RaDistance Safety Meter

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Abstract

Nearly 200 million people are affected by thyroid disorders worldwide. The thyroid gland is crucial for metabolic processes and hormone regulation, and serious symptoms can arise when the thyroid gland is malfunctioning. Treatments of thyroid disorders include medications and lifestyle changes. However, in more severe disorders such as cancer and hyperthyroidism, radioactive iodine (^{131}I) is utilized to destroy malignant tissue surrounding the thyroid, sometimes also including the thyroid. In these instances, radioiodine is taken into the body via liquid or capsule and concentrated in the thyroid cells, where it will spend four to six weeks decaying and destroying surrounding tissues. Because of its radioactive properties, radioiodine can also damage healthy tissues of those near the patient in treatment, warranting the need for a device that alerts the patient when he or she is within close proximity of another person. This device must alert the patient when a human is detected within a one-meter radius, as well as function a continuous 16 hours on a single charge. Through discussion with the client and brainstorming with the team, four design concepts were chosen for deliberation and comparison. The most successful design based on weighted criteria was composed of distance and thermal sensors embedded in a belt-like framework, powered by a lithium ion battery and controlled with a microcontroller. This design is based on simplicity and adaptation for the user. Future work must be done to fabricate the device and test for accuracy and reliability.

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Introduction

Background

The thyroid is one of the largest glands in the human endocrine system. Responsible for regulating metabolic processes, the gland sits at the base of the human neck. In coordination with the anterior pituitary gland and hypothalamus, the thyroid regulates metabolic processes, growth, behavior, and puberty. The hormones secreted by the thyroid, triiodothyronine (T3) and thyroxine (tetraiodothyronine or T4), contain three and four iodine atoms respectively (**Figure 1**). These hormones are produced and stored withing the gland for later excretion into the bloodstream. When the subject is under radioiodine treatment, the rich concentration of ^{131}I is utilized to replace a significant amount of the non-radioactive isotope.[1][2]

Triiodothyronine (T_3)   Thyroxine (T_4)
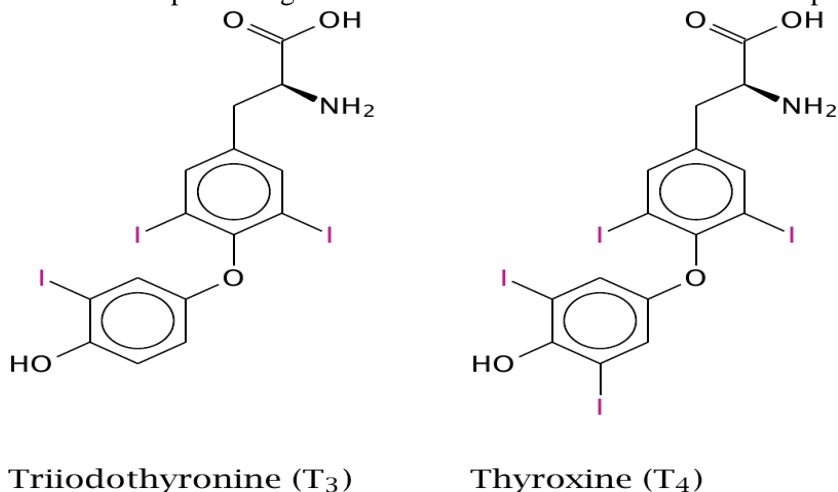
Figure 1: These are the Lewis Models for the thyroid hormones T3 and T4. Note the prevalence of the iodine atoms represented in violet. *http://watcut.uwaterloo.ca*

Upon creation of these radioactive molecules, they are stored within the thyroid gland. As the Iodine atoms decay (half life of 8.01 days[2]) it produces both beta (β) and gamma (Γ) radiation. The β radiation is responsible for destroying any tissue within ~2 mm of the molecule. This is the basis for why this treatment is so effective and accurate at isolating the thyroid area. No other part of the human anatomy contains this type of Iodine concentration. The next significant organ is the liver which functions to break down these hormones. The Γ radiation is the focus for this project however. [3]

Γ radiation is a very strong electromagnetic wave that, in the case of radioiodine, poses danger to individuals within one to two meters away from the patient. The main subjects that are at risk for second hand radiation exposure are family members and physicians of the patient but also children and pregnant women as well. Since this type of radiation is undetectable by the human senses, a device that would raise caution to the patient and any individual within this "danger zone" could effectively reduce the amount of secondhand exposure during the following weeks of a radioiodine administration.[4][5]

Problem Motivation

During the next one to two months after radioiodine treatment, patients will constantly be emitting radiation at levels of concern for surrounding individuals. Patients are asked to remain isolated from extended close contact (more than 2-3 h) during this time period; a difficult task for a timespan of up to six weeks. Clients

Dr. Hagi, assistant professor faculty of medicine at King Abdulaziz University, and Dr. Webster, professor emeritus of biomedical engineering at University of Wisconsin – Madison, have recognized a need for a device that will respond to a human proximity breach of 1 to 2 meters from the patient during this time.

The main concern of the device is being able to accurately and effectively detect a distance breach by a *human*, not just any object. Another is communicating these phenomena to not only the patient, with those around the user whom may not be aware of the danger. This will typically not be the case however as the individuals of most concern will be family members, friends, physicians, and possibly coworkers; all groups who will likely have previous awareness of the patient's treatment.

The overall goal is to effectively introduce a device that will help alert the user surrounding individuals of a proximity breach in order to reduce the chance of secondhand radiation exposure.

Competition

No current device exists to solve the specific problem of this design. However, there have been two past design projects with two different approaches to cheaply and effectively detect humans within one meter of the user. The first design consisted of a belt with a 15° front field of view and a 9 V battery controlled by an Arduino Uno. This design had a limited field of view and no rechargeable battery. The second design consisted of several Bluetooth beacons with a smartphone app connection. This approach required the user to own a smartphone, could only detect those with a Bluetooth beacon, and was very costly. Overall, competition is not a major concern in this project.

Design Requirements

The design requirements include constructing a device capable of detecting and distinguishing humans within a one-meter radius. The accuracy of the device should allow detection in a ±10 cm range. The device should also possess a 360° field of view such that reorienting of sensors is not necessary for detection. After detecting another human, the device will need to alert the user of a distance breach through audio, visual, or physical means. Finally, the device should be light (< 0.5 kg) and capable of lasting approximately 16 h on one single battery charge. Additional detailed requirements can be found in the product design specifications (**Appendix A**).

Design Alternatives

The first consideration of the design is the placement on the user. All alternative placement choices will employ the same number/model of sensors and electrical components since they are largely independent of each other. These pieces include a 9 V battery to power an Arduino pro mini microcontroller, vibrational motor, wires and LED. The placement will be divided into four categories: the head, neck, torso, and hip region. All designs except the torso will consist of a band-like model that will either be secured using a Velcro or buckles. The use of Velcro in many of the designs is ideal for adjustments based on the user's body size. As a result, elastic materials will not be necessary; stiffer fabrics can be used for increased durability and strength.

Design #1: Headband

The headband design (**Figure** 2) was one initial solution for detection humans and alerting them of a one-meter distance breach. The device will have sensors located around the band with a microcontroller and a 9 V battery attached. About four to six distance sensors coupled with thermal sensors will be used to provide a 360° detection angle. The electrical components will be sewn onto a durable polyester fabric and secured using Velcro. The length of the device will be approximately 50 cm long and should accommodate people with head sizes ranging from 40 to 50 cm in circumference. The total estimated weight of this device would be under 0.5 kg. After the sensors detected humans within the one-meter range, it will likely trigger a vibrating motor also located on the head band. The motor should not cause discomfort to the patient, so it will be calibrated to vibrate in a small, but noticeable manner.

The advantage of this design is that there are no limb obstructions that can disrupt or trigger the sensors. On the other hand, placing a 9 V battery and microcontroller on someone's head may cause discomfort after extended use. In addition, the accuracy and sensitivity of the sensors may be influenced by the user's height. Multiple calibrations may be necessary as a result. The estimated cost per unit is approximately $235.
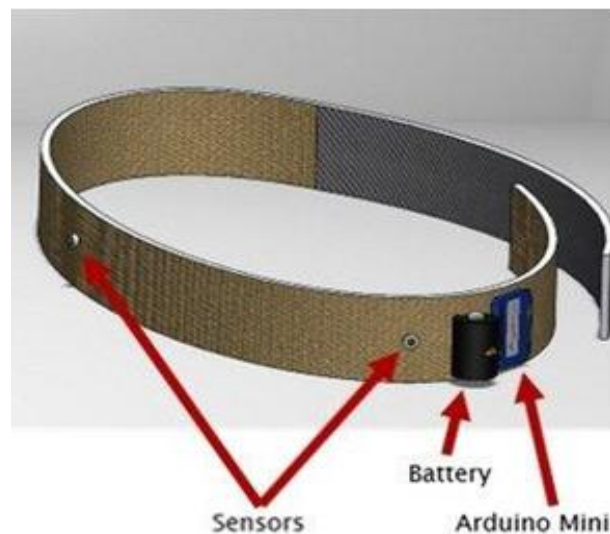
Figure 2: Headband design used with polyester fabric. Sensors are located around the band with one 9V battery and microcontroller.

Design #2: Collar

The second design (**Figure 3**) is titled the neck warmer. This alludes to a scarf-like design in which wool will be used as the primary fabrication material. Elastic bands will be sewn into the wool to allow stretching. The diameter of the device should be capable of extending from 8 cm to 13 cm. Similarly, the 9-volt battery, microcontroller and vibrational motor will also be located on the band itself. The advantages and disadvantages of this design is similar to the head band in that there are no limb obstruction to block the view of the sensor, but it is rather bulky for placement around the neck. The accuracy of the sensor will also be affected by the height and posture of the user. Furthermore, the heavier portion of the neck warmer will cause sagging, thus altering the device's lateral viewing angle and cause discomfort to the user. The estimated cost per unit is $235.
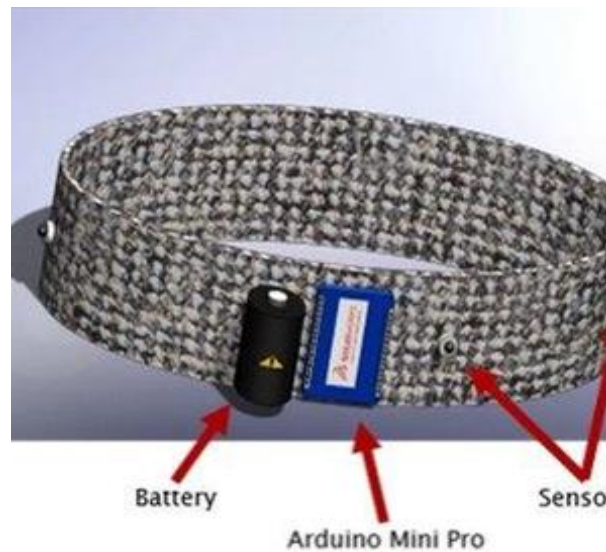
Figure 3: Collar design made wool. Similar in design to the head band, contains one battery and microcontroller with four surrounding sensors.

Design #3: Shoulder Pads

The third design (**Figure 4**) is titled the shoulder pads. It has a harness that is secured around the user with a Velcro in the back. There will be two shoulder pads with sensors located on the edges. There will be sensors, a battery, and a microcontroller located in the center of the harness. Circuits embedded within the harness will connect them. The placement of the sensors (On the shoulders, chest, and back) allows a 360° view from the user. As a result, there are no potential obstructions caused by the limbs. In addition, the shoulder pads can be secured snug on the user, allowing more comfort for extended use. The drawback of this design is that the harness will have limited size, thus it cannot accommodate all size users. Furthermore, movement of the arms may trigger the sensor to provide a false positive signal. The total cost per unit is estimated to be $295. It is the least cost effective design compared to the other three.
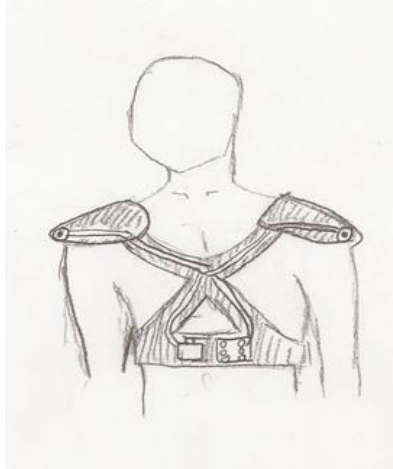
Figure 4: Shoulder pad design with microprocessor, 9v battery and four sensors; two are located on the shoulder pad, one in the front and one in the back.

Design 4: Belt

The last design is titled the belt because it is a webbed nylon fabric secured around the user's hip with a buckle in a manner very similar to a traditional belt. Further detail about the belt can be found in the *Final Design* section

Design Matrix

Table 1: Design matrix for the four design alternatives.

Criteria (Weight)	Headband	Collar	Shoulder Pads	Belt
Fabrication (20)	16 (4)	8 (2)	4 (1)	20 (5)
Cost (10)	8 (4)	8 (4)	4 (2)	6 (3)
Aesthetics (15)	9 (3)	9 (3)	9 (3)	12 (4)
Safety (10)	6 (3)	6 (3)	8 (4)	8 (4)
Accessibility (20)	12 (3)	16 (4)	12 (3)	20 (5)
Ergonomics (25)	15 (3)	10 (2)	25 (5)	25 (5)
Total (100)	66	57	62	91

Since the patient is expected to wear the device for 16 hours a day, the device must be comfortable and easy to use. Therefore, comfort and ergonomics was the highest weighted criteria with a score of 25 as shown in

Table 1. The belt design had the best score in this category, as the waist is relatively non-intrusive to the patient's daily operations and close to the hands. Ease of fabrication is crucial, as one semester is devoted to designing, fabrication, and testing of the device. Programming the microcontroller and wiring the various element connections, warranting a weighted score of 20, also stress the fabrication time. The headband and collar designs tied for highest scoring in fabrication, as they both required the least amount of material in a simple form factor. With a score of 20, accessibility is a very relevant criterion to consider. The device will be worn for four to six weeks and needs to be easy to put on, take off, and adjust. Because of its close proximity to the hands and familiarity with belts, the belt design won the accessibility category.

The device must not be intrusive on the patient's life, which includes appealing aesthetics that do not make the patient feel uncomfortable to use in public. A score of 15 was assigned to aesthetics when applied to the design aspects. Since the belt design is the most covert design and can pass as a belt, it scored highest in aesthetics. Cost is weighted lower at 10 because there are no competing prices to meet and the patient will not own the device, but rather rent it from the physician or clinic. The designs with the least amount of fabric and sensors, the headband and collar designs, won the cost category. Although the device was designed as a safety measure, it is not of great concern of safety to the patient due to its low-powered components, durable materials, and enclosed design, justifying a weight of 10. The designs with the best-rated safety were the shoulder pads and belt because the components could be placed relatively far from the face and head compared to the headband and collar designs.

Sensor Alternatives

Each sensor shares several features that need not be considered in the matrices. Firstly, all sensors are capable of detecting objects at and within one meter. It is not necessary if a sensor can detect anything past this range, and increased range will not be beneficial to the goal of the design. In addition, the power consumption for all sensors is very low and comparable. Lastly, the distance sensors specifically are capable of relaying the distance measurements to the microcontroller, and therefore do not need to be ranked in this category.

Sensor Matrix

Table 2: Matrix constructed to determine which distance sensor to implement. The MB Ultrasonic Range Finder was chosen.

Criteria (Weight)	Infrared Proximity Sensor Long Range	Ping))) Ultrasonic Distance Sensor	MB Ultrasonic Range Finder EZ0
Field of View (30)	12 (2)	12 (2)	18 (3)
Accuracy (25)	15 (3)	10 (2)	20 (4)
Cost (20)	12 (3)	4 (1)	8 (2)
Fabrication (15)	9 (3)	15 (5)	12 (4)
Safety (10)	10 (5)	10 (5)	10 (5)

Total (100)	58	51	68

Table 3: Matrix constructed to determine which thermal sensor to implement. The Omron D6T8L06 was chosen.

| Criteria (Weight)	MLX90614	Omron D6T8L06	TI-TMP007
Field of View (30)	18 (3)	18 (3)	18 (3)
Accuracy (25)	15 (3)	20 (4)	15 (3)
Cost (20)	8 (2)	8 (2)	12 (3)
Fabrication (15)	6 (2)	12 (4)	9 (3)
Safety (10)	10 (5)	10 (5)	10 (5)
Total (100)	57	68	64

Field of view was the highest scoring category due to its importance in detecting humans while keeping costs low. The better the field of view, the less money spent on sensors. It also keeps our design more efficient and lighter. Field of view, therefore, has a weight of 30. The winning distance sensor in this category was the MB EZ0 due to its wide field of view, while each thermal sensor scored the same due to similar narrow fields of view. Accuracy received a weight of 25 because it is essential for the device to be able to distinguish humans from the surroundings. The most accurate distance sensor was the MB EZ0 due to its high quality transducer and specialized beam pattern. The most accurate thermal sensor was the Omron D6T8L06 due to its grid detection system. Cost is very important, as each sensor can be relatively expensive. Therefore, cost has a weight of 20. The lowest priced distance and thermal sensors were the Infrared Proximity Sensor Long Range and the TI-TMP007, respectively.

Although fabrication is necessary, it is not a huge factor when determining sensors, scoring a weight of 15. This is because most sensors have relatively similar circuit integration methods that do not require extensive wiring to function properly. The Ping))) Ultrasonic Distance Sensor scored the highest in fabrication, as the sensor is has simple connections to a circuit and is made specifically for use with Arduino and other similar microcontrollers. For the same reasons, the Omron D6T8L06 is the winner for the thermal sensors. Since the sensors emit relatively small amounts of heat and are generally durable and light, safety is not a major concern. Consequently, safety received a weight of 10. Each device for both distance and thermal sensors scored identically for safety, as each poses very minimal threat to the patient.
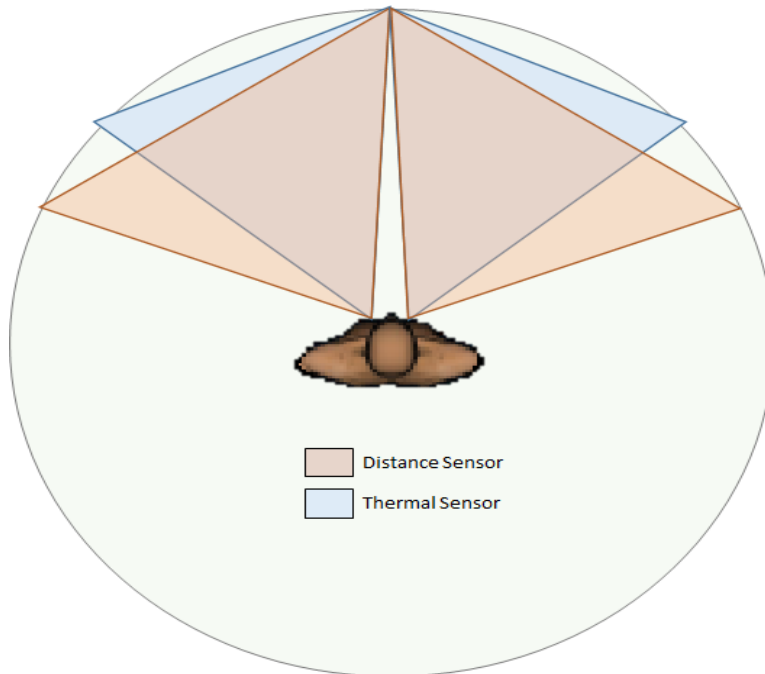
Final Design

Hardware

The final prototype that was chosen for this project is the belt design coupled with the MB EZ0 distance sensors and the Omron D6T8L06 thermal sensors. The belt material is made of double layered webbed nylon that is 86 x 4 cm. The four sensors will be placed on the opposite end of the buckle as shown in Figure 2. The thermal sensors will each be placed 2.5cm from the center while the MB EZ0 distance sensor is placed outside. This minimizes any blind spots in the center of the belt since the Omron D6T8L06 has the limiting field of view of 63 degrees. In order to attach these sensor securely to the belt, sensor housing units were 3D printed to meet the attachment requirements (**Figure 5**). The nominal viewing area of all four sensors combined (**Figure 3**) is around 120 degrees. The entire device is powered by two 9V batteries while the sensors are controlled by an Arduino Pro Mini microcontroller. A plastic housing is attached on the left side of the belt to contain all electrical components. Furthermore, the housing also contains a power switch, LED indicators, and an arduino connection port. An external connection port for the arduino microcontroller allows for calibration and data collection when necessary. This device has three ways of alerting the user and surrounding people of radiation exposure: LED strip, LED indicator, and vibrational motor. The LED strip is placed around the belt as shown in Figure 4. Both the LED strip and indicator will start flashing when a detection is made. A small vibration motor is located inside the plastic housing, and similar to a phone buzzer, the user can have tactile feedback when the signal is present. The final weight of the device is about 2 kilograms.
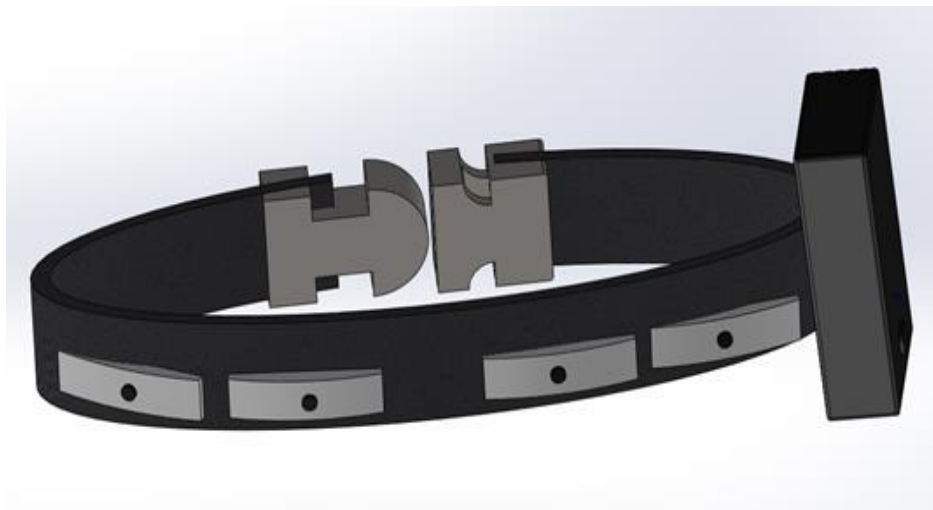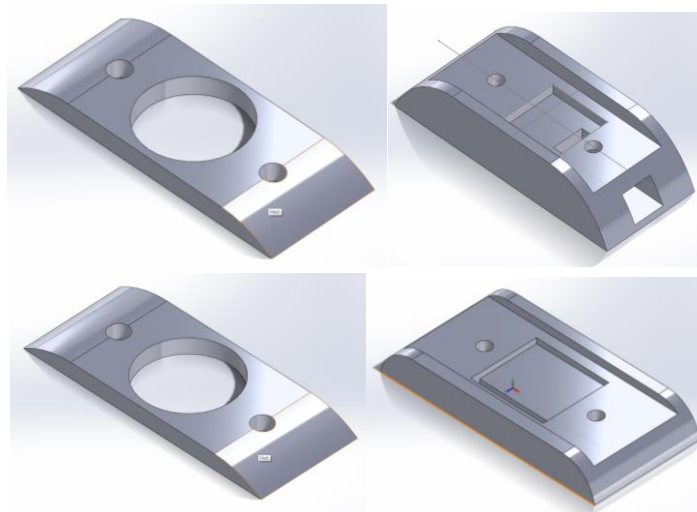

Figure 2: A 3D model of the final design. In front the sensor housing units are represented and to the right is the housing box for processing components.

Figure 3 (Left): The nominal viewing area of all four sensors as proposed in the final design.
**Figure 4 (Right):** not the thin LED strip at the top of the belt.

Figure 5: Each housing unit is composed of two pieces, a top and bottom. The top two represent the thermal sensor housing and the bottom two represent the motion sensor housing. Two holes were utilized to rivet through the housing and belt for attachment.

Code

The logic flow diagram of the arduino code is shown in **Figure 6**. When the power switch is applied to the microcontroller, the arduino will direct the EZ0 distance sensor to collect a measurement. If the distance is below 1 meter, the arduino will then trigger the thermal sensor to collect temperature data. If the temperature is within the detection range of 30°C to 36°C, the LED and buzzers will be triggered to alert the user,

otherwise, the LED and buzzer will turn off or remain off. This will be looped back to the distance sensor to repeat the cycle.
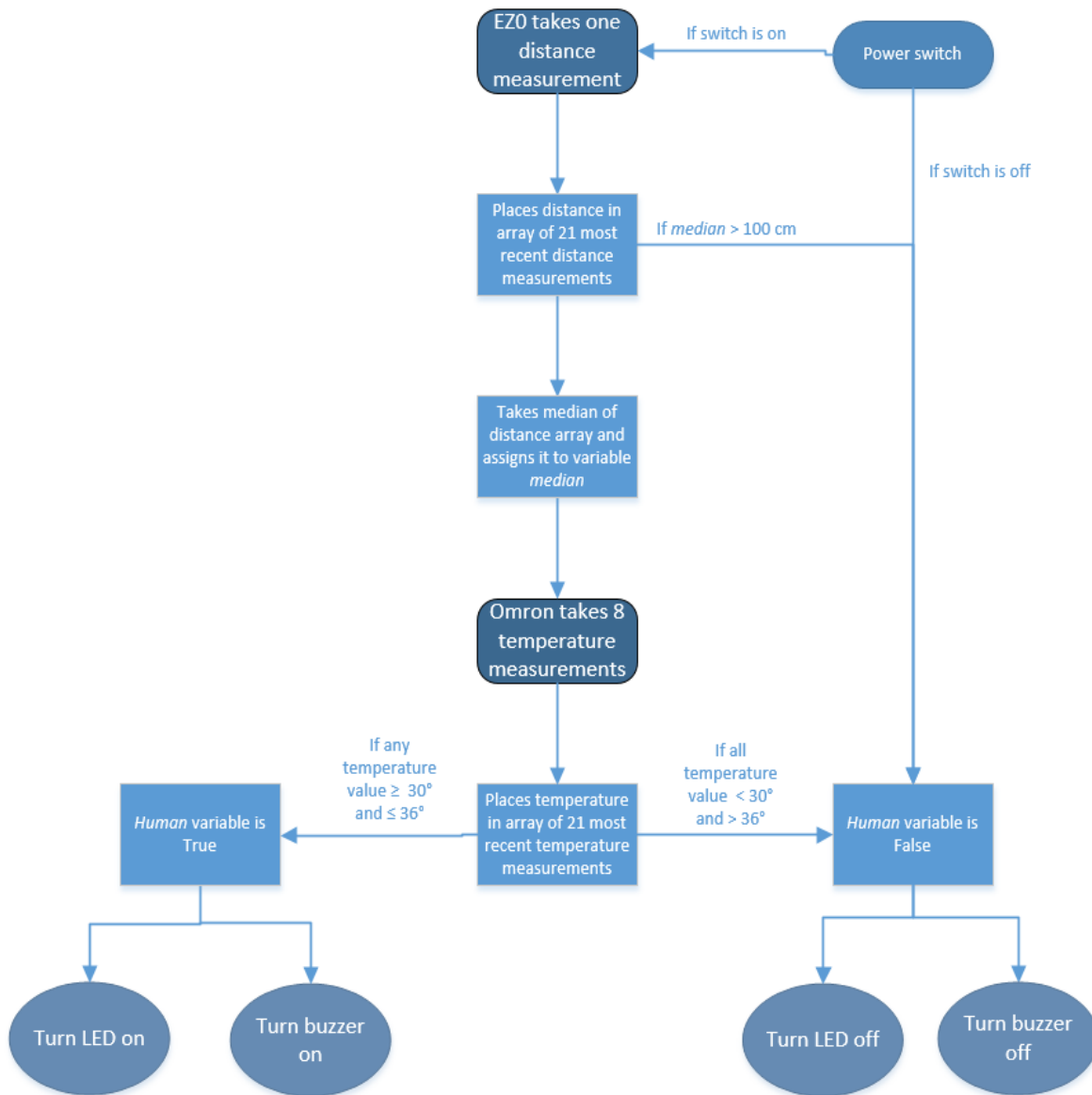
Figure 6: The logic flow that is in a constant iteration pathway.

Testing Methods

Setup

Each of the following tests had the same apparatus as shown in **Figure 7.** In an empty room, the belt prototype was placed on a flat surface with the sensors facing away from the wall. Masking tape was used to mark the points at which the sensors were triggered. A tape measure was used for all distances

recorded. The test subject was substituted with a jar containing hot water. This allowed for increased accuracy of detection. The complete Arduino code is located in **Appendix B**.

Field of View

The belt was placed against a wall. Increments of 10 cm were placed from the center of the belt up to 1.0 m. The belt was turned on. A test subject entered into the field of view at one increment from both sides of the sensors. When the LED turned on, the subject placed a marker at the spot of detection. This was repeated for every increment.

Range

The belt was placed against the wall. Starting at 2 m away from the center of the belt, a test subject slowly moved towards the belt. When the LED turned on, the subject placed a marker at each the spot of detection. This was repeated ten times.

Figure 7: A demonstration of the testing procedure to measure the angle of the lateral viewing area of each sensor.

Results

Field of View

The results for the field of view (**Table** 4) showed an average angle of 47 degrees per set of sensors. Since we used two sets, the total viewing angle of the device is 94 degrees. Although this is below the advertised 120 degrees viewing angle for the Omron thermal sensor, it is still adequate for this project to detect humans.

Table 4: Measured viewing angle of device at various distances (n=3). Average viewing angle is 47°

Center Distance (cm)	Angle Mean (°)	Angle Standard Error (°)
10	50.15	2.31
20	45.85	0.75
30	48.62	1.60
40	44.85	1.38

50	48.78	2.79
60	47.67	1.70
70	47.54	2.04
80	45.93	0.86
90	45.60	0.89
100	45.13	0.73
Total	47.01	1.11

Range

The average range of detection is 1.25m with a standard error of 9.74cm. There is a 25cm differential from the expected 1m; however, it should be noted that the maximum distance of the thermal sensor is greater than 1 meter. Therefore, if a non-human object is within 1 meter of the distance sensor, it will trigger the omron to read objects beyond one meter.
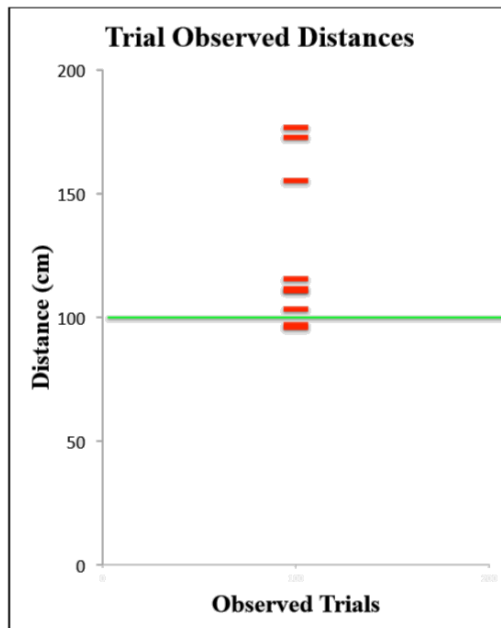
Figure 8: Observed detection distances for the device. Mean = 1.25 ± 0.097m. Green line represents ideal detection distance of 1 meter.

Discussion

Fabrication

To compete in the emerging market of wearable electronics, several distinct changes would need to be made to the current prototype. One of the most notable designs of the belt is the external circuitry. To improve safety, durability, and ease of use, along with many other factors, the circuitry would have to be internalized with the belt material. This includes not only the wiring, but also the sensors, buzzers, microcontroller, and battery, with the lights embedded on the surface. This would allow for a seamless appearance with the wearable and electronic components of the design, appealing to a mass consumer audience. In addition, a rechargeable battery would create a more environmentally friendly product and provide the customer with a more compact design. To appeal to a wider scope of potential users, the belt would need to have more

variability in sizing. This would allow the belt to be worn more comfortably by more body types. Further improvements include more customized housing for the sensors that would be flexible and firmly position the sensors inside the belt while also providing added protection from impacts. To enhance detection, more advanced sensors could be implemented. This would decrease the amount of materials used and lighten the belt.

Software

To improve the software, a database would be constructed to store information about the patient's use. This would allow the user to adjust his or her behavior based off of patterns indicated by their daily use. In addition, a Bluetooth connection with a smart device would give the user immediate information at any point the belt is on, allow for the user to monitor and control the function of the device to better suit his or her specific needs.

Testing

Aside from modifying physical aspects of the design, further testing would also be necessary to assure accuracy and reliability of the ultrasonic and thermal sensors. This testing would encompass a more rigorous and methodical approach to all tests previously performed, and include real world testing to ensure the user benefits from the belt.

Conclusion

The prototype produced sufficiently met the clients requirements. It accurately reacted to human signatures within the 1-2 meter radius, but this device still has room for improvement. The belt was comfortable, however unfashionable, but met the goals of the project. the threshold between this design and a commercial product has been furthered from past designs to this year. It is still a work in progress, but this has been the most effective design created from the past two iterations of this project. This project is recommended to be continued by this years design team, and many have expressed interest being involved. Dr. Hagi and Dr. Webster were very available for consults and provided necessary background information to the design team in order to accurately understand the need for such a device. Dr. Saha also provided crucial advising points from notebook syntax to actual design components of the device. These individuals input greatly impacted the success of the project, and for that they have an immense amount of gratitude from the engineering staff.

References

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Appendix A: PDS

Product Design Specifications

Radiation Distance Safety Meter
David Mott, Justin Faanes, Elliott Janssen Saldivar, and Jesse Wang
Current as of May 6, 2015
Clients: Prof. John Webster
& Dr. Sarah Hagi

Problem Statement: Patients treated with therapeutic doses of radioactive iodine (I-131) can be potentially harmful to those in close proximity when discharged. The radiation from the doses can be a threat to those less than one meter away from the patient, especially family members and healthcare providers who are in frequent contact. Our client, Dr. Sarah Hagi, from the radiology department at King Abdulaziz University Hospital, requested a device that alerts the patient if individuals are within one meter. A device will be created that provides acoustic and optical feedback to alert the patient of his or her proximity to others.

Client Requirements:
- Must sense a human within a one-meter range
- Must provide a feedback to alert the patient
- Must be comfortable enough to where on a daily basis

Design requirements:
1. Physical and Operational Characteristics
a. *Performance requirements*: The device must detect human presence within one meter for at least 6 weeks. Must provide feedback to alert user of human presence. Must function under mild radioactive conditions.
b. *Safety*: The device must have a sufficient feedback mechanism to warn user of unsafe distances with minimal discomfort. The materials must not become radioactive in the period of use. Electrical components must be concealed.
c. *Accuracy and Reliability*: The device must be battery powered and function accurately for at least 6 weeks. The device must detect distances within a 0.1 meter tolerance.
d. *Life in Service*: When the patient is discharged from the hospital after therapeutic radioactive iodine treatment, it is recommended he or she avoids coming within one meter of another person

for 4-6 weeks. The device would have to be constantly active for this period of time. It is possible that the device could be recharged at night while the patient is sleeping. The device should hold a charge for at least 16 hours/day, 7 days a week, for 6 weeks.

e. *Shelf Life*: The device should be able to be stored for 10 years without using any of its functionality.

f. *Operating Environment*: The device will be operated in various interior and exterior environments throughout the world. For this reason, it should ideally be operational at extreme temperatures (-25 – 50 degrees Celsius) and humidity (5 – 95 percent) ranges. It should also be water resistant in the event of rain or spilling.

g. *Ergonomics*: The device must be comfortable to wear throughout the day for up to 6 weeks.

h. *Size*: The device must be small enough to not disrupt the patient's daily activities.

i. *Weight*: The device must weigh no more than one kilogram.

j. *Materials*: The materials must not be affected by radiation from I-131. The device should not be made out of a common allergen, such as latex. Electrical components should maintain their electrical properties in the presence of radiation.

k. *Aesthetics*, *Appearance, and Finish*: The device should be aesthetically appealing to ensure the patient feels comfortable wearing the device.

2. Production Characteristics
a. *Quantity*: One prototype.
b. *Target Product Cost*: Around $100.00.

3. Miscellaneous
a. *Standards and Specifications*: The device must meet the requirements of the National Institute of Standards and Technology.
b. *Customer*: Therapeutic iodine radiation clinics and hospitals and the patients they treat.
c. *Patient-related concerns*: The device needs to be durable and comfortable.
d. *Competition*: There are no devices currently on the market targeted towards therapeutic radioactive iodine patients.

Appendix B: Arduino Code

```
#define SDA_PORT PORTD
#define SDA_PIN 5
#define SCL_PORT PORTD
#define SCL_PIN 6

#include <SoftI2CMaster.h>

#define OMRON 0x0A
```

```
#include <Wire.h>

int SDApin = A4;
int SCLpin = A5;
int SDApin2 = 5;
int SCLpin2 = 6;
int distSensorCont = 9;
int distOneIn = A0;
int distTwoIn = A1;
int deviceAddress = 0x0A;
double temperatures[9];
double distances[2];
double distLimit = 100; // in cm
boolean objInRange = false;
double tempLimit = 29.0; // in Celsius
int vibratorCont = 10;
int LEDCont = 11;
int yellowCont = 8;
int greenCont = 7;
int redCont = 12;
boolean personDetected = false;

void setup() {
  Wire.begin();
  Serial.begin(9600);
  pinMode(distSensorCont, OUTPUT);
  pinMode(vibratorCont, OUTPUT);
  pinMode(LEDCont, OUTPUT);
  pinMode(yellowCont, OUTPUT);
  pinMode(greenCont, OUTPUT);
  pinMode(redCont, OUTPUT);
}

void loop() {
  // Reset before checking again
  personDetected = false;
  objInRange = false;

  // Read distance sensors
  getDistances();

  // Check values
  if (distances[0] < distLimit || distances[1] < distLimit)
```

```cpp
  {
    objInRange = true;
//    digitalWrite(LEDCont, HIGH);
//    digitalWrite(vibratorCont, HIGH);
  }

  // Obtain temperatures if an object is in range
  if (objInRange == true)
  {
    getTemperatures();

    // Check values
    for (int i = 0; i < 9; i++)
    {
      if (temperatures[i] > tempLimit)
      {
        // Remember that we have detected a person
        personDetected = true;

        // Trigger first alarm (or all)
        digitalWrite(vibratorCont, HIGH);
        digitalWrite(LEDCont, HIGH);

        // Configure LED strips
        digitalWrite(yellowCont, HIGH);
        digitalWrite(greenCont, LOW);
        digitalWrite(redCont, HIGH);
      }
    }
  }

  // If person is not detected, turn off alarms
  if (personDetected == false)
  {
    digitalWrite(vibratorCont, LOW);
    digitalWrite(LEDCont, LOW);

    // Configure LED strips
    digitalWrite(yellowCont, LOW);
    digitalWrite(greenCont, HIGH);
    digitalWrite(redCont, LOW);
  }
  else
  {
```

```
    // For testing
    Serial.println("Person Detected");
  }

  // Reset temperatures
  for (int i = 0; i < 9; i++)
  {
    temperatures[i] = 0;
  }
}

// Gets the average temperature in each grid location and stores
// them in the temperatures array.
void getTemperatures() {
  // For testing
  Serial.println("Getting Temperatures");

  double tempValue;
  int i = 0;

  Wire.beginTransmission(deviceAddress);
  Wire.write(0x4C); //What is the meaning of 0x4C?
  int writeStatus = Wire.endTransmission();
  if (writeStatus != 0)
  {
    Serial.println("Fail");
    return;
  }

  Wire.requestFrom(deviceAddress, 18);
  while (Wire.available() > 1 && i < 9)
  {
    tempValue = (Wire.read() + Wire.read() * 256) / 20;
    temperatures[i] = tempValue;
    i++;

    // For testing
    Serial.println(tempValue);
  }
}

// Gets the distances read by each distance sensor. (9.8 mV/in)
// Multiply value by 1.26678 to get distance in cm.
void getDistances() {
```

```
    // For testing
    Serial.println("Getting distances");

    // Conversion factor to go from digital value to cm.
    double conversion = 1.26678;

    // Activate distance sensors
    digitalWrite(distSensorCont, HIGH);
    delay(0.05);

    // Read sensors
    distances[0] = analogRead(distOneIn) * conversion;
    distances[1] = analogRead(distTwoIn) * conversion;


    // For testing
    Serial.println(distances[0]);
    Serial.println(distances[1]);

    // Deactivate distance sensors
    digitalWrite(distSensorCont, LOW);
    delay(50);
}
```