Ultra-Thin Wearables for Real-Time Health Monitoring

Project Plan

Team: sddec19-20

Client: Liang Dong

Advisor: Liang Dong

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List of Definitions

Android - The basic operating system by Google company

Electrolyte - Matter in sweat

ECG (electrocardiogram) - the test for medical which measure any problem in heart

IOS - The basic operating system by Apple company

Mobility sensor - the test for movement which measure any movement between two different location

Optimization - It means how some program is working well at the particular environment

Sensor - The device which can measure the characteristics of particular tangible things

Sweat sensor - Through electrolyte, analysis of sweat, and check any healthy condition.

Technology Stack - Set of programming tools and languages that is working behind the scenes in applications

Prototype - A quick and dirty implementation of a potential solution

Endpoint - A communication and data retrieval point for an application

1 Introduction

1.1 Acknowledgement

Client/Advisor: Liang Dong

Thank you to Dr. Dong for allowing us to use his lab and it's equipment. Due to his generosity, creativity, and support, we have been so fortunate to work on such an interesting project.

1.2 Project Statement

Currently there is a lack of options in regards to personal health monitoring, which can be troublesome for at-risk patients who wish to be in control of their health. Smart watches provide some rough approximations in regards to cardiovascular data, however, smart watches are expensive and do not provide enough data for true personal health monitoring.

Our task is to design an ultra-thin wearable (comparable to a bandaid) and create a manufacturing process for the wearable. We also are tasked with developing a mobile application which will communicate with the ultra-thin wearable through bluetooth technology.

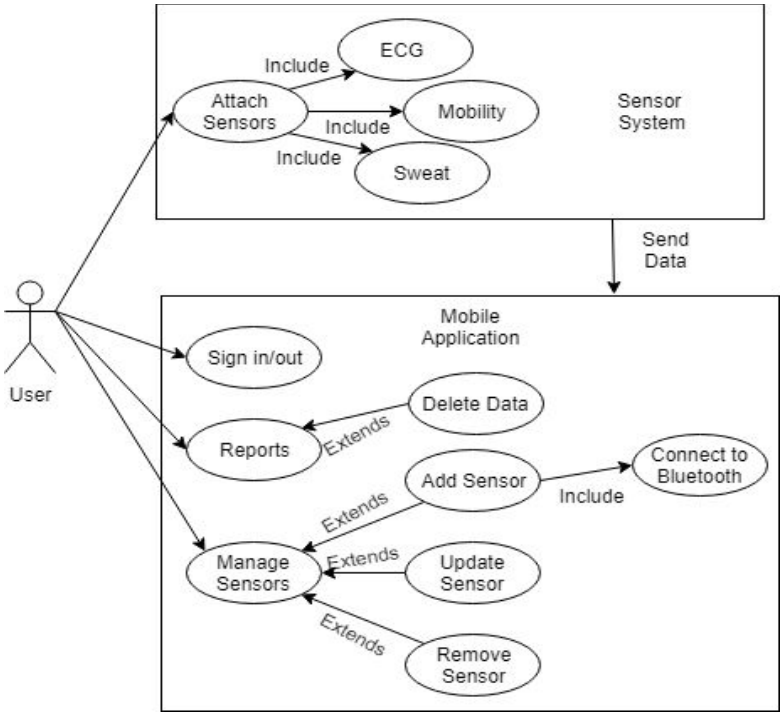


Figure 1: Use Case Diagram for the Ultra-thin wearable system

The above figure (Figure 1) is the use case diagram which is a helpful, high-level view of our entire project. It is a little unordinary due to the nature of our project - as we have two products we are working on, a wearable sensor and a mobile application.

1.3 Operating Environment

The ultra-thin wearable is meant to be placed directly on the skin, under clothing. The wearable should be able to withstand a minimal amount of moisture (sweat), the wearable will not be subject to extremely harsh weather conditions, as it will be directly on the skin and under clothing of the user. In addition, it should not be affected by body movement. Thus, it should be flexible.

1.4 Intended Users and Intended Uses

The intended users are at-risk patients or individuals who wish to have the ability to monitor their health. These users can be anyone, thus, the application must be extremely user friendly and we must make the assumption that our users are non-technical.

The intended uses are for high quality personal health monitoring without the need of remaining as an inpatient. The user should only be able to view their respective health data.

1.5 Assumptions and Limitations

Assumptions

- Wearable portion has already been created
- Medical algorithms to convert raw data into usable data will be provided
- Client will provide lab access so that we can use their 3D printer for creating multiple variations of the ultra-thin wearable

Limitations

- Total funding of $500
- The existence of flexible/micro technology (i.e. bluetooth device) is limited and can tend to be costly.

1.6 Expected End Product and Other Deliverables

The expected end product is a ultra-thin wearable which is placed on the skin and provides high quality health monitoring data via bluetooth to an iOS application. The device should be able to monitor:

- Cardiovascular activity (heart beat)
- Monitor sweat (will help with heart beat reading)
- Movement of knee (to see if user has fallen)

The client expects the following final deliverables

1. A home-made on-skin sensor system consisting of multiple home-made wearable sensors
2. Mobile application for on-skin sensor system

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The objective of our project is to develop an ultra-thin wearable device which can monitor personal health and detect potentially dangerous heart rhythms or falls for at-risk patients. The wearable can also be used by athletes who are monitoring their health statistics while training. This device will have a mobile application so users of the device can view their previous statistics and can be used for real-time health monitoring.

2.2 Functional Requirements

There will be two sets of functional requirements, one for the hardware (ultra-thin wearable) and one for the mobile application.

2.2.1 Ultra-thin Wearable Functional Requirements

The ultra-thin wearable shall

FR.1: Use sensors to monitor heartbeat

FR.2: Use mobility sensor to monitor the movement of users knee

FR.3: Use sensors to monitor sweat

FR.4: Have the ability to register a fall

FR.5: Transfer data through bluetooth

FR.6: Be flexible and durable

FR.7: Require low power

2.2.2 Mobile Application Functional Requirements

The application shall

FR.1: Securely handle user data

FR.2: Use bluetooth to communicate with ultra-thin wearable device

FR.3: Provide real-time health monitoring with at most 3-second delay

FR.4: Save health monitoring data for later access

2.3 Non-Functional Requirements

There will be two sets of non-functional requirements, one for the hardware (ultra-thin wearable) and one for the mobile application.

2.3.1 Ultra-thin Wearable Non-Functional Requirements

The ultra-thin wearable shall

NFR.1: Be > 95% accurate

NFR.2: Detect serious falls with no less than 99% accuracy

NFR.3: Provide electrolyte measurements to no less than 90% accuracy

NFR.4: Not shock the user

NFR.5: Never irritate the wearers skin

2.3.2 Mobile Application Non-Functional Requirements

The application shall

NFR.1: Interpret data in a second or less

NFR.2: Receive data over bluetooth in at most .25 seconds

NFR.3: Be accessible for iPhone and Android users

NFR.4: Save data for a user specified time

NFR.5: Delete data at user's discretion

NFR.6: Not hang during computations

2.4 Standards

The wearable is subject to IEEE standards due to the adhesive patches we are using, the standards are discussed at length in the paper: Adhesive RFID Sensor Patch for Monitoring of Sweat Electrolytes (https://ieeexplore.ieee.org/document/6953152). Since the wearable is to conform to the human skin, the chemicals of the wearable/adhesive must not be chorosive or an irritant to the skin. Also, the wearable must have a low enough voltage as to not injure the user.

The application will be written in Swift, which has an API design style guide [1]. This style guide helps keep designs modular and non-blocking. This guide will be used in the development of the mobile application. We will also follow the App Store guidelines [2]. A goal of this application is to create a completed product.

Our products will follow the standards above so that we do not produce an unethical product and or violate any laws.

2.5 Constraints Considerations

Our major constraints are due to economic factors, we are limited in what we can purchase. We have a total of $500 for usage to purchase various devices necessary for our ultra-thin wearable device. Thus, not allowing us to have a whole lot of freedom when it comes to experimentation with potential hardware. In terms of development of the application we are constrained to an iOS application, at least for the current status of the project.

2.6 Previous Work And Literature

While a few different products are starting to surface, there are only a few articles and academic papers that discuss ultra-thin wearables. These articles talk mainly about how the technology for miniaturization and new flexible materials have allowed for this to become possible [4]. They talk about the practical application of this technology and its use in studies more than the development process of it [6].

While the steps for development are sort of unclear, there are plenty of products on the market for use in our construction of such a device. Tools that we can use such as ECG sensors, Sweat sensors and the algorithms to make use of the data are available to us. In most parts it will be the case of fitting parts for certain jobs together in order to make a fully functional wearable.

2.7 Proposed Design

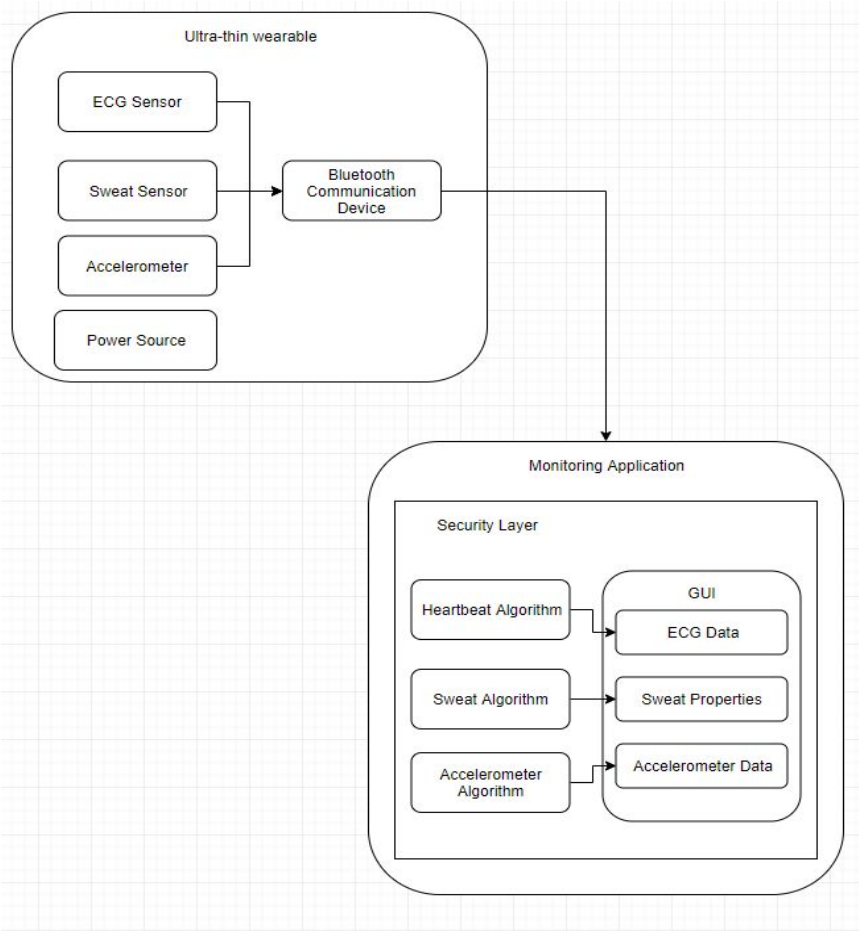


Figure 2: Block Diagram for the Proposed Design

The project consists of two major aspects, the ultra-thin wearable (hardware) and the application (software). The ultra-thin wearable will have 5 main components, ECG sensor, sweat sensor, accelerometer, power source, and a bluetooth communication device. The sensors and accelerometer are to gather data on the user and then it will be sent via bluetooth to a mobile application.

The application will contain a secure layer and inside that layer our provided algorithms will allow us to transform raw data (transmitted from the bluetooth device) into human-readable data. Within our secure layer we will also have a nice user interface which provides past and real-time health monitoring, containing various graphs and other statistics.

2.8 Technology Considerations

2.8.1 Hardware

There are several technology considerations. First of all, it should be a device that attaches to the body that includes a safe wearable component. Secondly, it should be as flexible as skin (i.e. bandaid) but also strong durability. Thirdly, this device should be light enough to prevent the user from feeling uncomfortable. Finally, the device should be able to connect with mobile device and use low power.

The hardware options for the device are limited due to these constraints. There are very few micro/flexible bluetooth chips available, and the same goes for the other sensors required for the ultra-thin wearable.

2.8.2 Software

The main consideration is which device to develop on, iOS or Android. We decided to go with iOS because the general public of the United States generally uses iPhone [7]. We are also developing an iOS application because the Software Architect uses a Macbook. iOS will allow us to bootstrap an application quicker than on an Android, and it will be easier on iOS when it comes to interactivity due to the limited amount of screen sizes on iOS devices.

The main application front end will be developed in React Native so that we have the potential to port the application to Android in the future. The initial backend will be Objective-C/Swift, because this is the provided technology stack for iOS development [1].

We are using MongoDB for the database so we have the ability to save the data in a JSON like format. This will allow us to have some data portability and we do not have to mess around with the strictness of SQL syntax.

2.9 Safety Considerations

The ultra-thin wearable device will be transferring data via bluetooth and we have to consider bluetooth sniffing as a potential issue. However, bluetooth sniffing is extremely difficult because bluetooth communication occurs over 79 different channels, and hops between these channels. However, light encryption here might be a good option.

The application aspect of the project is dealing with highly sensitive data and keeping that highly sensitive data secure is the largest safety consideration. We will be reading and saving personal

health data on the mobile application and within a database for later access. So we must correctly secure our endpoints and the data access within the database.

2.10 Task Approach

2.10.1 Hardware Task Approach

Our client and advisor had a solid outline for how this project should be approached, for the first half of the semester, the hardware team will focus on the design, accumulation of parts, and manufacturing of the ultra-thin wearable device. During this time, the software engineers will focus on getting an application up and running, preparing the software architecture design will be an important aspect.

2.10.2 Software Task Approach

The software architecture has been completed and once the client has provided us complete freedom to implement as we see fit. Before we being developing software, we need to develop a prototype using raspberry pi 3s and other small circuits which will simulate the sensor patches. This prototype will allow us to test the software we write. The next step would be to prepare a prototype to communicate with bluetooth through various secure endpoints.

2.11 Possible Risks And Risk Management

During the circuit and prototype design, we will have to solder, and there is a potential to be burned. To avoid any injuries in our team, we will use safety equipment such as goggles, gloves, and clean workspaces. Further, during the testing aspect we may use electric current and thus our team must be acquainted with the safety regulation. Finally, while using the 3D printer, we must continually check safety regulations, work with an expert (i.e. graduate student in the lab), and take notes from the advice received from said expert.

2.12 Project Proposed Milestones and Evaluation Criteria

Ultra-Thin Wearables for Real-Time Health Monitoring			
Project process	**Member**	**Completed**	**Note**
Steps	**Name**	**Y / N (oo%)**	**Additional info/note**
Research on Background Technology	All	Y / N 80 %	

Circuit Design based on program(ECG)	Sangwon	Y / N ___%	
Simulating on program(ECG)	Sangwon	Y / N ___%	
Circuit Design based on program(Sweat)	Omar	Y / N ___%	
Simulating on program(Sweat)	Omar	Y / N ___%	
Circuit Design based on program(Accelerometer)	Sung Min	Y / N ___%	
Simulating on program(Accelerometer)	Sung Min	Y / N ___%	
Activate DMD 3D printer	Electrical Member	Y / N 100 %	
Manufacturing Semiconductor	Electrical Member	Y / N ___%	
Testing Sensors(ECG)	Sangwon	Y / N ___%	
Testing Sensors(Sweat)	Omar	Y / N ___%	
Testing Sensors(Accelerometer)	Sung Min	Y / N ___%	
Software Architecture Design	Sovann	Y / N 100 %	
Initial Mobile Backend	Sovann & Justin	Y / N ___%	
Initial Mobile Frontend	Sovann & Justin	Y / N ___%	
Prototype (Communication between Software and Hardware)	Sovann & Justin	Y / N 30 %	Parts have been ordered and received. Now we need to piece together the prototype.
Implementing Security and up to 50% Test Coverage	Sovann	Y / N ___%	

Implementing Graphing API	Justin	Y / N ___%	
Up to 95% Test Coverage and Polished Application	Sovann & Justin	Y / N ___%	
Testing Application	Sovann & Justin	Y / N ___%	
Project Testing	Sovann & Justin	Y / N ___%	

Table 1: Table for the Project Proposed Milestones and Evaluation Criteria

2.13 Project Tracking Procedures

Since our team is split into a hardware aspect and a software aspect, we will be using Trello to track each others progress. Trello is an easy tool which is comparable to sticky notes. We will create multiple sticky notes and place them into one of three categories:

- Backlog
- In-Progress
- Finished

This will allow us to keep track of the work being done on both sides of the project without the learning curve for team members unfamiliar with Gitlab.

2.14 Expected Results and Validation

For the three sensors such as ECG, sweat and mobility sensors, most expected results are very accurate. Specifically, expected results depend on how accurate our ECG [3] sensor can measure dangerous symptoms of the heart, and how accurate our sweat sensor can measure electrolytes in sweat, and how accurate our mobility sensor can measure movement of specific body parts [5].

For the ECG sensor, after comparing non-strenuous activities with readings after strenuous activities, it will be possible to validate our results.

For the sweat sensor, using the difference between of measurements before the sweating and after sweating, we can validate our results.

For mobility sensors, through checking measurements before and after bending of the particular body parts, it will be possible to validate our results.

For the application aspect, using high level of optimization at each operating system, and consensus with measurement of sensors are the expected results. Through observation and testing of our application, we can determine if it is working on each operating system, and it will be possible to validate our results through this process.

2.15 Test Plan

2.15.1 Sensors

There will be three sensors for heartbeat readings (ECG), sweat content readings, and mobility sensors.

- ECG sensor: measure the all of group members' heart rate, and compare with the result of measurement with other devices (ex-Apple watch ECG sensor).

- Sweat sensor: when group member does not sweat, measure it, and after sweat (working out), measure it again and observe the difference to determine whether it is working well or not.

- Mobility sensor: after putting the patch (mobility sensor) on a group member's straight knee, and then bend the knee, and observe any difference. Also, drop the sensor on the ground, and check whether this sensor can measure any difference in change of velocity.

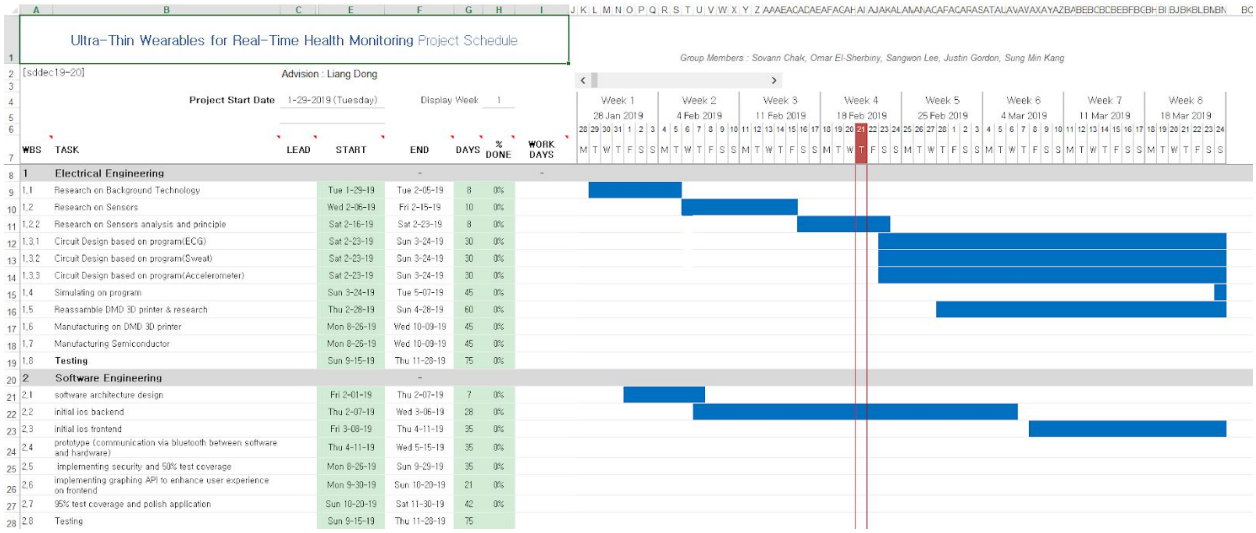
2.15.2 Application

After developing applications, we will have a controlled environment in which one of the group members will monitor the application and instruct the group member with the ultra-thin patch to do various activities. Through observation of our real-time data and the provided movements, we should be able to test for specific results.

The application will contain three pages which encapsulates all of the data for each sensor and the accelerometer, so we can seperate the results and easily narrow down if sensors are acting out of order, or if the application is malforming the raw data.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline



Ultra-Thin Wearables for Real-Time Health Monitoring Project Schedule

[sddec19-20] Advision : Liang Dong

Group Members : Sovann Chak, Omar El-Sherbiny, Sangwon Lee, Justin Gordon, Sung Min Kang

Project Start Date 1-29-2019 (Tuesday) Display Week 1

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	Electrical Engineering			-			-
1.1	Research on Background Technology		Tue 1-29-19	Tue 2-05-19	8	0%	
1.2	Research on Sensors		Wed 2-06-19	Fri 2-15-19	10	0%	
1.2.2	Research on Sensors analysis and principle		Sat 2-16-19	Sat 2-23-19	8	0%	
1.3.1	Circuit Design based on program(ECG)		Sat 2-23-19	Sun 3-24-19	30	0%	
1.3.2	Circuit Design based on program(Sweat)		Sat 2-23-19	Sun 3-24-19	30	0%	
1.3.3	Circuit Design based on program(Accelerometer)		Sat 2-23-19	Sun 3-24-19	30	0%	
1.4	Simulating on program		Sun 3-24-19	Tue 5-07-19	45	0%	
1.5	Reassamble DMD 3D printer & research		Thu 2-28-19	Sun 4-28-19	60	0%	
1.6	Manufacturing on DMD 3D printer		Mon 8-26-19	Wed 10-09-19	45	0%	
1.7	Manufacturing Semiconductor		Mon 8-26-19	Wed 10-09-19	45	0%	
1.8	Testing		Sun 9-15-19	Thu 11-28-19	75	0%	
2	Software Engineering			-			
2.1	software architecture design		Fri 2-01-19	Thu 2-07-19	7	0%	
2.2	initial ios backend		Thu 2-07-19	Wed 3-06-19	28	0%	
2.3	initial ios frontend		Fri 3-08-19	Thu 4-11-19	35	0%	
2.4	prototype (communication via bluetooth between software and hardware)		Thu 4-11-19	Wed 5-15-19	35	0%	
2.5	implementing security and 50% test coverage		Mon 8-26-19	Sun 9-29-19	35	0%	
2.6	implementing graphing API to enhance user experience on frontend		Mon 9-30-19	Sun 10-20-19	21	0%	
2.7	95% test coverage and polish application		Sun 10-20-19	Sat 11-30-19	42	0%	
2.8	Testing		Sun 9-15-19	Thu 11-28-19	75		

Table 2: Table for the Project Timeline

3.2 Feasibility Assessment

For the overall feasibility of this project we need to look at the separate tasks that make up this project. The creation of the ultra-thin wearable includes a process for creation, actual creation of the wearable and the development of an application for the user to view this data.

Creating an ultra-thin wearable and a process for manufacturing it is going to be the main challenge of this project. Using a printer to attach circuits/sensors to the wearable will be the first step. Once the circuits and sensors are in place the sensors will relay data to the monitoring app so that the user can access this data.

The Monitoring Application will be an application that is accessible on mobile devices. It will use several algorithms to decode the data sent by the wearable to a point where it is human readable. This data will also be passed through a graphing API to create nice visuals for the users.

Overall this project seems feasible, interesting, and challenging. This is no small task and considerable effort will have to be put into its development in order to create a suitable prototype for a wearable that may be used in everyday life.

3.3 Personnel Effort Requirements

Task	Description	Estimated Time
ECG sensor	Sensor monitors heartbeat	8 ~ 10 Weeks
Sweat sensor	Sensor monitors sweat contents	8 ~ 10 Weeks
Accelerometer (Mobility sensor)	Sensor monitors movement of patient and detects falls	8 ~ 10 Weeks
Bluetooth connectivity	Connect device to wearable and share data	2 Weeks
Application	App to display data gathered from sensors on wearable	8 ~ 10 Weeks
Apply circuits to wearable	Ultra-thin Wearable is constructed and sensors are attached	4 Weeks
Printer activation	Set up and program printer for use in applying circuits	6 Weeks

Table 3: Table for the Personal Effort Requirements

3.4 Other Resource Requirements

Producing a wearable prototype that can monitor bodily functions of the wearer will require resources that can be split into 3 different aspects

1. Crafting the wearable
    - Materials to be used in the design
    - Printer used to attach circuits to the wearable
2. Sensors for the wearable
    - ECG sensor
    - Accelerometer
    - Sweat sensor
3. Creating the application used for displaying the data
    - Various Software APIs
    - Bluetooth communication device
4. Biological Signal Analysis Algorithm

- Heartbeat algorithm
- Sweat component algorithm
- Accelerometer algorithm

3.5 Financial Requirements

Financial requirements for this project will include the cost of the materials used to produce the wearable which includes a bluetooth device to share the data the wearable receives, the accelerometer, and the sensors for accumulating the data from the user. These sensors and bluetooth device must be flexible enough to allow for bending in line with movements of the user. A printer for creating the circuits has already been acquired for use.

4 Closure Materials

4.1 Conclusion

Health monitoring is a necessary process in the modern world. The technology that is in place now for this is bulky, uncomfortable to use, and outdated. New technology and smaller more flexible parts allows for a better device that can be used in order to watch the health of the user.

Our project is going to be developing an Ultra-Thin wearable device that will monitor the users health with ECG, sweat and accelerometer sensors. This data with then be sent to an IOS application that will convert it into presentable statistics for the user. Resulting in a safe, comfortable, easy-to-use,and disposable ultra-thin wearable, the goal of this project is to provide patients with a new device that can be adopted easily for the use of everyday health monitoring.

4.2 References

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