Ultra-thin Wearables for Real-Time Health Monitoring

Design Document

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List of Definitions

Android - The basic operating system by Google

Concurrency - Independently running processes on an application

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

Electrolyte - Matter in sweat

Endpoint - A communication and data retrieval point for an application

IDE - An acronym for Integrated Development Environment

iOS - The basic operating system by Apple company

Lithography - the step for printing like applying ink only at the part to be printed

MA - An acronym for mobile application, used as an identifier of the functional requirements for the mobile application

MAT - An acronym for mobile application test, used as an identifier of the tests for the mobile application

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

Polydimethylsiloxane - chemical compound for making organic polymer

Prototype - A quick and dirty implementation of a potential solution

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

SU-8 - liquid for photoresist

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

UTW - An acronym for ultra-thin wearable used as an identifier of the functional requirements for the wearable

UTWT - An An acronym for ultra-thin wearable test, used as an identifier of the tests for the wearable

Wafer - Very thin board

1. Introduction

1.1 Acknowledgement

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 Problem and 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. Smartwatches 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 wireless sensor with wearability comparable to a simple BandAid, and design and develop a low-cost manufacturing process for the wearable sensor. We also are tasked with developing a mobile application which will communicate with the sensors through bluetooth technology.

Through the efforts of our team, we hope to develop an affordable and reliable manufacturing process by which we can develop these ultra-thin wearables at a cheap cost and streamlined pace. We also hope to release a stable and user-friendly mobile application which allows a user to monitor their health information in real-time. In short, we would like to have a mobile application which allows a user to monitor real-time health information with the assistance of ultra-thin wearables.

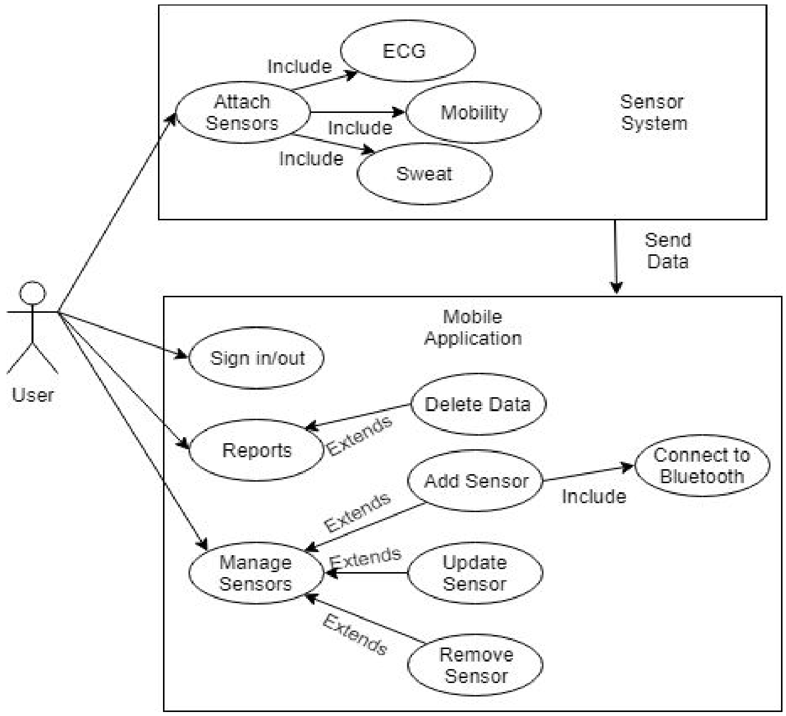

Figure 1: Use Case Diagram

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 Operational Environment

The ultra-thin wearable is meant to be placed directly on the skin, under clothing. Flexibility is of paramount concern, along with strength and durability. Hence, the wearable must be conformable to the human body, and should be able to withstand a minimal amount of moisture (i.e. 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.

1.4 Intended Users and Uses

The wearable sensor is to be designed to track various important health and activity markers such motor functions and mobility, electrolyte levels, glucose levels, cholesterol levels, hydration levels, and electrical activity of the heart.

Electrical activity of the human heart provides information on heart rate and rhythm. It also shows if there is organ enlargement due to high blood pressure (hypertension), or evidence of a previous heart attack. Potential users of this functionality are people at risk of developing heart disease or strokes like hypertension patients. Patients suffering from coronary artery disease who are at risk of developing heart attacks would also utilize the cholesterol level functionality to keep their cholesterol levels in check.

The wearable is also intended to be used by the elderly population as it has been steadily increasing in the United States, and with it a monumental strain on the availability of nurses and caregivers [3]. A common problem with seniors is their reduction in mobility; hence, having a wearable device that can analyze mobility would enable medical practitioners to perform an early diagnosis of potential issues. This, in turn, will increase chances of full recovery and help mitigate the possibility of a serious fall that could lead to long hospitalization and, not seldomly, death. The wearable can also be applicable for athletes who are interested in their performance data.

1.5 Assumptions and Limitations

Assumptions

- The wearable portion has already been created by our client
- Medical algorithms to convert raw data into usable data will be provided using a device similar to a Melexis RFID chip
- Client will provide lab access so that we can use their 3D printer for creating multiple variations of the ultra-thin wearable
- Each of the three sensors will have independent channels of communication with the mobile application

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 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 various personal health related information such as cardiovascular activity, the data will be read from a patch placed on the skin, over the heart. The application shall also read glucose levels by monitoring sweat, a patch will be placed in the armpit. Finally, the application will be able to alert if the user has fallen by monitoring the movement of the knees, a patch will be placed on the knee (which contains a micro accelerometer).

The client expects two main deliverables by the end of the project, due to the nature of the project, we cannot provide specific dates, this project dips closer towards research than an actual, commercialized product. The following final deliverables are a home-made on-skin sensor system consisting of multiple home-made wearable sensors described above (heart sensor, armpit sensor, and knee sensor) and a mobile application for monitoring the sensor systems in real-time.

Since the software aspect doesn't require a strenuous amount of work, we have decided to develop both an android and iOS application. The client has not specifically requested two mobile applications but we have been provided the freedom to develop two applications. So an expected deliverable is at least *one* mobile application - but we're aiming for two (Android and iOS).

The hardware aspect will be finished much later than our software aspect due to the complexities of research related work - so the software team must put focus on creating hardware using raspberry pi 3s in order to test the software we create. So, when we have the patches ready, we already have a proof of concept and we do not have to change much in regards to software. We may need minor tweaks but we expect the received signals (patches vs raspberry pi 3) signals to be similar.

2. Specifications and Analysis

2.1 Proposed Design

The following two tables are the functional requirements for the ultra-thin wearable and the mobile application respectively.

Requirement	Description	Test
UTW.1	Shall use sensor placed on skin above heart to monitor heartbeat.	UTWT.1
UTW.2	Shall use accelerometer sensor placed on knee to monitor the movement of the body.	UTWT.2
UTW.3	Shall use sweat sensor placed on armpit to monitor electrolyte, hydration, and cholesterol levels through one's sweat.	UTWT.3
UTW.4	Shall have the ability to register a fall or collapse of user.	UTWT.4
UTW.5	Shall transfer data from sensors through bluetooth to mobile device.	UTWT.5
UTW.6	Shall be flexible, durable, and conform to the natural	UTWT.6

	contortions of human skin.	
UTW.7	Shall require low power.	UTWT.7

Table 1: Table for the functional requirements of the ultra-thin wearable (hardware)

Requirement Id	Description	Test Id
MA.1	Shall securely handle user data	MAT.1
MA.2	Shall use bluetooth to communicate with ultra-thin wearable device	MAT.2
MA.3	Shall provide real-time health monitoring with at most 3-second delay from the various patches to the mobile application	MAT.3
MA.4	Shall save health monitoring data locally for later access	MAT.4
MA.5	Shall provide accurate, readable data for the intended users by using medical algorithms provided	MAT.5

Table 2: Table for the functional requirements of the mobile application (software)

To completely cover and properly test the functional requirements/solve the problem at hand we must follow a sequential path. First, a prototype is to be completed, which will be a rudimentary version of the sensor system to be designed and manufactured. The prototype will be used to test the mobile application(s) and assure that we have a working and robust platform. We will then compare our readings on the mobile application to commercial devices which to assure we have some level of accuracy. Once the sensor system is finished, we will connect our mobile application(s) to the sensor system and once again compare the readings with our prototype to assure the sensor system is acting as expected. Once we are assured the sensor system is acting as expected, the software engineers will polish the application(s) and the electrical engineers will begin the manufacturing process for their sensors; with the goal of finding a cheap and efficient method of reproducing the ultra-thin wearables.

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 [1]. 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.

2.2 Design Analysis

Initially, our project was focused on the design and development of the manufacturing process for the sensors. Two manufacturing processes were considered: a 3D printer using a Digital Micromirror Device (DMD), and a standard microelectronics fabrication process. The 3D printer manufacturing process was explored, and it came with several challenges outlined below:

- Initially, our project was focused on the design and development of the manufacturing process for the sensors. Two manufacturing processes were considered: a 3D printer using a Digital Micromirror Device (DMD), and a standard microelectronics fabrication process. The 3D printer manufacturing process was explored, and it came with several challenges outlined below:
    - Purchasing a DMD that can reflect UV light is not a viable option as the device is expensive, and beyond our budget.
    - Optical lenses, which are to be used in the implementation of the 3D printer, are a lot more expensive if they are to work well with high-frequency light, as opposed to the more affordable lenses that work at the low frequency visible range.
- A design for the circuits of the sensors has not yet been implemented specifically; however, we have some basic concept for our three kinds of sensors, and this concept will be applied on three of them.

For example, designing mobility sensor

1. The wafer will be prepared as basic board, then pre-heating the wafer at 100C for 5 mins.

Figure 2. The Wafer

2. After setting up the spin coater for two cycles, pour SU8 liquid onto the water.

Figure 3.SU-8

3. After finishing coating, baking the wafer at 75C for 3 mins. Then, baking again at 100C for 20 mins. Then, based on our goal of senser, design pattern using CAD program, and printed out this pattern. For mobility sensor, it should be flexible and stretched, so S pattern will be used [2]. For printing this pattern, we may use 3D printer.

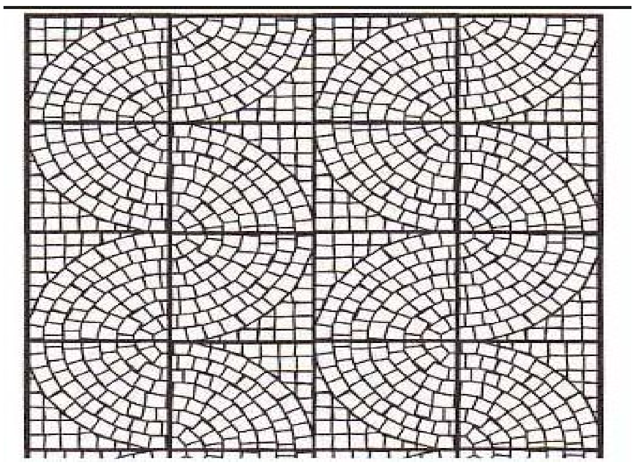

Figure 4. Curve Pattern

4. After putting our photomask on the wafer, and expose it to the UV light for 75 seconds with 8mW intensity.

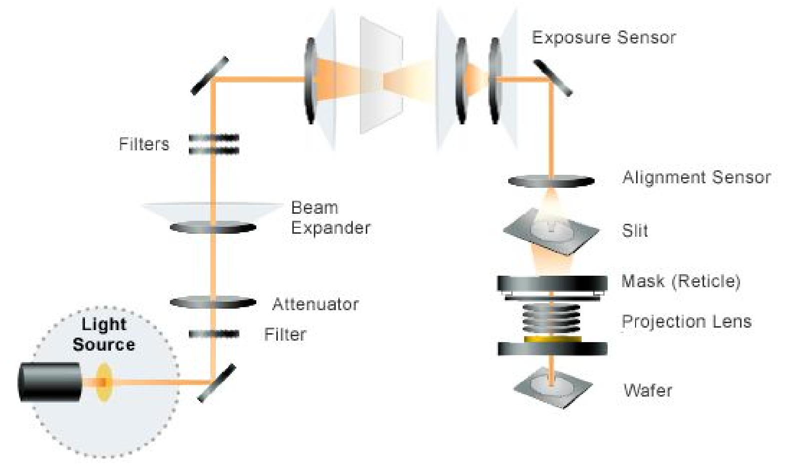

Figure 5. Lithography by Light

5. Put SU-8 liquid a little bit more, then rinse the wafer with acetone and water until our pattern can be visible.

6. After heating our wafer at 90C for 5mins again, applying Polydimethylsiloxane (PDMS) on this pattern for getting mold. The ratio will be 10:1, and put into the degassing chamber until there will be not any bubble. This one will resemble a polymer.

Figure 6. Polydimethylsiloxane (PDMS)

7. Waiting until our PDMS mixture is cured, then remove this PDMS mold from the wafer.

Figure 7. Solid PDMS

8. After getting mold, we will peel out our pattern by using tape. According to the resistivity for our senser, we will peel out several times for getting ideal resistivity.

Figure 8. Tape for Sensor

For designing electrocardiogram (ECG) sensor, we will use pressure sensor. The step for making the pressure sensor is almost same with mobility sensor. However, the way each device measures is different.

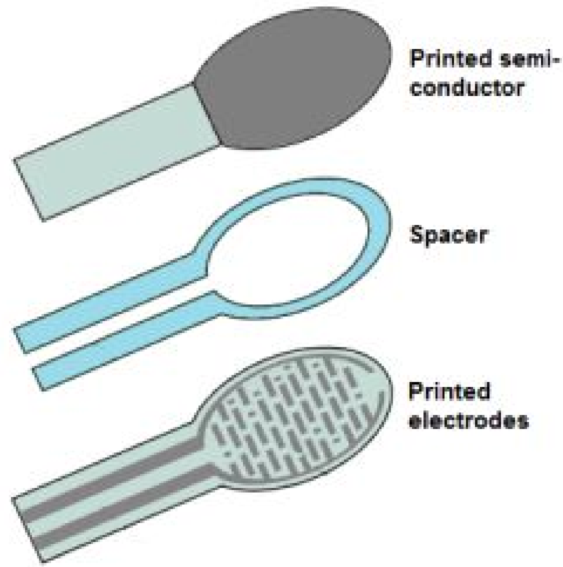

Figure 9. The Basic Principle for Measuring ECG

Through same steps with mobility sensor, we can get printed electrodes. However, at this time, it does not have to be stretched, so pattern may be more simple than the mobility sensor.

First, above our printed electrodes like carbon material, put some non-conductive material like rubber, then above this material we put semi-conductive material, like silver.

If we give some pressure on semi-conductive material, the resistivity area on non-conductive will be increased, so resistivity will be decreased. However, if there is not pressure on semi-conductive material, the spacer will have much space, so resistivity will be increased.

Using this change of resistivity, we can apply at ECG sensor, because pressure by heartbeat will be changed continuously.

The client had a general idea of what the circuits should be like so initially it was thought that it would be better to utilize our time working on the manufacturing processes. Since the project is more research based, the client redirects the path of the project as they see fit. In this regard, the focus of the project shifted from its manufacturing aspect to its design aspect.

The manufacturing problem will be tackled later as we have a clearer picture of how exactly the sensors will operate; however, this could present problems in the future if our design requires something that is later found out to be unfeasible. This would require tweaking the design, which could bring about a major complication if this ‘tweak’ requires a fundamental change of the design. It is indispensable that we keep our manufacturing capabilities in mind while designing our circuits. This will be challenging as the manufacturing process is not completely designed or developed. Nonetheless, since we got insight into what the manufacturing process will be like with the equipment available, if we revisit the manufacturing process as we move forward with the circuit design, we could anticipate any issues before they arise.

There is a plethora of literature to be reviewed as we finalize the circuit design. This will mainly be limited by the budget and scope of our project, since a lot of the available literature is a product of research funded with large grants. We anticipate the 'final' circuit design to not be final as it will most likely be revisited as we finalize the manufacturing process. In turn, the manufacturing process will also require some change depending on how the circuit design changes. It will most likely be an iterative process until an optimal solution is reached.

To properly begin development on the mobile application we needed to put together a quick prototype that has similar functions to the various wearable sensors. Using a Raspberry Pi 3 device, a bread board, and several sensors which provide readings such as ECG, accelerometer, etc. The prototype is to be tested as we are just now receiving the necessary parts, however, some concerns regarding the prototype is the lack of sweat monitoring sensors. The sweat sensors exist - however the price of such a sensor far outweighs any good it could provide.

Figure 10. Raspberry Pi 3

We believe that the prototype is essential for building a robust, initial version(s) of the mobile application, otherwise the software engineers would have to wait until we have a final wearable developed; which would not allow enough time to develop a usable, tested application.

The strengths of the Raspberry Pi 3 prototype

- Provides a cost effective solution to create a robust mobile application
- We can create multiple prototypes and compare the data to find potential outliers when reading data

The weaknesses of the Raspberry Pi 3 prototype

- We may not be able to test the sweat monitoring portion of the application due to cost constraints
- The prototype is extremely bulky making accelerometer data a difficult task to record and retrieve data

3. Testing and Implementation

3.1 Interface Specifications

A large part of this project is the interfacing between the ultra-thin wearables and the application used to monitor this data. We will need to be able to send, receive, decode, and interpret the data from each sensor effectively and accurately, all in real time with minor delay.

Each of the different sensors will be communicating with the users mobile device, and the data will be stored locally in a native application (Android/iPhone). Both devices support and will use bluetooth to receive the data from an integrated bluetooth chip in the respective sensors. The data will be sent through a secure channel and then, using provided medical algorithms, made readable and inserted into easily understood charts.

We have been provided algorithms for calculations relating to the raw data as well as use of a lab where we can validate our readings against the actual outcomes of the test. Since the goal of this project is to scale down the sensors into an ultra-thin easy to use wearable, we will have outside resources that are currently in practice to compare our research to.

3.2 Hardware and software

In order to test our design we will require a number of hardware and software solutions for the problems we intend to solve. All of the hardware has either been provided by our client or has been approved for purchase through an Iowa State sponsored channel. The software is available for free and we do not foresee needing to purchase or obtain any software with further effort than a simple download. We have been provided access to several labs in which there is equipment we can make use of for testing for free when it is required.

Hardware

- Spin Coater

  To spin wafer after applying materials, to spread the materials equally.

Figure 11: Spin Coater

- Multimeter

  The sensor (after fabrication) needs to test resistance depending on conditions to collect raw data. The multimeter will assist with resistance testing.

Figure 12: Multimeter for resistance testing

- Stepper/Scanner

  Using UV light on silicon wafer to verify positive photoresist or negative photoresist.

- Raspberry Pi 3 Prototype

  The Raspberry Pi 3 will be connected to a breadboard which will contain either a heartbeat sensor or accelerometer. The built in bluetooth on the Raspberry Pi 3 will assist in testing the transfer of data (testing bluetooth). The various sensors on the breadboard will be a prototype/simulation of the sensors which are to be developed by our hardware team. The sensors to be connected to the breadboard will be heartbeat monitor and accelerometer, which are accessible in our clients lab.

Software

- Intellij IDE

  The Intellij IDE contains a suite of extremely useful tools, which are all conveniently free to students. The IDE is easy to setup and requires very little technical knowledge, also the support team at Intellij is extremely helpful and the active community leaves barely in questions to be answered. The Intellij IDEA IDE natively supports useful plugins such as Maven (dependency manager), Kotlin (used for Android development), and allows for easy debugging for each of these tools.

- Xcode IDE

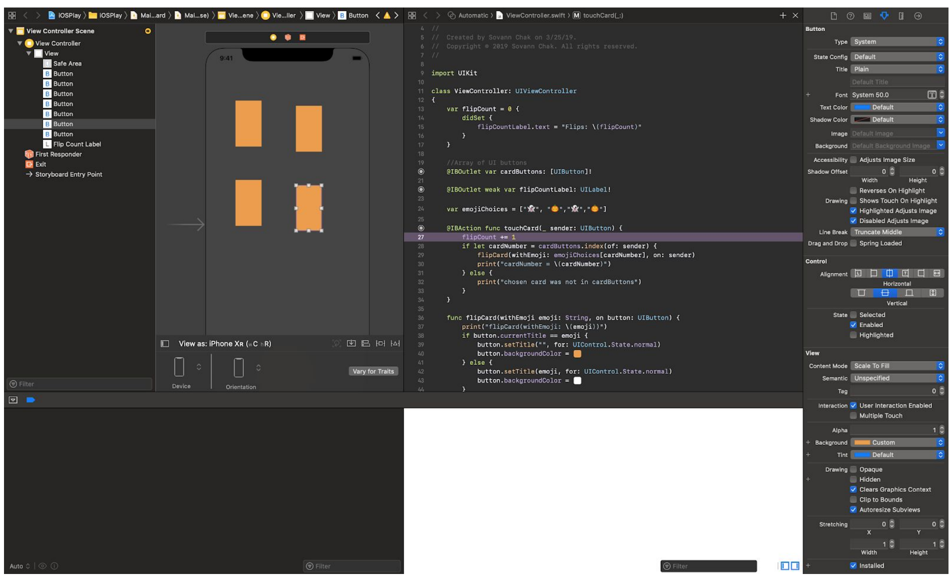

Figure 13. Xcode IDE

  The programming language used in development for iOS devices is Swift (backwards compatibility with Objective-C) . This language will be used for developing an application to monitor the data received from the sensors and making it human readable. The best IDE for iOS/Swift development is Xcode, it has a debugger and extremely helpful tools regarding all things Swift.

- Android Studio

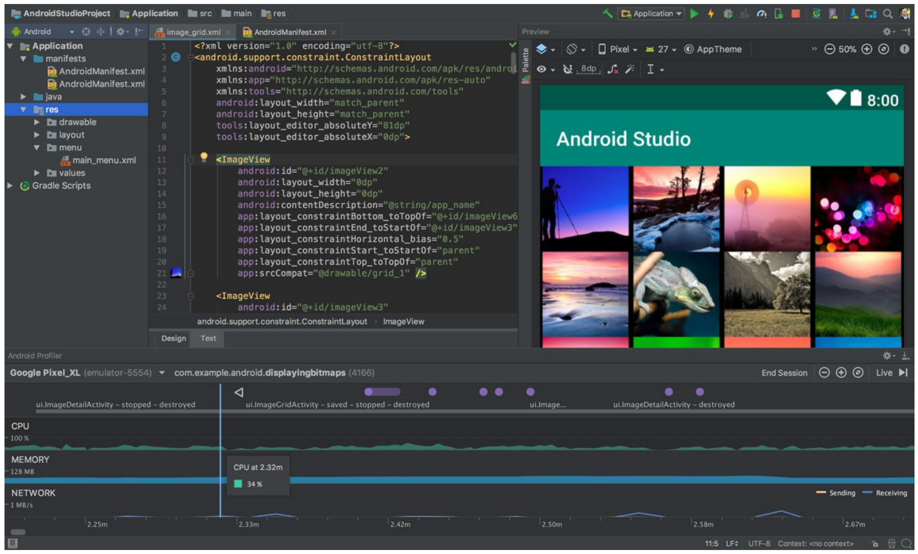

Figure 14. Android Studio

Google built an extremely useful add-on for the Intellij IDE which streamlines Android development for easier code completion, debugging, and quick testing. This add-on is called the Android Studio.

3.3 Functional Testing

The functional requirements are listed in Tables 1 and 2 and will be referred to in the following section.

Test	Required Result	Test Status	Corresponding Requirement
UTWT.1	Sensor placed on over left breast detects heartbeat and transmits data	Not attempted	UTW.1
UTWT.2	Sensor placed over knee shall transmit different readings when the knee is moved	Not attempted	UTW.2
UTWT.3	Sensor placed on armpit shall transmit data when user's sweat makes contact	Not attempted	UTW.3
UTWT.4	Drastic change in knee acceleration sensor shall be detected as a serious fall	Not attempted	UTW.4
UTWT.5	The bluetooth chip on each of the respective sensors shall be transmitting data constantly while connected to	Not attempted	UTW.5

	mobile device		
UTWT.6	Flexible enough to match the natural contortions of human skin without damaging sensors	Not attempted	UTW.6
UTWT.7	Low power to sustain multiple days of usage (up to a month)	Not attempted	UTW.7

Table 3: Table for the functional tests of the ultra-thin wearable (hardware)

Test	Required Result	Test Status	Corresponding Requirement
MAT.1	Data shall not be transmitted outside of the communication between mobile app and sensors	Not attempted	MA.1
MAT.2	Data shall be read when connected to sensor via bluetooth (up to 3 simultaneous connections allowed)	Not attempted	MA.2
MAT.3	Infographics on mobile application shall contain real-time data interpretations	Not attempted	MA.3
MAT.4	Data shall be saved locally	Not attempted	MA.4
MAT.5	Easy to understand infographics due to usage of medical algorithms	Not attempted	MA.5

Table 4: Table for the functional tests of the mobile application (software)

UTWT.1 Procedure, UTWT.2 Procedure, UTWT.3 Procedure:

1. In a lab environment, place sensor on the designated area (breast plate, armpit, knee)
2. Assure data is being read from sensor by viewing raw data on raspberry pi terminal

UTWT.4 Procedure:

1. In a lab environment, place accelerometer sensor on a subject's knee
2. Instruct user to move knee with sensor at specific time intervals (i.e. user bend knee at t0 and unbend knee at t1)
3. View the log for the accelerometer sensors to assure that the data at the specific time intervals is indeed different

UTWT.5 Procedure:

1. Connect each sensor to mobile device with bluetooth at a specific time
2. Stay connected for some random interval of time

3. View the logs on the mobile application at the specific and random time interval to assure data communication via application and sensor system

UTWT.6 Procedure:

1. In a lab environment, place the sensors on the designated areas (breast plate, armpit, knee)
2. Have the subject wearing the sensors to various physical activities such as stretching, running, and light lifting
3. Repeat test cases UTWT.1 - 5 and assure each test is successful

UTWT.7 Procedure:

1. Place a sensor in one of the designated areas (breast plate, armpit, knee)
2. Leave the sensor on skin for multiple days
3. Attempt bluetooth connection

MAT.1 Procedure:

1. In a lab environment, place sensor on the designated area (breast plate, armpit, knee)
2. Attempt to access data outside of bluetooth connection with mobile device (Bluetooth sniffing)

MAT.2 Procedure:

1. In a lab environment attach the 3 sensors to a person in their respective areas
2. Connect each sensor individually to a mobile device
3. Observe data output from sensors

MAT.3 Procedure:

1. Attach sensors to respective areas on a subject
2. Observe data output within mobile application
3. Ensure data is being transmitted in real-time through time logs of received data

MAT.4 Procedure:

1. Gather and store data through other tests
2. Access data stored through mobile application

MAT.5 Procedure:

1. Graph data in mobile application
2. Present to client to ensure infographics are understandable to a necessary degree

3.4 Non-Functional Testing

Test	Required Result	Test Status	Testing Category
UTWT.8	Accuracy of the heartbeat sensors is	Not attempted	Performance

	>95%		
UTWT.9	Serious fall detection is >99%	Not attempted	Performance
UTWT.10	No more than 10% error for the electrolyte measurements	Not attempted	Performance
UTWT.11	The device should not shock the user	Not attempted	Security
UTWT.12	The device should never irritate the skin (due to chemicals in the adhesive)	Not attempted	Security

Table 5: Table for the non-functional tests of the ultra-thin wearable (hardware)

Test	Required Result	Test Status	Testing Category
MAT.6	Data shall be interpreted in at most 1 seconds	Not attempted	Performance
MAT.7	Mobile device shall receive data from connected bluetooth stream in at most .25 seconds	Not attempted	Performance
MAT.8	Mobile application shall be accessible from iOS or Android mobile devices	Not attempted	Compatibility
MAT.9	Data shall be saved locally for x amount of time (x is decided by user)	Not attempted	Security
MAT.10	Data shall be deleted at user discretion	Not attempted	Security
MAT.11	Mobile application shall not hang during computations	Not attempted	Usability

Table 6: Table for the non-functional tests of the mobile application (software)

UTWT.8 Procedure, UTWT.10 Procedure :

1. In a lab environment, connect user two sensors, one being our sensor and a commercial product
2. Obtain some time interval of data t for both sensors
3. Record data into excel spreadsheet
4. Compare data

UTWT.9 Procedure:

1. In a lab environment, connect an accelerometer sensor to a test subject in the designated area (knee)

2. Obtain a soft (padded) surface
3. Have the subject conduct a series of serious falls

UTWT.11 Procedure, UTWT.12 Procedure:
1. Review our design of the sensors
2. Assure that our product follows the IEEE standards of biomedical devices [1] (these standards provide guidelines to avoid issues of user hazard for our device)

MAT.6 Procedure:
1. Obtain data from previous tests
2. Run data through algorithms to produce infographics
3. Time the duration of the program that is producing infographics

MAT.7 Procedure:
1. Attach each sensor to a user in intended place
2. Have user make different movements
3. Compare the time each movement happened against the time that the mobile device received each point of data

MAT.8 Procedure:
1. Download application from both iPhone and Android devices
2. Access the application and the various features

MAT.9 Procedure:
1. Save data for x amount of time (user specified)
2. Attempt to observe data past x point of time

MAT.10 Procedure:
1. Save data to users mobile device
2. Request to delete data (stored locally)
3. Attempt to view data which was deleted

MAT.11 Procedure:
1. Using static analysis tools (such as Atlas available through the University) to run an analysis on our source code
2. Review computationally heavy aspects of the code (i.e. medical algorithms running in real-time)
3. Follow concurrency standards of iOS and Android development

3.5 Process

The functional and non-functional testing can be grouped together, as many of the tests overlap - with the non-functional tests simply providing a more quantifiable outcome. There is a sequence in which we will test our sensors and mobile application, touched on lightly in section 2.

The Prototype

A prototype will be built which simulates many of the functions of the sensor system which is being built. These functions include bluetooth communication, accelerometer, ECG readings, and potentially sweat monitoring (depending on the technology provided to us by the client). These functions will help us test the mobile application to assure we a providing accurate translations of raw data provided to the application via bluetooth signals. The initial API we build for applications will include logs with timestamps so we can have an accurate reading of data and the time is retrieved from the bluetooth streams. From there we can view thousands of data points and compare and contrast with commercial products provided to us in the clients lab (which are solely for testing purposes). Once we are sure the prototype is correct, we can begin doing various detailed tests on the mobile applications.

The Mobile Application

Using the logs discussed shortly in the previous paragraph, we can now have large sets of data (which we know is fairly accurate) and with this data we can graph it and compare it in excel with other sets of data to figure out if our application is becoming bottlenecked at specific times or in specific cases. We an also assure the accuracy of our data by using excel spreadsheets to compare data with the commercial products. Once we are sure that the mobile application is meeting its functional and non-functional goals, we can use it to test the actual sensor system once it is finished.

The Sensor System

Now we have a relatively accurate prototype, multiple commercial products for testing purposes, and a solid mobile application foundation to begin testing on the sensor system, using archived data we can now compare and contrast data between the sensor systems’ data and the archived data from the prototype and commercial products. Once we are sure we are hitting our functional test goals - we can begin optimizing to meet our non-functional test goals as well as potential optimizations of manufacturing goals.

To reiterate, this project lays heavily towards research rather than an end commercial product and due to the nature of this project our end goals may change a focus may once more be shifted towards optimizing manufacturing over an actual working sensor system. It is in the hands of or client, Liang Dong.

Flow Diagram

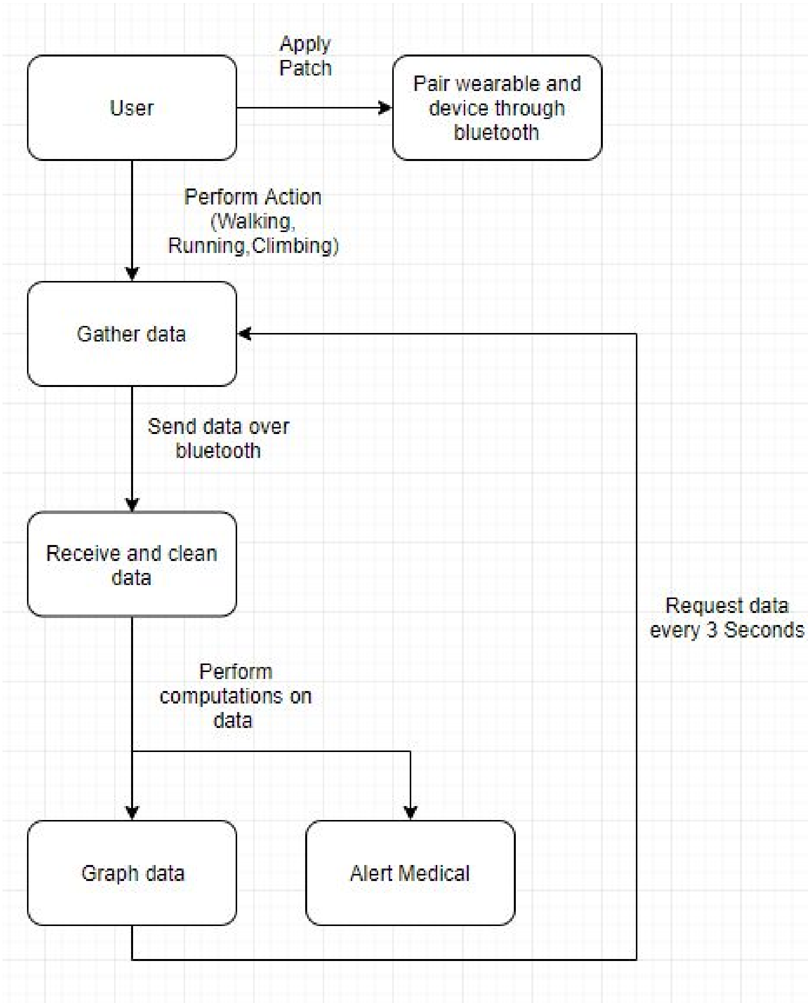

Figure 14. Flow Diagram

The flow diagram (Figure 14) is how we believe the flow of data will occur at the completion of our project. It is a generalized data flow for each of our sensors within the system communicating with our mobile application.

3.6 Modeling and Simulation

Software

Xcode 10.1 and Android Studio are the integrated development environments (IDEs) we will be using to develop our mobile application. A core feature embedded in these IDEs is the ability to simulate actual phone devices and simulate the program we are working on, on these simulated devices. With these models we are able to refine our designs before the actual porting of our application.

Hardware

The prototype we are building for testing the mobile application is meant to simulate the ultra-thin patches. The prototype will contain bluetooth compatibility as well as an accelerometer and heartbeat detection. This allows the software team to work in parallel with the hardware team, and at the end of next semester we can interface our products. A working prototype will assist in the exposure for the software team which is essential to a smooth integration.

3.7 Results

We are currently in the research stage of our project and are currently learning what we need to do in order to complete a project of this magnitude. We have not had the opportunity to test aspects of our project since we are still developing the ultra-thin wearable. Once we have a functioning build we will continue to run the tests we have laid out in previous sections and address any challenges we have while implementing our design of an ultra-thin wearable.

The test conditions we have developed will most likely be examined with a series of practical tests where we are actively using the ultra-thin wearable while monitoring it. This will ensure most of the functional requirements fall within expected limits. One person in our group will wear the sensor and perform different tasks while the others are checking to make sure the functional requirements are met, for example detecting a fall and transmitting data once the sweat sensor comes in contact with the users sweat.

Using the data from the functional tests we can then look towards the non-functional requirements and inspect the time stamps and data logs to ensure that the sensors and data are meeting the requirements we have laid out. These nonfunctional tests are going to have a greater emphasis on generated test cases to ensure over a large volume of use the ultra-thin wearable remains as effective as intended.

These two approaches are a good blanket and will cover most requirements for when we are able to begin testing. Some different approaches may need to be developed in special cases such as data being interpreted in less than a second., however, these special cases are far enough out of the current scope that we will not need to address them for quite a while. This will give us a chance to brainstorm and note possible solutions to the unique tests we will need to perform.

Although we have not begun the implementation process yet we foresee a few challenges that may arise. The wearable will be newly developed and thus we may need to go through several iterations of design before a fully functional network of devices is made. Creating a process and turning it into a “science” in order to fully understand where a problem is happening in the chain of steps to create the wearable will be a challenge that once overcome will be extremely useful in diagnosing any problem we may encounter. Another challenge that must be overcome is the interconnectivity of the sensors and the need for them to behave as a single unit with separate parts. Allowing the sensors to communicate freely with the mobile application while having almost no knowledge of the other sensors will be an issue we will need to work through. Connecting all of these pieces and getting them to run smoothly is going to present a challenge to everyone involved in this project.

4. Closing Material

4.1 Conclusion

Our work so far has been ordering parts and rigorous research to find the best path towards a solution. A solid plan of action has been decided amongst team members with the help of our client, his resources, and his graduate teaching assistant.

Our main end goals are to

- Develop a solid prototype for testing and development purposes
- Create at least one solid application which can interface with a fleshed out sensor system via bluetooth
- Establish a successful communication between various sensor bluetooth streams and a mobile application
    - Successful meaning, providing a useful and meaningful data and an application which provides easy to read graphics and a friendly UX
- Establish at *least* a rudimentary manufacturing processes for the ultra-thin wearables

So far we have a solid plan of action, develop the prototype. Then develop the initial mobile application(s) while the sensor system is being designed and implemented. Begin our testing on both the mobile application(s) and the prototype. Then once the sensor system is complete, we need to hook up the application(s) with the sensor system and continue testing, refining, and, polishing. Initially we were going to focus on the manufacturing process, however, we would never actually have a sensor system until late in the *second* semester. So we switched our focus towards a more product based result, allowing us more time for testing on both mobile application and the wearable.

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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