Smart Vest For Blind Dogs

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1. Declaration

”The design elements of this project and report are entirely the original work of the authors and have not been submitted for credit in any other course”

- Rushabh Patel - Luisa Palechor

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2. Abstract

Wireless devices have a significant impact on animals' health. These devices have helped improve animal medical treatments and prevent diseases in farm and domestic animals. The market for domestic animal wearable devices is fastly growing, and products with new functionalities are like smart collars or harnesses are released frequently. Nowadays, wearable devices for dogs, i.e., PetPace, monitor location, position and environmental temperature. On the other hand, some researchers have also focused on building new sensors to improve the wearable approach. However, to the best of our knowledge, no studies focus on wireless devices to help blind domestic animals. This report presents a novel design for a wearable device. The design includes a health monitoring module and a prevent crashes module for dogs who have recently lost their vision. The first module measures temperature, heartbeat, and respiratory rate. The second module calculates position, measure GPS location and detects 30cm near obstacles by using ultrasonic sensors. The design includes a vibration feedback module to warn the dog there is an obstacle.

3. Background

Dogs have been humans' best friends for decades, and it makes us very sad when our furry friends start to age and gradually lose vision due to eye diseases. An example of one such disease, glaucoma is very common in certain dog breeds such as the cocker spaniels, poodles, and siberians. Unfortunately, 40% of the dogs affected by glaucoma will lose their eyesight in the affected eye within the first year [4].

There are some studies that have worked on wearable devices for dogs' health monitoring. Foster et al. [13] have developed a 6-pin comb-shaped array of electrodes to sensor hear rate assessment in guide dog puppies. Later, Brugarola et al. [15] used this sensor on five dogs to evaluate its performance and comparing with commercial ECG electrodes. Foster et al. [16] developed a device that measures heart rate variability. He was able to demonstrate the feasibility of his system when tested on dogs that were walking at a speed of 5-10km/h. However, to the best of our knowledge there are no researches focus on wearable devices for blind dogs.

4. Functional requirements

To provide a useful device for blind and deaf dogs, we have designed a wearable smart vest for dogs to advise them through vibrations feedback when an object is near. The system will also monitor the dog's health by measuring heartbeats, respiratory patterns, and temperature. The measured data will wirelessly send to the dog's owner and display it through a mobile app.

- The smart vest will include a tight strap to ensure the vest fits well. Moreover, it will be lightweight, and rechargeable.

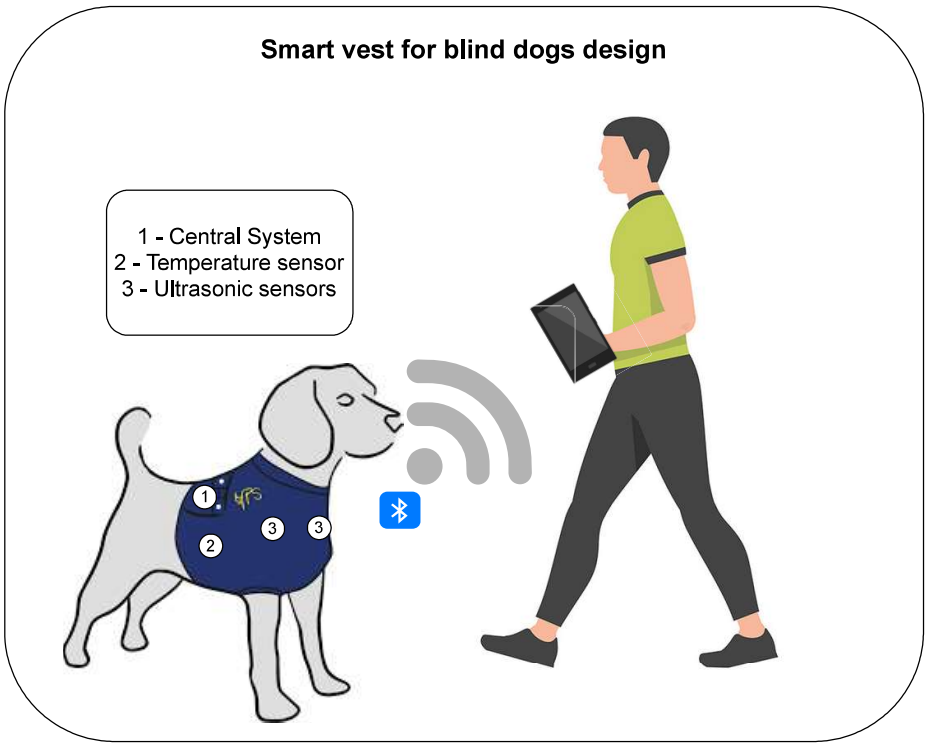

Fig. 1. Overview of the system and the location of each module

- There will be smart vest sizes for small, medium and large blind dogs.
- The system will detect objects that are 30 cm away from the dog and notify blind and deaf dogs.
- The system will detect when dog positions, e.i, laying down, are accidentally blocking any of the proximity sensors.
- Positions like standing, lying down, walk, climb stairs, down ramp will be detected by the system.
- The system will provide the dog's location, heartbeat pulse and temperature to the dog's owner cellphone via Bluetooth.
- Application Mobil for Android and IOS will display the health monitoring and the dog's location data to its owner.

There some challenges this design face due to wearable technology for dogs has been recently developed and to the best our knowledge, there are not low-cost heartbeat and oximeter sensors for dogs. Next is presented the challenges faced:

- Dog's fur could lead to a false positive heart and respiratory rate sensor. The smart vest will need to be very tight to avoid wrong measurements.

- Dogs' heartbeats are very different from humans. The heart rate range may vary from 60 to 100 bpm in humans and 120 to 160 in dogs. However, when humans exercise, heartbeats could rise up to 185 beats/min, while dogs' heartbeats could be more than 310 beats/min [12].
- Many of the commercial oximeter sensors are built for human health and might not be suitable to measure dog's respiratory rate. For example, dog's respiratory rates can be very high compared to its heart rate. This behaviour, which humans do not have, may inhibit the respiratory rate' correct measurement.

To minimize the errors in heart and respiratory frequency monitoring, the design will sensor this data only in the dog's resting state. Some studies have tested human-oriented sensors in dogs and they have exposed these sensors might be liable for the dog's stationary state but not for intensive activity [14, 17, 18]

5. Design and operation

- **Processor:** 48Mhz clock speed, 3x AMBA AHB-Lite interface, Nested Vectored Interrupt Controller, datasheet [2]
- **Memory:** 275KB of nonvolatile memory storing GPS data, Ultrasonic + Accelerometer + Gyroscope data, Temperature data, Heart rate data, and pressure sensor data, datasheet [2]
- **Transmission method:** Embedded Bluetooth 5.1 low energy
- **Power source:** 2500mAh @ 3.7V lithium-ion rechargeable battery, datasheet [6]
- **Battery lifespan:** $\geq$ 500 cycle life at 25°, datasheet [6]
- **Battery life**:

$$BatteryLife = BatteryCapacity/LoadCurrent$$

$$BatteryLife = 2500mAh/ \sim 147.051$$

$$BatteryLife = \sim 17Hours$$

- **GPS:** Update Rate: 1Hz - 10Hz, Channels: 72, Accuracy: 2.0m, 3.0V - 5.5V @ 50mA, datasheet [1]
- **Ultrasonic sensor:** $<$15% mearsuring angle, 2-450cm detection distance with 0.3m + 1% accuracy, 2.4-5.5V @ 2mA, datasheet [10]
- **Vibration motor:** 13000±3000 rpm, 2.3-3.6V @ 60mA, datasheet [3]
- **Temperature sensor:** -40 to 125 °for sensor temperature with Accuracy 0.02°, 3V, datasheet [8]

- **IMU (accelerometer + gyroscope):** 6 Degrees of Freedom (x,y,z,yaw,roll,pitch), acceleration range of ±2/±4/±8/±16 g, angular rate range of ±125/±245/±500/±1000/±2000 dps, 8K data buffer, 1.71-3.6V @ 0.9mA - 1.25 mA, datasheet [5]
- **Heart rate sensor:** Two 8-bit LED Current DACs, SpO2 Monitoring, Ultra-Low-Power Operation, 1.8V, datasheet [7]
- **Pressure sensor:** 0 - 10 kg, 3.3v, website [9]
- **Led:** 150-200mcd, 1.8-2.2V @ 20mA, datasheet [11]
- **Weight:** $\sim$ 91.8g
- **Operating Temperature:** -20°to +60°

The following diagram shows the overview of the parts inside the wearable device:

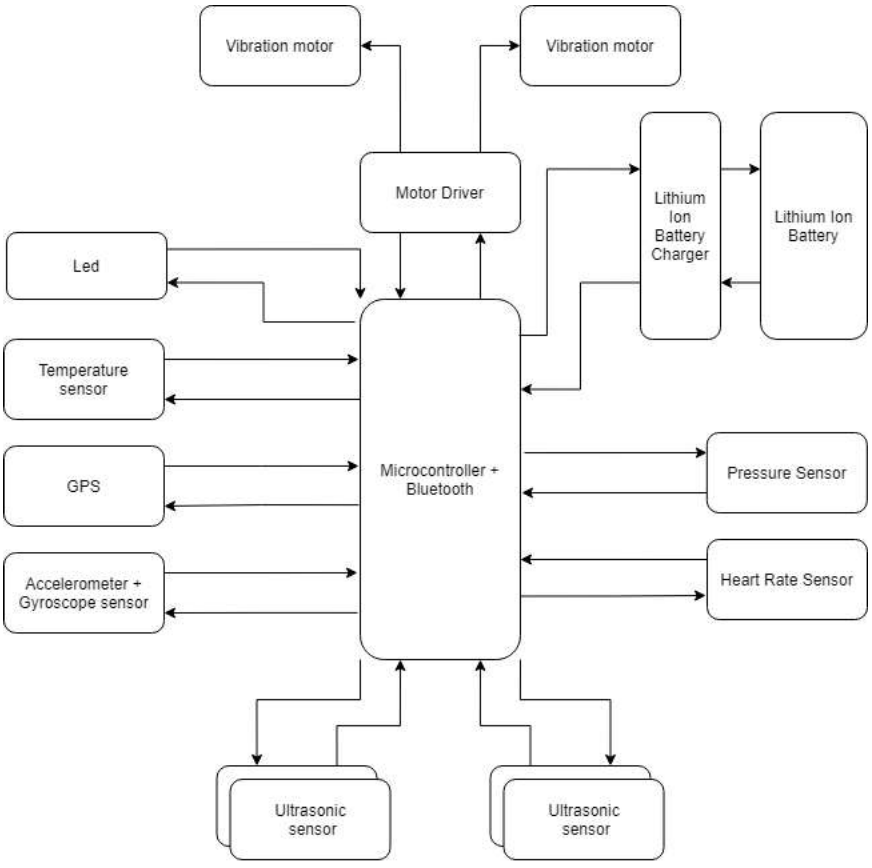

Fig. 2. Hardware Block Diagram

The following diagram shows the overview of the data flow of the wearable device:

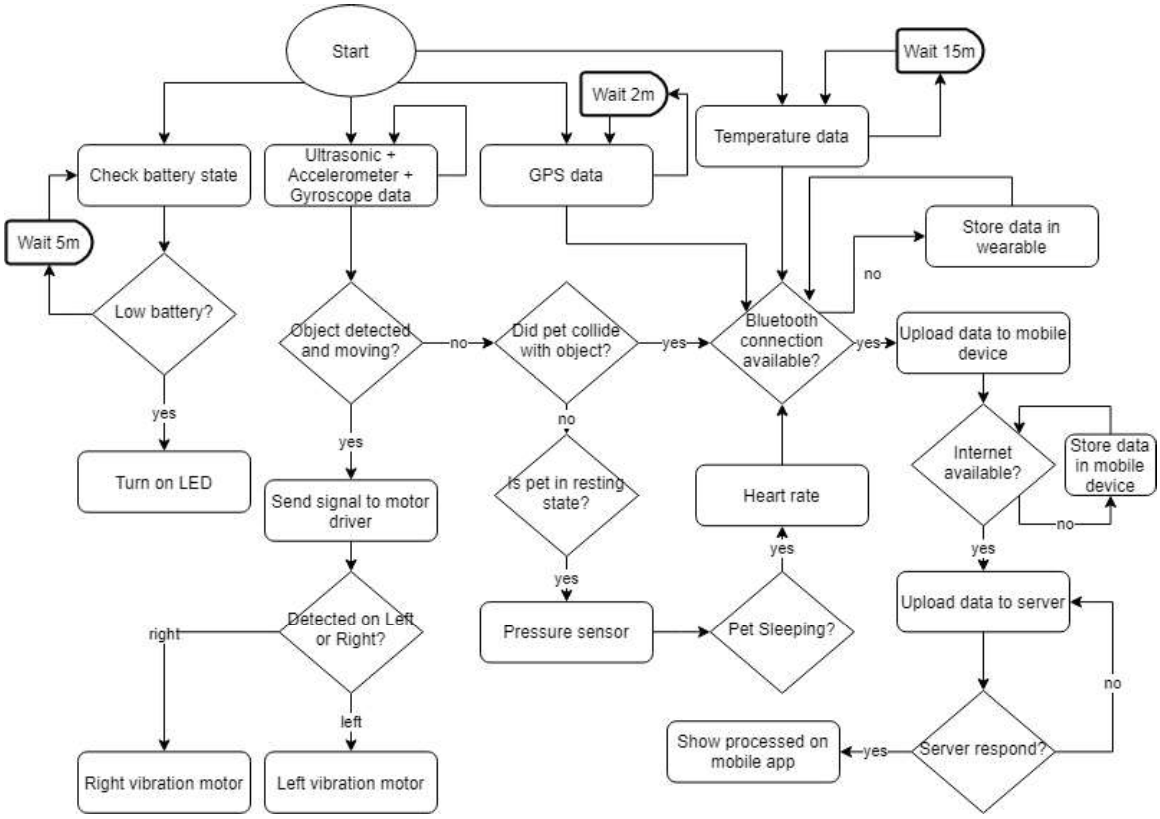

Fig. 3. Data-flow Diagram

6. Hardware and software requirements

Choosing technologies for blind dogs is difficult, there are many factors to consider, such as detecting uneven ground, dogs rolling on their backs, potential deafness, etc. When choosing these technologies, we have to sacrifice some functionality such as a high-end detection module to meet other functionality such as higher battery life and/or reduce overall cost. To make sure our device's functions remain competitive while meeting the specific needs of the target market, we have decided on using the following hardware and software technologies.

6.1 Hardware requirements

- Sensors

  There are a couple of sensors that can be used in a wearable device for it to simulate a blind guide such as camera, sonar, infrared, Li-DAR, etc. These sensors paired with accelerometers and gyroscopes generate surprisingly accurate warnings. For our use

case, we are utilizing the sonar type of sensor known as ultrasonic distance sensor to predict the distance between the dog and the object. We are pairing the distance sensor with an IMU which detects the acceleration and the angular position of the dog to accurately warn the dog in time whether it will collide with an object. To warn the dog, we were initially planning on audible feedback but decide to settle for haptic feedback as the dog could potentially have or develop hearing loss over its lifetime. Furthermore, we decided to add temperature, heart rate and pressure sensor to monitor the dog's health during the day and night. As a bonus, we also added a GPS module in case the dog went missing.

The ultrasonic sensor we chose was the HC-SR04. According to the datasheet [10], this sensor has an emitter and detector. The device calculates the distance to an object by emitting an ultrasonic wave and waiting for an echo wave. Using the elapsed time between the wave emitted and the detection of the bounded wave, we could calculate the distance by using the following formula:

$$D = v * t, v = 340 m/s \text{ [10]} \tag{1}$$

The operative frequency of this sensor is 40KHz. Although it is in the range of the dogs' audio frequency range, it may not be harmful.

The temperature sensor is a contactless sensor that measures the dogs' body temperature, which is between 32.2 and 40 degrees Celsius. We have chosen an infrared thermometer instead of electrodes because the fur and the subcutaneous fat may affect the measurement.

- Wireless

  We will be using Bluetooth 5.1 low energy as our wireless module, this will typically be paired with a cellular device. The Bluetooth 5.1 offers very high data transfer rates and a longer connectivity range than Bluetooth 5.0 or earlier low energy models, datasheet [2].

- Memory

  We have 275KB of nonvolatile memory including 128KB of in-system programmable flash memory on our processor, including 28KB of SRAM, of which 20KB is ultra-low leakage and 8KB of SRAM cache, datasheet [2]. We wanted to have a lot of memory to use to account for inefficient code and future expansions.

- Processor

  Our microcontroller uses the ARM Cortex M3 processor, which is very powerful and energy-efficient, which makes it a perfect choice for our wearable device. It can also process floating-point values.

- Power

  The power usage was higher than we had hoped due to always-on sensors and as a result, we decided to use a large 2500mAh lithium-ion battery. We then added a USB lithium-ion battery charging module so the users can recharge the batteries at convenient times.

- Cost

  The total comes to $111.64, see table 1 for a breakdown of the costs. The reason for the total being higher than normal is due to utilizing higher quality parts from known distributors and not factoring in a bulk purchase.

6.2 Software requirements

- Applications

  Since the device will generally be paired to cellphones, our application will a Mobile application hosted on Android and Apple app store which is connected to the cloud for data processing.

- Data Analysis

  Using data from ultrasonic sensors, accelerometer, and gyroscope, we will report the number of times a dog collided with its environment per day, per week and then compare with the numbers to the previous week. We can also report the daily steps via the built-in pedometer in our IMU. Using the GPS module we will allow the user to set a safe zone, which when crossed by the dog will raise a notification it will also allow the app to report the dog's previous location, and routes. With the temperature and the heartbeat sensor, the app will report max, mean, min and current temps and heartbeats, this data will be used by our app to give insights on the dog's health. The pressure sensor is used for sleep monitoring, which combined with the heartbeat sensor can report accurate sleep times per day and average sleep hours per week. For an overview of the data flow process, please refer to figure 3 to see the data flow of our system.

7. Part list and cost

The following table consists of a list of modules with their corresponding reference ID and cost:

Module	Device Reference	Price (USD)
GPS	Beitian BN-220	$21.11
Accelerometer + Gyroscope	LSM6DS3	$11.50
2x Vibration Motor	ROB-08449	$4.30
Led	COM-09590	$0.35
Battery	LIPO785060	$14.95
USB LiIon/LiPoly charger	MCP73833	$12.50
SparkFun Haptic Motor Driver	DRV2605L	$8.50
4x Ultrasonic sensor (2 each leg)	HC-SR04	$12.28
Oximeter and Heart Rate Sensor	MAX30112EWG+	$8.94
Temperature Sensor	MLX90614	$8.56
Pressure sensor	SF15-130	$7.80
Bluetooth + microcontroller	CC2640R2L	$0.85
Total		$111.64

Table 1. Parts list and Cost

8. Conclusions

The smart dog vest could be a good opportunity to continue taking care of our pets. This design of a wearable device with obstacle detection for blind dogs is a novel feature that may improve the quality of life of dogs. The vibration feedback could give the dog not only awareness of obstacles but also confidence.

There are great opportunities in the wearable device market for pets devices. However, the solutions may require work along with research and development areas because the dogs' behaviour is not only different from humans but also different between breeds. An interdisciplinary team will be required to meet the advanced requirements.

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[11] "YSL-R531R3D-D2 Model." [Online]. Available: https://www.sparkfun.com/datasheets/Components/LED/COM-09590-YSL-R531R3D-D2.pdf
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