occur and that value will be stored for later use.

After taking a value for the heart rate, the accelerometer can be used to detect the current motion of the pet. For example, if a pet has an elevated heart rate while moving, it may be in danger of another animal or a moving vehicle. If the pet has an elevated heart rate and is not moving, the pet may have been injured. Following the detection of an elevated heart rate, the accelerometer will record data at an amount of time about five to ten seconds after an elevated heart rate is detected. This data, along with the detected heart rate, will be analyzed in the processing unit, where a notification type will be generated and sent back to the owner in the form of a mobile device notification. The process described above will be accomplished using a combination of integrated software on the ESP32 and software designed for the mobile application.

For this application, the accelerometer is required to detect running speeds and act as a pedometer of sorts. Because this is a relatively low speed application, there are a variety of accelerometer chips which are capable of being easily programmed with the Arduino IDE. An accelerometer which detects speeds between two g and four g should be sufficient [15]. The ADXL363 appears to be an accurate fit for this specification, measuring speeds from two g to eight g with a low current output of about 1.8 µA in normal operation [16].

- PUM-4: The accelerometer shall capture the acceleration of the pet over a 5 to 10 second interval and send the maximum acceleration during this time to the owner via notification.

2.3.4 GPS Tracking Device

Global positioning systems integrate the use of 24 satellites to compute a strong approximation of the latitudinal and longitudinal coordinates of a GPS receiver device anywhere in the world regardless of weather conditions. This technology uses low power radio signals to achieve this communication and represents the ideal way to determine the exact location of a lost pet. GPS receivers collect three important pieces of information: pseudorandom code which corresponds to a device identification number, ephemeris data which give information about the satellite the receiver is communicating with and almanac data which supplies the data necessary to correspond the satellite location with the device location [17]. The coordinates received from the GPS receiver will directly be sent back via the communication module to the owner's mobile device. Through the application the user will be able to view the pet's location while they wear the harness at any time. Additionally, the user can set a delimitation radius to receive a notification if the pet's coordinates are outside of the set radius. Typical devices used for Arduino based GPS applications include the NEO-6M which will be considered for this project.

- PUM-5: The GPS receiver shall record and transmit the coordinates of the pet through the Communication Module with a tolerance of ±0.005 degrees in both the latitudinal and longitudinal planes.

2.3.5 Camera

A small camera device will be positioned on the harness to be able to capture images when an elevated heart rate is detected from the heart rate sensor. Once the image is captured, it is sent via the communication module to the owner's mobile device through a notification. By viewing the contents of the image, the owner will be able to identify the variety of danger the pet is experiencing, or if it is not a danger at all. Much like the other sensors used in this design, the camera will require interfacing with the ESP32 module. Some parameters that will be considered in the selection of the camera include the quality of image, the amount of data that will be transferred as well as the camera's bulkiness and ease of positioning on the harness.

- PUM-6: The camera device shall have a resolution no less than 0.3 Megapixels.

2.4 Communication Module

In order for the owner to receive the information gathered on their pet's harness, Bluetooth communication will be used. The harness will have its own Bluetooth component that will send information collected from the sensors to the user's cellphone. The mobile device will be connected through Bluetooth every time the owner puts the harness on the pet.

2.4.1 Bluetooth Transmitter

The Bluetooth transmitter will be attached to the harness, and its purpose is to send all the information gathered from the harness' sensors to the user's cellphone. This information, however, will first be processed by the processing unit, which will determine what kind of signal must be sent via Bluetooth to the owner. Therefore, the Bluetooth will transmit the signal received from the processing unit to the software application on the cellphone, and the software will send the notification accordingly. The Bluetooth transmitter will also send the picture taken from the camera to the phone whenever one is taken.

The range of this Bluetooth connection needs to be large, which means a Class 1 Bluetooth is necessary [18], with around 100 meters of range. If the pet gets away from this range, the user will be notified and, because of the GPS tracking, the pet's last recorded position will be shown on the app such that the owner can check on the pet. With a Class 1 Bluetooth, the power consumption can be very high. Therefore, Bluetooth Low Energy is being considered, which could decrease power consumption by sending signals every few seconds instead of constantly [19]. This might not be possible given the amount of data that will be sent, but, even if Classic Bluetooth is used instead, the battery will be able to supply the amount of power needed.

The biggest difference between the original project and this version when it comes to Bluetooth communication is the amount of signals being transmitted. It was decided to still use Bluetooth rather than Wi-Fi because the signal could extend to the backyard of a house, or, if the owner decides to go to a park for example, they can still track their pet. Also, a big difference is the ability to have multiple pets connected to the same network, in the case the owner has more than one pet. Each pet would have its own harness, and all would be connected to the same phone, which would enable the notifications to not be sent if it is detected both pets are playing together. This feature could also be beneficial if the pet encounters other pets from the neighbourhood, in which case a notification could be sent to the owner warning them that their pet has encountered another pet. In the latter case, no information about another owner's pet would be shared beyond the picture sent by the harness.

- COM-1: The Bluetooth transmitter shall have a range of 100 meters with a tolerance of ± 10 meters.
- COM-2: The Bluetooth transmitter shall establish a connection with the mobile device application with a failure rate of 5%.

2.4.2 Mobile Device Bluetooth Receiver

The mobile device carried by the user, which may be a smartphone or a tablet, will be connected to the harness via the device's internal bluetooth capabilities. A software application in each device will enable the user to have all the information the harness will provide, including real time location of the pet.

2.5 Software Module

When it comes to software, there are two main components on this project: the integrated software that goes into the processing unit, that will gather and route all the data from the sensors, and the software application for use on a mobile device, which will allow the user to receive all the information needed from the harness, such as the GPS location and the notifications. This module will focus on the latter.

The notifications are one out of the two the most important features of this application, since it is the mechanism through which the user will be warned of their pet's condition. Table 1 describes the type of notifications that will be sent depending on each situation. The notification type will be determined by the processing unit's integrated software and a signal will be sent to the mobile device via Bluetooth to be displayed as a notification on the application for the user to see. The second most important feature is the GPS live tracking. The user will be able to view the location of their pet at all times, since, if the pet is unsafe, they know where to go to mitigate the situation.

This application will have a user-friendly graphical user interface (GUI), which will prompt the user for a radius delimitation, a name for the harness, and calibration steps for the heart rate monitor at first use. The radius delimitation, called 'backyard radius', will be a delimitation such that, if the pet leaves it, a notification will be sent, and the harness name is useful for users who have multiple pets and need a way to recognize each harness. The calibration will be done so that the system can recognize the pet's normal and elevated heart rate. At first use of the application, the user will be prompted to put the harness on their pet, and, once done, click on an 'OK' button. After this, the user will be asked to make sure that their pet is calm and still, and, once done, press 'OK' again. Finally, the user will be prompted to make their pet excited or move around, such that their heart rate is elevated, and click 'OK' a final time.

Once the application is initialized, the user will be able to see three tabs: one with all the notifications that were sent, organized by newest, another with the pet's live location from the GPS feature, and another with all the pictures taken by the harness, also organized by newest. On the top right corner,

there will be a gear icon, symbolizing the settings of the application, in which the prompted options at the beginning, including the calibration, are available to be modified.

The features highlighted on the last paragraph show a substantial difference from the application made for the original project, which only sent alerts about creatures being detected. Our solution proposes to improve on that idea by adding additional features such as the GPS tracking and pictures, while improving on the alerts, which will be specific to the type of threat the pet might have encountered. As said before, the new solution focuses on the pet's condition rather than finding other creatures that could harm the pet.

- SWM-1: The graphical user interface on the application shall have a notification tab and a GPS tab.
- SWM-2: The application shall have an option to change the pet's weight, the harness name and the backyard radius.
- SWM-3: The application shall prompt the user for the pet's weight, the harness name and the backyard radius on first use.

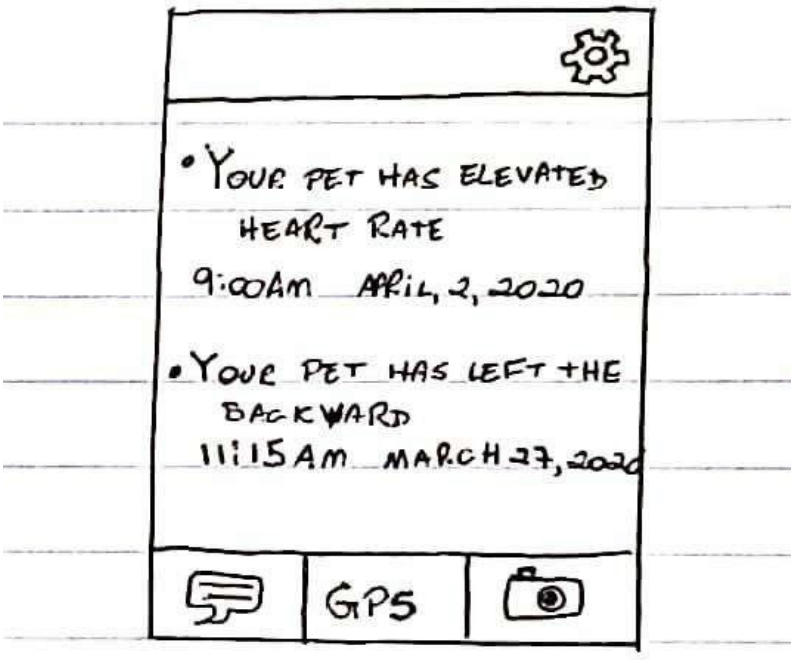

Figure 4 - Sketch of the software application; GUI and example notifications

2.6 Risk Analysis

Table 2 - Risk Analysis: green - low, yellow - moderate, red - high

	Low Risk	Mid Risk	High Risk
Low Severity	Physical Harness		
Mid Severity		Software Module, Processing Unit Module (Software)	
High Severity		Power Supply Module	Processing Unit Module (Sensors), Communication Module

Upon considering all modules of this project, the sensors and the bluetooth communication have the highest risk and severity, since, if those fail, the product would not function as planned in the high level requirements. For this reason, necessary precautions were taken to minimize the risk of these components failing, such as protective enclosures for the electronic components made of waterproof material to account for weather conditions. The power supply module has high severity if it fails, but not a lot of risk. As with any battery, it can overheat and cause explosions. However, the Lithium Polymer battery was chosen to minimize these risks. This is a widely used battery and, with the appropriate safety measures, such as a short protection circuit, this battery can be safely used. There are other safer chemistries available in the market, such as the Lithium Ion Phosphate battery, but the latter option is more expensive, has lower power density and lower voltage [20].

When it comes to the software module and the processing unit, both have medium risk and severity. That is because, when it comes to software, it is easier to debug and release an update to the user. If a bug were to happen in hardware, as with the sensors mentioned before, the whole product would need to be replaced. Lastly, the harness has low risk and severity, since it is just made out of durable and elastic fabric to allow the pet to move freely.

3 Safety and Ethics

The IEEE Code of Ethics was used as a reference to make design decisions for this project. In particular, the nature of the design required the group to heavily focus on policy numbers one, three, seven and nine. The first code referenced in the IEEE Code of Ethics states that this design should "hold paramount the safety, health and welfare of the public, to strive to comply with ethical design and sustainable practices, and promptly disclose any factors that might endanger the public or environment [21]." When working with any electrical or non-electrical device, the safety of the user is a primary concern, especially when the intention of the design is to promote the safety of individuals and their pets. Code number three directly references the honesty and realism of the experiment being conducted [21]. This was an important criteria for developing this design largely due to the importance of receiving accurate data from the sensors and interpreting it correctly. For example, a variety of sensors are used in this design along with the camera to provide the owner with honest measurements of the pet's condition by attempting to be as comprehensive as possible. As a revision of a previous year's project, it was also important to consider the effects of IEEE 7.8 Safety and Ethics #7 which covers accepting criticism of technical work, identifying and amend errors and crediting sources which contribute to the work performed [21]. With this design, Group 45 seeks not only to revise the design of Group 8 from the Fall 2019 semester but improve on the concepts it introduced to create technological advancements in the field of animal health and science. Furthermore, any contributions derived from the previous project's design architecture were carefully cited to ensure the intentions and originality of various components of this design are clear and all parties are credited for their respective work. The ninth code referenced by the IEEE Code of Ethics pertains to avoiding injuring or harming others "by false or malicious action [21]." Similarly to codes one and seven, this incentivises honesty and transparency in development to avoid injuring other parties both physically and in reputation. Due to safety being a primary concern in the development of this technology, this requirement was carefully followed .

All of the other codes were also carefully adhered to but many were followed naturally by the guidelines given for the project and by consequence of other design decisions made. For example, IEEE 7.8 Safety and Ethics Code #4 refers to rejecting bribery in all forms which is irrelevant to this design considering there is no manufacturing that will occur and there are no plans to commercialize the device. Another example of this can be seen in Code #2 which states that conflicts with other parties will be avoided and no conflicts of interest will occur. Because the only other parties involved with this design are the sources used for the development of its architecture there should be no other conflicts of interests that would occur outside of ensuring each source is cited properly. Following this standard is a result of closely following IEEE Codes #7 and #9.

Though for the most part, the pet threat detector is based on providing an added layer of security for pets, there still are some potential hazards that are present. One of the biggest concerns is how the electromagnetic radiation could harm the pets while the device is in use. High frequency electromagnetic radiation can have a harmful effect on biological tissue [22], which could potentially cause more harm than good for the pet wearing the device. This concern pertains to the safety of the public and must be considered in adherence to the first policy of the IEEE Code of Ethics [21]. Despite these concerns, the actual device specifications do not actually call for the use of signals that would be

different than that of a cell phone signal. Both humans and animals are frequently exposed to signals of similar magnitude by using electronic devices in close proximity. While the impact from this is non-zero it also has a comparatively insignificant impact on the lifetime of the pet and would provide greater benefits to its safety than detriments. If this product were to be commercialized, the product packaging would include a disclaimer about this impact and its effects on pets.

Another concern is largely related to the use of attaching a battery-using device to a pet in order to operate the device. Different environmental factors such as excessive heat or precipitation could cause the battery to catch on fire, explode, or leak its contents, which would be detrimental to the health of a pet. In accordance with this, different preventative measures mentioned previously on the power supply module and on the risk analysis will be taken such that the risks are as low as possible. One of these measures is to conceal the battery in an enclosure and have that inside the physical harness itself, covered by a high durability fabric such as polyester.

The ethics of using various collars and harnesses as a means of restraining animals has been called into question before, especially with dogs. Several varieties of collars cause physical pain, stress and anxiety for dogs when used to restrain them. This would be in violation of the first policy of the IEEE Code of Ethics [21]. For this reason, considerations were taken in the design process to avoid harming pets in use. The non-profit organization People for the Ethical Treatment of Animals (PETA) recommends the use of harnesses to alleviate tension in the neck and to avoid spinal cord injury while in use. For this reason, dogs should be relatively safe when using this device. PETA's harness and collar safety guidelines were also used as a baseline for determining how devices should be protected to provide the safest environment for the pet [23].

References

[1] “How Does A Pet Tracker Work?,” Barking Out Loud, a blog by Findster, 18-Feb-2019. [Online]. Available: https://blog.getfindster.com/how-does-a-pet-tracker-work/. [Accessed: 31-Mar-2020].

[2]“History and Utility of Passive Integrated Transponders (PIT) Tags for Fisheries Studies,” Idaho Fish and Game, 26-Sep-2018. [Online]. Available: https://idfg.idaho.gov/blog/2017/01/clone-history-and-utility-passive-integrated-transponders-pit-tags-fisheries-studies. [Accessed: 01-Apr-2020].

[3] L. Willoughby, “Inner Workings: SMART collars help track and conserve wildlife,” Proceedings of the National Academy of Sciences of the United States of America, 28-Mar-2017. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5380070/. [Accessed: 01-Apr-2020].

[4] PawTracker, “Top 18 GPS Pet Trackers Dog and Cat Friendly [Best of 2020 Reviewed],” PawTracker. [Online]. Available: https://www.thepawtracker.com/blogs/the-pet-tracker-blog-by-the-paw-tracker/84621315-top-13-gps-pet-trackers-dog-and-cat-cell-phones-best-of-2016-reviewed. [Accessed: 01-Apr-2020].

[5] M. Hedlund, Z. Tronco, and K. Schildgen, “Pet Pest Protector.”

[6] “U.S. pet ownership statistics,” American Veterinary Medical Association. [Online]. Available: https://www.avma.org/resources-tools/reports-statistics/us-pet-ownership-statistics. [Accessed: 01-Apr-2020].

[7] GensTattu Blog. 2020. *How To Choose A Lipo Battery For RC*. [online] Available at: <https://www.genstattu.com/blog/how-to-choose-a-lipo-battery-for-rc/> [Accessed 4 April 2020].

[8] LearningRC. 2020. *RC Lipo Battery Guide: Explanation, Safety, And Care • Learningrc*. [online] Available at: <http://learningrc.com/lipo-battery/> [Accessed 4 April 2020].

[9] Amazon.com. 2020. [online] Available at: <https://www.amazon.com/2200mAh-POVWAY-Compatible-Airplane-Helicopter/dp/B07TT4573Y/ref=sr_1_29?dchild=1&keywords=11.1%2Blipo%2Bbattery&qid=1585962801&sr=8-29&th=1> [Accessed 4 April 2020].

[10] “Nylon Vs. Polyester Fabric,” LEAFtv, 14-Mar-2019. [Online]. Available: https://www.leaf.tv/articles/nylon-vs-polyester-fabric/. [Accessed: 03-Apr-2020].

[11] IoTbyHVM - Bits & Bytes of IoT. 2020. *ESP32 BLE Tutorials | How To Use ESP32 With BLE*. [online] Available at: <https://iotbyhvm.ooo/esp32-ble-tutorials/> [Accessed 4 April 2020].

[12] D. Vu, H. Nguyen, and M. Horton, “Smart Harness.”

[13] World Famous Electronics LLC., “Pulse Sensor Easy to Use Heart Rate Sensor and Kit,” SEN-11574 datasheet. [Accessed: 02-Apr-2020]

[14] “Normal Heart Rate, Body Temperature, & Respiration For Dogs,” Dogtime, 12-Apr-2019. [Online]. Available: https://dogtime.com/dog-health/55273-normal-heart-rate-body-temperature-respiration-dogs. [Accessed: 03-Apr-2020].

[15] “Choosing the Most Suitable Accelerometer for Your Application-Part 2,” Choosing the Most Suitable Accelerometer for Your Application-Part 2 | Analog Devices. [Online]. Available: https://www.analog.com/en/analog-dialogue/articles/choosing-the-most-suitable-accelerometer-for-your-application-part-2.html. [Accessed: 03-Apr-2020].

[16] Analog Devices, “Micropower 3-Sensor Combination Including Acceleration and Temperature,” ADXL363 datasheet. [Accessed: 02-Apr-2020]

[17] “How to Interface GPS Module (NEO-6m) with Arduino,” Arduino Project Hub. [Online]. Available: https://create.arduino.cc/projecthub/ruchir1674/how-to-interface-gps-module-neo-6m-with-arduino-8f90ad. [Accessed: 03-Apr-2020].

[18] Science ABC. 2020. *What Is The Range Of Bluetooth And How Can It Be Extended?*. [online] Available at: <https://www.scienceabc.com/innovation/what-is-the-range-of-bluetooth-and-how-can-it-be-extended.html> [Accessed 4 April 2020].

[19] Novel Bits. 2020. *The Ultimate Bluetooth Low Energy (BLE) Guide - Novel Bits*. [online] Available at: <https://www.novelbits.io/basics-bluetooth-low-energy/> [Accessed 4 April 2020].

[20] Quora. 2020. [online] Available at: <https://www.quora.com/Can-and-should-cell-phone-batteries-be-made-from-LiFePO4> [Accessed 4 April 2020].

[21] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 29- Feb- 2016].

[22] “Are Pet Trackers Safe For Pets?,” Pet Tracker Reviews, 05-Nov-2018. [Online]. Available: https://www.pettrackerreviews.com/are-pet-trackers-safe-for-pets/. [Accessed: 04-Apr-2020].

[23] “Hey, Stop Choking That Dog!,” PETA, 14-Oct-2013. [Online]. Available: https://www.peta.org/blog/hey-stop-choking-dog/. [Accessed: 04-Apr-2020].