Mithril Smart Shirt Final Report

Abstract

Most wearable technologies today only cover a small part of your body and do not provide comprehensive analytics. The purpose of Mithril is to not only provide more feedback on the state of your body, but also assist athletic activities with features such as night time visibility, an emergency alert system, and biometric tracking. These features are implemented with a lightweight Arduino microcontroller and multiple sensors that send data via Bluetooth to an Apple iOS mobile phone application easily accessible to the user. The design uses a long sleeve compression shirt to provide closer contact to the skin so that the sensors can receive more accurate data. Mithril aims to prove that a wearable device that covers more of the body can provide more data with greater accuracy than today's small wearables. The study concludes that although the shirt successfully transfers a significant amount of biometric data to the mobile application, the lightweight, off-the-shelf technology used in the experiment limits the rate of data transfer to a byte of data per half second. However, using more robust technology and additional sensors negatively affects the weight and practicality of the smart shirt. Further research and custom fabricated parts can solve this. Overall, the experiment is successful in providing comprehensive data, and the system obtains 4 more types of biometric data that current wearables cannot.

Introduction

There are many versions of smart wearable technology in the market today, such as the Apple Watch and Android Wear watches. These devices are mainly targeted at making interfacing with mobile devices more convenient for users, with features such as reminder notifications that reduce the number of steps required to view information on a smartphone. Users are able to check, manage and to an extent respond to any notifications on their wrist without the added action of taking out their smartphone. The most recent versions of devices have started to experiment with biometric tracking to appeal to fitness enthusiasts by including features such as heart rate sensing.

With the rise of the smartwatch comes the rise of health applications available on the new devices. Unfortunately, the smartwatches' strength is also its' weakness in the field of personal health. The human body is large and our vital signs are spread out, meaning that to obtain more biometric data a device will need much coverage. The smartwatches are meant to be small accessories worn on the wrist. This form factor makes sense for a device meant to mainly serve notifications to the user, but is not feasible for health oriented smart wearable devices. The only information one can obtain from a form factor covering only the wrist is heart rate, while full body coverage of a device would allow for more varied and comprehensive biometric readings such as body temperature and hydration. One form factor considered by many is the shirt, a device people are comfortable wearing daily. Additionally the shirt gives coverage of the entire torso and upper arms of the human body, allowing for the collection of more detailed biometric readings. To develop this form factor, smart textiles must be considered in the construction and feasibility of the device. The data collected from the device would enable the user to store biometric data to be used for data visualizations on their smartphone, enabling the viewing of workout and health progress.

There is extensive research in the field of smart wearable textiles, with initial products such as conductive thread and Velostat being released for public use. These devices are meant to replicate the form of materials used to construct textiles, such as thread, but also hold the properties of electronic components that enable the creation of electronic circuits. Many hobbyists are already experimenting with the applications of smart textiles, with projects such as clothing interfaces for smartphones and textile-based embedded robotics control.

The Mithril Smart Shirt is an exploration into the field of both smart textiles and smart wearable technology. It is focused on the health-based potential of smart wearable devices and takes advantage of developments in smart wearable technology and textiles: namely smartphone device interfacing and material availability. The Mithril Smart Shirt provides the data that a smartwatch cannot and tests the limits of smart textile technology. The paper will further describe the Mithril Smart Shirt in depth, discussing the following areas of the project:

- The technical components of the project. The software and hardware of the project will be described, as well as the materials used for construction of the final product.
- The next section will describe the project timeline and project milestones to give an idea of the development and implementation process of the project.
- In the final section, conclusions regarding the project, the smart wearable market, and the smart shirt's feasibility will be discussed.

Technical Material:

Materials

Shirt:
- Under Armour Men's HeatGear Sonic Compression Short Sleeve Shirt

Mobile Application:
- Device:
    - Apple iPhone 6
- Software:
    - Xcode

Microcontroller:
- Arduino Module:
    - Atmel ATMEGA328-AU
- Software:
    - Arduino IDE, Atmel Studio 6
- Bluetooth Module:
    - Texas Instruments CC2541
- Software:
    - CC2542 Development Kit
- Clock:
    - 32 MHz oscillator
- Antenna:
    - Johanson 2450AT18A100E
- Battery:
    - 3.7V

LEDs:
- Adafruit NeoPixels

Voltage Regulator:
- Pololu 5V Step-Up Voltage Regulator

Sensors:
- Heart Rate:
  - Pulse Sensor Amped
- Temperature:
  - TMP36 Analog Temperature Sensor
- Light Sensor:
  - YWRobot Analog Light Sensor
- Pressure Sensor:
  - Aluminum Foil, Clear Adhesive Material, Velostat
- Accelerometer:
  - SparkFun Triple Axis ADXL335

Code

(see bitbucket repository https://bitbucket.org/jamesjedn/mithril-smart-shirt)

Final Summary

The microcontroller, all of the sensors, and the voltage regulator powered by a 3.7V battery. The NeoPixels and the heart rate, temperature, light, and pressure sensors are connected to analog pins on the microcontroller. The voltage regulator is connected to the light sensor because it needs 5V to power it. The NeoPixels are connected to PWD pins on the microcontroller.

The microcontroller, four NeoPixels, and the pulse sensor attached to the chest area of the shirt. Two NeoPixels are attached to each shoulder area and are activated by the light sensor. The accelerometer is attached to the bottom right of the shirt. The light sensor is attached to the stomach area of the shirt. The temperature sensor is attached to the armpit area of the shirt. The battery is stored in the front pants pocket of the wearer. The pressure sensor is attached to the collarbone area of the shirt.

Milestones:

By Saturday week 4 have core biometric sensors working:
- DONE: Have Arduino output “Hello World” and blink an LED
  - This was pretty basic so we don't have pictures/videos of this working
- DONE: Have accelerometers reading data
- DONE: Have heart rate sensor reading data
- DONE: Have light sensors reading data and communicating with LEDs
  - Temperature sensors were not in this week so worked on light sensors instead
- DONE: Have Bluetooth module sending and receiving dummy data
- DONE: Complete UI layout of iOS app
  - John completed extra work on the iOS app that we did not foresee would be done this week.

By Saturday week 6 begin working on communication between circuit and iOS device:
- DONE: Test voltage regulators with Arduino
  - Using voltage regulators instead of amplifiers
- DONE: Have temperature sensor reading data
- DONE: Have the Bluetooth module to send the data read from the sensors

- DONE: Get I2C and SDL working on Arduino

By Saturday week 7 prototype safety feature sensors:

- DONE: Build and test fabric pressure sensors
- DONE: Develop and implement biometric algorithms
- DONE: Have iOS application ready to accept sensor data

By Saturday week 8 prototype entire circuit, start building and testing:

- DONE: Prototype and test entire circuit on breadboard
- **CANCELLED**: Test fabric pressure sensors with peak detection circuit (have to prototype and build)
    - **This milestone was created because current pressure sensors need a peak detection circuit to detect sudden impact**
    - **Unfortunately, we were never able to get the peak detection circuit working, so the pressure sensor was only able to detected prolonged impact**
- **DONE**: Have pulse sensor read data better from ear and BPM
    - ~~Pulse sensor not able to read data accurate from chest contact, so we need to try using the ear~~
    - **Pulse sensor was actually able to read accurately from chest**
- **REVISED:** Build circuit and ~~stitch~~ connect circuit to shirt
    - **Conductive threading was proven to be an unreliable way to connect the circuit, so we had to use wire, which makes the shirt bulkier and not waterproof**
- **DONE:** Implement the data ~~graph~~ visualizations for the iOS app.

By Saturday week 9 continue and finish building and testing final circuit. Start filming:

- **INCOMPLETE**: Continue building and debugging the final circuit
    - **We ran out of time to fully implement our shirt the way we wanted to. More specifically, nothing was waterproofed, the pressure sensor did not behave as well as we wanted it to, and the battery was never attached to the shoulders as planned**
- **DONE:** Develop and implement emergency system algorithms
- **CANCELLED:** Implement Health Kit from Apple
    - **We ran out of time so we weren't able to use these features provided by Apple**
- **DONE:** Start shooting project video

By Saturday week 10 continue working on filming and presentation:

- **DONE:** Shooting the Video
- **DONE:** Preparing presentation

Conclusion:

The Mithril Smart was successfully able to transfer all the biometric data we envisioned with our final milestones. The smart textile materials used to construct the devices were very effective under normal and light exercise circumstances, but were not strong enough to handle more demanding physical activities. The conductive thread would snap when the user engaged in demanding physical activity, disrupting communications between components until repairs were made. The data transfer with the smartphone application was accurate but limited by the slow data transfer rate of the off-the-shelf Texas Instruments CC2541 module used in the project. Due to the highly physically demanding nature of the users who would use the Mithril Smart Shirt and comfort, custom built parts as opposed to off-the-shelf parts will be required in a production ready release of further versions of the Mithril Smart Shirt. The smartphone application needed more refinement but was successfully able to meaningfully visualize the biometric data collected form the user's body.

In future versions and applications of smart textile technology, more powerful and protected materials will be required to create more complex devices. Combined with a young smart wearable market where consumers are not yet committed to purchasing smart wearable technology, the market is not yet ready for smart wearable shirts. However, with custom built parts, further development in smart textile materials, developments in the smart wearable market, and greater consumer demand the smart shirt form factor could potentially become a widespread device with the fitness community.