ECE 445 Project Proposal

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Pet Guardian

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Introduction (Objective)

There are many scenarios in which pet owners (especially owners of larger pets/dogs) let their pets outside for long periods of time, or even have their pet reside outside, if the conditions are suitable. However, knowing whether these conditions are suitable or not can be tricky for the owner to identify, and long enough exposure of that pet in the wrong conditions could leave the pet in a life-threatening situation [1]. In order to ensure that an individual's pet is never accidently left outside in the wrong conditions, we are creating a *Pet Guardian* harness that can detect if a pet (testing on a dog) is being adversely affected by its surrounding environmental condition/temperature, and send that information to the owner via a mobile application. Our outfitted harness would be able to obtain information about the surrounding environment temperature, the pet's respiratory activities, and the pet's heart rate, all of which are factors that can be used to tell whether a pet is at risk of a heatstroke, hypothermia, or any other other life-threatening condition.

Background

Although encounters with other creatures do pose a threat to pets, environmental conditions also pose as one of the biggest threats [2]. In certain areas and neighborhoods, environmental factors and changes can be an even bigger threat than encounters with other animals, especially in fenced or gated communities. The biggest difference between our project (*Pet Guardian*) and the original project (*Pet Pest Protector*) will be the sensing of environmental factors on the dog's well-being, rather than other animals. As stated before, for certain communities and other groups of people (based on location, living conditions, etc.), environmental factors could prove as a greater threat to dogs than other wild animals. "There is no notion of *the best solution*, because *best* is relative depending on the community and group of people that are using the product" - Professor Jing Jiang. In other words, different solutions can be bad or good based on the consumers buying them. For example, because the *Pet Guardian* harness will detect environmental changes that pose as a threat, this product will appeal to a more niche market/community in which pets are often left outside for longer periods of time (e.g. Large Dog Owners who have their dogs reside outside because of size constraints/regulations/preferences). While the *Pet Pest Protector* excels in locations with consistently-moderate temperatures safe for animals (like in North California), the *Pet Guardian* excels in locations which experience varying weather conditions harmful for pets (rain, snow, extreme heat & cold) that can prove more hazardous than wild animals.

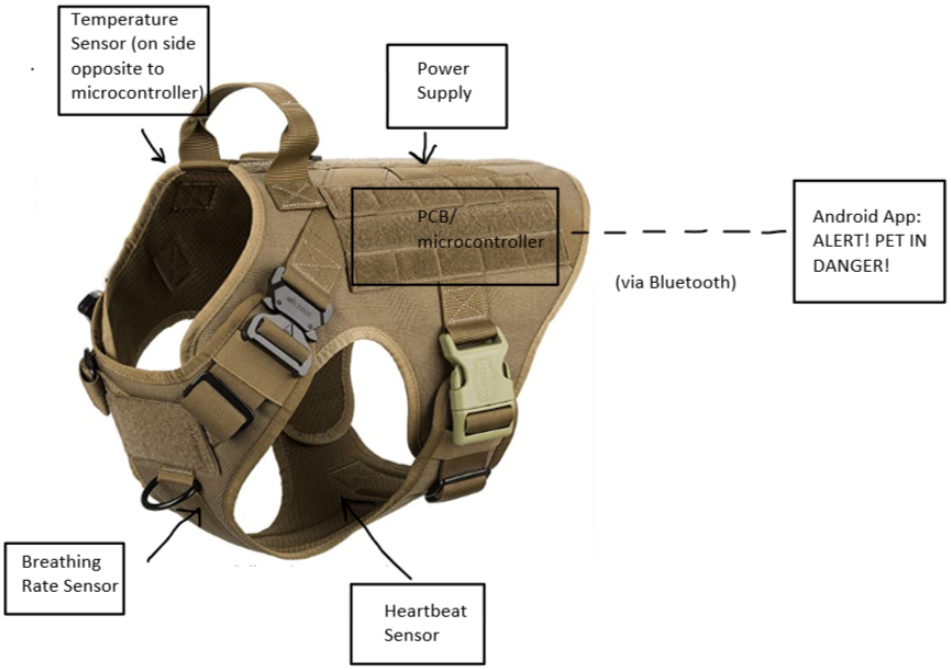
High-Level Requirements

1. All electrical components must be operable within temperature testing ranges (about 15-100° F), and must be operable for 6 hours (assuming fully charged).

2. Our design must fit on a size “Large” harness for dogs (50-80 lbs), and weigh less than 5 pounds [weight limit to ensure the dog is not weighed down too much].

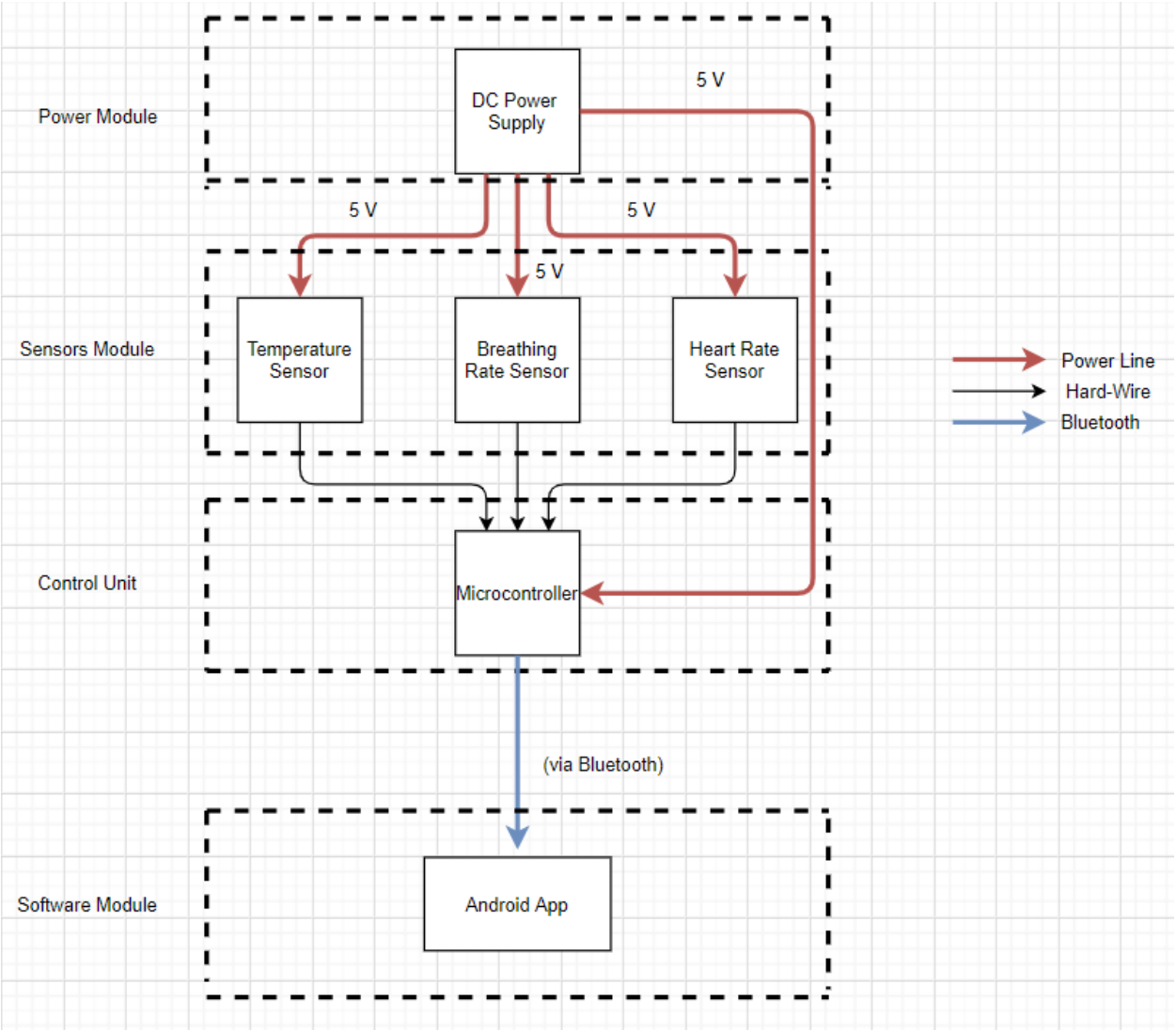
3. Microcontroller must be able to send one of three different messages to the Android App within less than 30 seconds of detection of unsafe conditions for the dog, with a maximum range of 45 meters.

Physical Design



The physical design above is a high level overview of our *Pet Guardian* design. It includes the sensors, power supply, and microcontroller, as well as the software interface. For the harness used for the physical design, Didrick already has two large Rabbitgoo Dog harnesses that can be used as the base harness for the *Pet Guardian.* Making use of one of these harnesses would be ideal since we would have to spend less of our budget. But, in the case that the harness does not have enough area to fit the sensors, battery, and microcontroller of our choosing, we can use a tactical dog harness instead, which covers a much larger area that can be used for these components.

Block Diagram



The modular design of our block diagram ensures that all components that will be used will be able to fit on a size “Large” dog harness. We made sure to include only the components that were crucial to the monitoring of the dog’s well-being, as any miscellaneous component that does not further our monitoring needs would only act as a hindrance and add bulkiness to the overall product. The power supply provides power to all sensors and the microcontroller, while the microcontroller takes the data received from the sensors as input and outputs a message via bluetooth to the user android app. The data transmission protocol via Bluetooth will depend on what microprocessor we ultimately decide on using, for example, if we were to use the Atmega we would need to utilize the UART protocol for data transmission; however other microprocessors, like the Raspberry Pi 4, have a built-in Bluetooth receiver/transmitter module.

Functional Overview & Block-Level Requirements

Sensors Module/Subsystem

This subsystem is responsible for collecting all the vital information needed in order to analyze the level of risk the pet is experiencing. This includes ambient temperature, heart beat rate, and breathe rate. Since the information we collect will be in a range of conditions/temperatures, we have to ensure that all sensors within this module can operate within these conditions/temperatures so that no vital information is missed or no circuit failure happens. This will guarantee overall success at a high level. All this vital information will be passed to the processor module, which will analyze this information and decide the risk intensity level. This module (sensors) also communicates with the power module, as it will be receiving power via hardwire.

Temperature Sensor

Description: A temperature sensor can be used to detect if environmental temperature conditions are too extreme/outside the bounds of safe pet conditions (for dogs its 32° F - 85° F; dogs can experience hypothermia/frostbite in temperatures lower than 32° F and heatstroke in temperatures higher than 85° F). We need to be sure that this temperature sensor can operate in the temperature ranges that we will be exposing the electronics to. This sensor will be great for detecting unsafe weather conditions that are not reflected through the dog's heart or breathing rate (e.g. dog getting frost bite on foot but breathing does not change much). However, since temperature is not the only factor in determining the pet's health, we will need more data from other sensors.

Requirements:

- Must be able to detect temperature ranges well beyond 32 - 85° F (safe dog temperature ranges)
- Must be able to detect temperature changes accurate to within ±1° F

Respiratory/Breathing Sensor

Description: The goal of this sensor is to obtain the breathing rate of the dog. A piezoelectric sensor measures changes in mechanical stress, like pressure, and converts it into an electrical charge. We can make use of this to reliably monitor the respiratory activities of the pet, which changes based on prolonged exposure to unsafe weather conditions. Obtaining a functional sensor which monitors respiratory activity can prove challenging because breathing sensors are relatively new and could not be found on the market a few years back. Current respiratory sensors today go for around $300 [3]. We will most likely make our own circuit for much cheaper by making use of a piezoelectric transducer. This will help turn the movement of the dog's chest into a voltage signal. We will most likely also have to create a filter for ensuring the movement is due to breathing, and not due to ambient movement (tail wagging or dog walking).

Requirements:

- Must be operable within ±15° F of safedog temperature ranges (17-100° F)
- Must successfully monitor breathing rate of dog accurate to within ± 5 breaths per minute (normal is around 15-25 breaths per minute, while abnormal is around 35-40 breaths per minute)

Heartbeat Sensor

Description: This sensor will be used for detecting the heart rate, which is the most notable change in a dog when at risk of experiencing heat stroke or hypothermia. The easiest circuit to fabricate would be an electrocardiogram (ECG) circuit, which measures bio-potential generated by electrical signals which control expansion/contraction of the heart chamber. However, safety issues arise during testing such as accidental current being passed through the pet through skin-electrode contact points. An alternative due to testing hazards can be a photoplethysmogram (PPG) circuit which achieves similar information as the ECG, but instead uses changes in light to sense the rate of blood flow controlled by the pumping heart. This would need to be attached to the pet's ear, which could prove uncomfortable for the pet, so each design choice has its tradeoffs. 60-100 beats per minute is the average for large adult dogs.

Requirements:

- Must be operable within ±15° F of safedog temperature ranges (17-100° F)
- Must successfully monitor heart rate of dog within an accuracy of ± 10 beats per minute

Processor Module/Subsystem (Control Unit):

This module is essentially the brains in deciding the conditions and thresholds for what it means to be in either 'Critical Danger!', 'High Risk', or 'Moderate Risk'. The information that will be analyzed will be collected and passed in through the sensors module. This module also communicates with the software module via bluetooth, as a message will be sent to the software module if unsafe conditions are detected. We need to make sure the message is rapidly sent so that we satisfy our third high level requirement, and to ensure the safety of the pet. This module will also be receiving power via hardwire from our power module.

Microcontroller

Description: We will be making use of a microcontroller in order to analyze the data received from the sensors. The inputs to the microcontroller will be the output of the sensors, and the output of the microcontroller will be an alert message. Rather than having just one 'alert' message, we plan on having three different alert messages (ranked High, Medium, and Low) so

that the owner can be aware of the intensity of the situation their pet is in. For example, the ‘High Risk’ would be sent if the safe temperature conditions are well out of bounds, and a ‘Medium Risk’ would be sent if the temperature is within the bounds, but the heart rate is starting to increase more than usual.

Requirements:

- Must convert sensor voltage input into data which can be used to analyze risk intensity level
- Must be able to send one of three messages (three different risk levels) to the android app if unsafe conditions detected (temperature, heart rate, or breathing rate abnormal), and must not alert the app otherwise

Power Module/Subsystem

This module is responsible for providing the necessary power to all the other modules (sensors and processor module) except the software module. All our components, including the sensors and microcontroller, will most likely be running on 3-5 Volts. We need to ensure these components obtain the power they need for at least a 6 hour time period, which will fulfil our high-level requirement. We also want this subsystem to be as modular and convenient as possible, either through a rechargeable or easily replaceable power supply.

Power Supply

Description: The power supply will be used for making sure all components on the dog harness have power, including the sensors and microcontroller we will be using for analyzing the input data so that we can send a signal to the owner’s mobile app if need be. As of right now, this power supply needs to provide constant power to the microcontroller and sensors for a prolonged period of time. Ideally, we would want the power supply to provide power for at least 12 hours, to account for dogs that reside outside for long periods of time. However, a more realistic goal is 6 hours. To achieve this, a power bank might be ideal, since we are only powering sensors and a microcontroller and nothing that requires a great deal of power consumption.

Requirements:

- The power supply (battery/power bank) must provide power to the components and maintain successful operating conditions for at least 6 hours.
- Power supply (battery/power bank) must be rechargeable (or easily replaceable), as well as detachable to the rest of the system/product.

Software Module/Subsystem

This module will only be communicating with the processor module. In fact, the processor module only sends information and the software module only receives information via bluetooth. However, the software module should only receive any alert from the processor module if the dog is in an unsafe condition, and not otherwise. We do not want to constantly spam the user app with the condition the dog is in, rather only alert the user app when certain thresholds are passed (e.g. too fast heart rate or too high temperature).

Android App/Bluetooth

Description: This subsystem will be used for allowing the *Pet Guardian* harness to send a message to the pet owner about the condition of his/her pet. Once the microcontroller detects the risk intensity, we want one of three different messages (corresponding to the one of three different levels of risk intensity) to be sent to the Android App wirelessly through bluetooth, since WiFi range would be limited dependent on the availability of a nearby WiFi source. The transfer of data will depend on our choice of microprocessor (i.e UART, Universal Asynchronous Receiver/Transmitter, protocol for data transmission if Atmega is ultimately selected)

Requirements:

- The device must be able to successfully connect to the Android App and transfer data between phone and microcontroller via bluetooth over an open air distance of 45 meters.

- The transfer of data must be done in a timely manner (less than 30 seconds) to ensure the user can act accordingly once an alert is received.

Risk Analysis

The module that poses the greatest risk to the completion of this project is the sensor module, in particular the respiratory sensor and the heartbeat sensor. The completion of these sensors is crucial, as these sensors will be providing the main data collected for analysis in order to decide whether a dog is in a healthy condition or not. If our sensors are faulty or inaccurate, this could completely throw off the signals being sent to the user's phone app, or even worse, not send a signal to the android app when a dog is detected in a critical condition. The challenging part for the breathing sensor is making a much cheaper alternative to the existing $300 respiration sensor in the market today, while still achieving similar accuracy. The hardest part in making this sensor will be making sure that we detect only changes in pressure due to breathing, and not due to other movement. A filter circuit will most likely need to be constructed in order to attend to this issue.

As for the heartbeat sensor, if we use an ECG circuit we have to ensure that we meet all safety standards and think of ways to safely test our ECG circuit such that we eliminate the risk of reverse current being passed through someone via the skin-electrode contact points. The alternative is to use a PPG circuit/sensor as this eliminates the risk of electrocution through the electrode contacts, while still obtaining average measurements. However, they both have trade off as an ECG can be more accurate, consume less power, and can obtain a reading in much less time [4].

Another interface that poses a great risk for similar reasons is the communication between the control unit and the software subsystem (or more accurately the microcontroller and the android app). The proper implementation of the communication between the microcontroller and android app is also crucial because, as discussed before, the only reason obtaining data about the heart rate, breathing rate, and temperature is useful is to be able to relay that information to the owner of the dog/android app. Detecting if a dog is in an unsafe condition would be pointless unless we can convey that information to someone that can help the dog (e.g. its owner with the android app). Similar to the above scenario, a faulty communication between the microcontroller and android app can cause the product to send false messages when the dog is not in danger, or even cause the product to send no alert when the dog is in a very dangerous environment/situation.

Ethics and Safety

Addressing ethical and safety issues is extremely important to us, especially considering that our final product is meant to be worn by a living household pet (in our case for testing purposes, a large adult dog), rather than an inanimate object. Therefore, because the health of a living animal can be at risk, I believe it is necessary to address liability issues that may inevitably occur.

To start, our product does NOT serve as a replacement to existing professional practices used to evaluate general pet health/well-being. As such, the owner of the pet using this product should still follow proper dog care techniques, such as twice-yearly veterinarian check-ups [5]. This product is initially intended for “Large” adult dogs (American Labrador Retriever will be breed used to set threshold limits), and though it can be used on other animals/dogs, *Pet Guardian’s* primary use will be on Large American Labs (50-80 lbs in weight); use on other animals and dog breeds might not guarantee same behavior/accuracy. It should also be noted that proper use of this product will require the awareness of the owner (owner must be aware and ready to act as soon as there is an alert message that his/her dog is in danger). To ensure safety of the dog used for testing, we have to be sure to test our product design in a safe environment and stable conditions when tested on the dog. Although we may test our components/circuit separately in other conditions, we must ensure safe conditions when testing with the dog. To prevent any discomfort for the dog, we will make sure to not alter the fitting or design of the harness. By doing this, we can ensure the dog’s safety (does not choke on harness or incur rashes) and also ensure safety of everyone during testing, as testing with an aggravated dog poses a risk to the dog, people around the dog, as well as the state of the overall product.

Moving forward, other safety and ethics issues arise when creating our design. In regards to the IEEE Code of Ethics first point [6], it is crucial that we make sure the materials we use for this harness are non-toxic to plants, people, and especially animals. The fact that this product will be used on a living animal makes this safety and ethics issue of very relevant and of utmost importance to us. This should not be taken lightly by any means, as we can be held accountable to liability issues that occur due to poisoning of a person or animal due to toxic materials. We have to also be sure to take into account the possibility that a certain component or material can become toxic when exposed to certain conditions (either too hot, too cold, rain, etc.), and be aware of what conditions create toxic effects, if any. Environmental conditions that can bring out any toxic hazards within the product components must be avoided.

One potential safety hazard that should also be addressed is hazards regarding the power supply. If using a simple Li-ion battery, we face the possibility of explosion of the battery due to thermal runaway [7]. This again is of huge concern to us, because the battery will be on the harness, which is connected to the dog. Any explosion or failure in the battery will result in damage to the dog, which is completely unacceptable. In order to ensure this does not occur,

we need to utilize a protection circuit/mechanism. One way could be to use a thermistor, which changes its resistance based on temperature. Utilizing this can disconnect the battery from the entire circuit if high enough temperatures are detected. Another viable solution would be to make use of a power bank, which excels in drawing low current for long periods of time, perfect for our application. One benefit is that a power bank comes equipped with a protection circuit to limit current drawn.

References

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