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D-Health Solution Inc.

Mar 6th, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 440W Design Specification for Health Reporter

Dear Dr. Rawicz

Attached below is the design specification for "Health Reporter", which is a health condition sensing device. We are designing a platform to provide diagnostic report and emergency notification to the clients about their health conditions. This device will give the possibility for clients to perform regular health check-up on their own instead of going to a clinic.

Our Design Specification describes the proof-of-concept model of Health Reporter. Also future development possibilities are discussed. All our team members will utilize this document as a reference for designing, developing and testing our product.

D-Health Solution Inc. is aiming to provide simple and convenient medical solutions to patients by developing Health Reporter system. We are formed of five engineering students: Jue(Carter) Chen, Simone Liu, Janice Mardjuki, Kai Geng, and Xing Qiao. If you have any questions or concerns regarding to our project, please contact me at 604-728-7157 or by email at carterc@sfu.ca.

Yours Sincerely,

Jue Chen

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CEO
D-Health Solution Inc.

Design Specification for Health Reporter

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Executive Summary

This design Specification demonstrates all the detailed descriptions for the design and development of Health Reporter at the proof-of-concept stage. Functional requirements marked as I and II, which was created in the *Functional Specification for Health Reporter* [1], will be discussed in this document. Additionally, some future research and development possibilities will be contained in this Design Specification.

At the proof-of-concept stage, which will be discussed in this document, there are five sensors with six set of data will be implemented. All sensors are sending out analog data sequence through Analog-To-Digital Converter and finally reach the raspberry pi, which will functioned as medical data analysis system. Five sensors are Patient Position Sensor, Air-Flow Sensor, Galvanic Skin Sensor, Pulse and Oxygen in Blood Sensor and Body Temperature Sensor. All sensors should be attached to the human body in order to make sure the Health Reporter maintains proper functionalities. Web Application and mobile application will be included in the deliverables to the customer. Therefore, only some led lights will be integrated to our device in order to provide the information on whether Health Reporter is working or not in an easily readable manner.

This Design Specification will also include the information and requirement on selecting the proper sensors, analog signal receiver, Analog-To-Digital Converter and data analysis platform. Software development and testing cycles will also be discussed in this document.

The completion date we set up at the beginning of the development cycle is sufficient for completing the Health Reporter. There will not be any change on the final release date.

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Acronyms

GPIO	General-purpose input/output
A/D	Analog-to-digital
LED	Light-emitting diode
BJT	Bipolar Junction Transistor
IRQ	Interrupt Request
HTTP	Hypertext Transfer Protocol
TCP/IP	Transmission Control Protocol / Internet Protocol

Glossary

"Health Reporter" Patients	"Health Reporter" Patients should have the following abilities · Patients should not have Contact Dermatitis · Patients should be psychologically fit to have additional electronic parts attached to their body
WiFi	Any wireless local area network product that is based on the IEEE 802.11 standards
XBee	The brand name from Digi International for a family of form factor compatible radio modules
Web Server	An information technology that processes requests via HTTP
MySQL	The world's second most widely used relational database management system
Apache Tomcat	An open-source web server and servlet container developed by the Apache Software Foundation
A database schema	A way to logically group objects such as tables, views, stored procedures etc.
Privilege	The delegation of authority over a computer system
JDBC	An API for the Java programming language that defines how a client may access a database
Raspberry Pi	A series of credit card-sized single-board computers

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1. Introduction

The Health Reporter is an integrated body monitoring system, which is developed for reporting and analysing body condition daily. At proof-of-concept stage of Health Reporter which is discussed in this document, there are five sensors with six sets of data implemented and integrated to the system. Sensors detect body temperature, skin condition (sweating or dry), body position, heart rate, breathing rate and oxygen in blood rate. Additionally, patient can view their body condition data and analyzed results from web and mobile application. For web application, all the parties with permission can log in to the website to view specific patient's report.

All development details and notifications are listed and explained in this design specification.

1.1 Scope

The design specification demonstrates all needed information for developing and testing the Health Reporter. This document mainly focus on proof-of concept stage of development. The design, development and testing shall follow the content in this design specification.

1.2 Intended Audience

The design specification is intended for use by all members of D-Health Solution Inc. during the design and development of the Health Reporter device. Development Engineers shall follow the design guidelines demonstrated in this document for completing all requirements of Health Reporter before final deadline. Quality Assurance Engineers shall utilize this document as a guidance for proceeding the testing cycle of Health Reporter and confirming all required functions perform properly.

2. System Specifications

Health Reporter will gather different type of medical data from the sensors which are attached to the human body. Then Health Reporter will transfer those data and analytical result to web and mobile application in order to give patient an easily understandable result.

Once patient has supplied AC with wall adaptor to Health Reporter, it will start working on capturing data from sensors automatically. Then, result will be updated on web and mobile application in every one second to give patient an update-to-date result.

3. Overall System Design

This section demonstrates the high-level system design and development details. Descriptions of design for individual parts can be found in their sections respectively.

3.1 High-Level System Design

This section demonstrates the high-level system overview of Health Reporter.
Figure 1 describes the data flow and relationship between different levels of system.

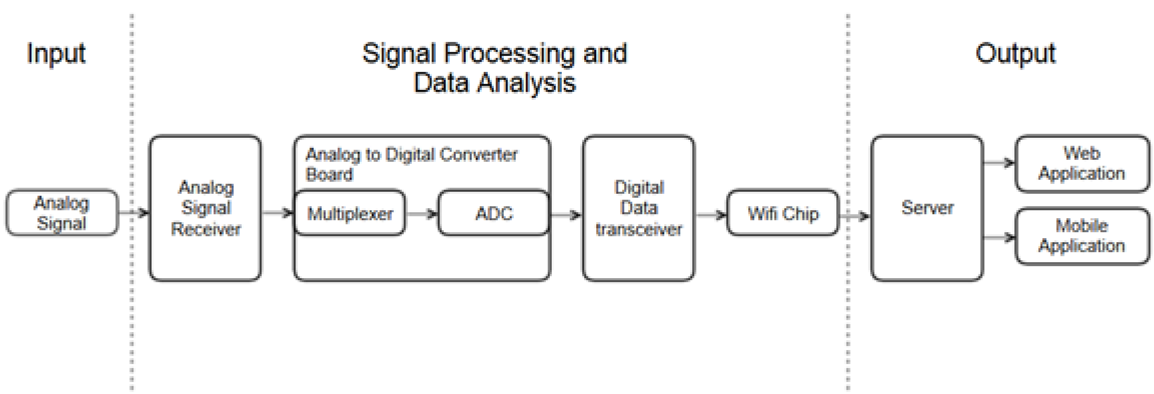

Figure 1: System Block Diagram

The only input to the system is the analog signal captured by sensors, which need to be attached to human body.

Once sensors start working properly, the main platform of Health Reporter takes over all signal and perform signal processing and necessary data analysis. This stage contains two microcontrollers and one single board computer.

Once all signals have been analyzed by the algorithm we developed, Health Report transfers the analyzed data to server through Wi-Fi Connection. After that, the web and mobile application function as User Interface in order to give the customer an easily readable expression of data and analyzed results.

3.2 Sensor Platform Design

Because the fact that the proof-of-concept stage will be carried out through the whole project of Health Reporter, only five sensors with 6 sets of data will be collected and analyzed by Health Reporter.

Here is the list for all sensors which will be integrated to Health Reporter:
1. Body Temperature Sensor
2. Pulse and Oxygen in Blood Sensor
3. Galvanic Skin Sensor
4. Air-Flow Sensor
5. Patient Position Sensor

Because of the fact that wireless medical sensors are still not available on market, the decision we made is to utilize wired sensors. Also wires of sensors have passed regular strength test in order to make sure sensors are working properly under normal circumstances.

All sensors are independent, this gives the possibility for customers to choose the specific information according to their preferences.

3.3 Firmware Design

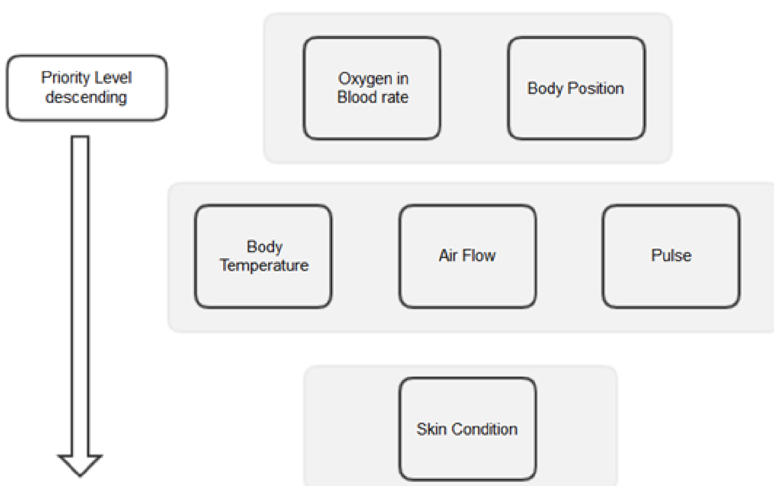

Figure 2: The priority level of data analysis algorithm

Figure 2 is the glance of how data analysis algorithm determines whether the patient needs immediate treatment or not. Because of the fact that all sensors are independent, patients may not attach all the sensors to their body. Therefore, we need at least two sets of data out six in order to make sure that the analyzed result is close to what the real circumstances are.

According to figure 2, we listed that rate of oxygen in blood and body position should be the two most significant information for the determination of emergency treatment. The reasons are:
1. If patient is falling down under unexpected situation, you may need immediate treatment from physician.
2. If patient's rate of oxygen in blood is too low (<90) because the patient's oxygenation is unstable. Patient may need for supplemental oxygen because human cannot live without constant oxygen supply.

There are three sets of data at the second priority level. Body temperature may varies because of the surrounding temperature change or regular physical motion. But still the body temperature will be a significant information when it reaches out of the regular temperature boundary.

Additionally, airflow rate associates with the oxygen in blood rate. Therefore when the patients' airflow rate is less than normal, the oxygen in blood rate will also decrease accordingly. Therefore the decision is to monitor the oxygen in blood rate as first level of priority and air flow rate comes to second.

The same theory applies to the pulse. This information varies due to surrounding temperature change or even limited physical and mental motion. Therefore it ranks in second priority level. The least important information is the skin condition. Because sweating is commonly happen during the human daily motion.

3.4 Server Design

Figure 3 illustrates the client-server communication model as well as the web server architecture. To setup web server, a web server application (e.g. Apache Tomcat) is needed to be installed on the host computer [1]. The server communicates with clients via HTTP request. Both Raspberry Pi and user machine are acting as web client. The application server will be implemented for supporting the construction of dynamic content and handling load balancing as application demand increases. The SQL database (e.g. MySQL) is built and located on the web server in order to store user information and data collected. MySQL will use JDBC driver to establish connection to web server [2].

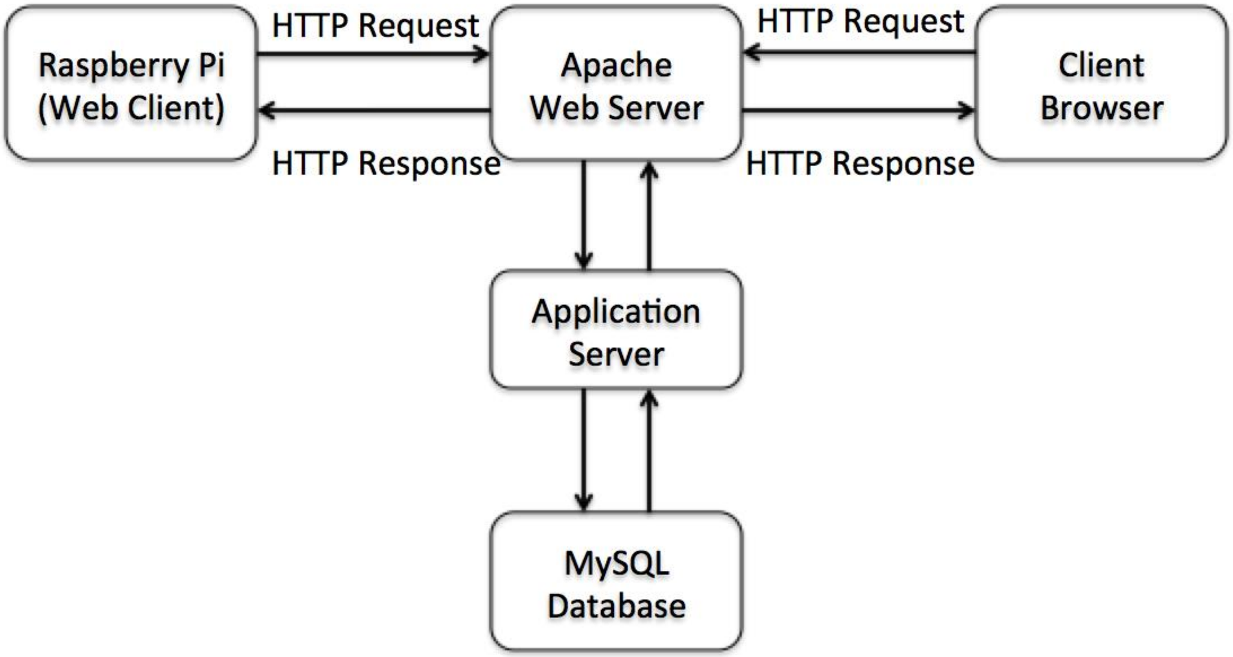

Figure 3: Client-server application framework

When measuring, Raspberry Pi will send HTTP request to server via either GET or POST method. CGI scripts running on the server process the request and read the data sent from Raspberry Pi. The data will be transferred and stored in MySQL database. The server then send back response message to the Raspberry Pi to indicate whether data is received.

When user requesting the data, the user machine (i.e. web browser) will send HTTP request to the server. The web server get the request and look up requested data from database. The scripting engine running on the web server processes instructions to create HTML page. HTML stream is then returned to the web browser. Brower processes HTML and displays page that the user requested.

4. Body Temperature Sensor

4.1 Sensing Mechanism

Body temperature sensor contains an analog device, which sends out voltage. Therefore, voltage is actually been measured from the hardware perspective.

4.2 Data Processing Mechanism

The data output of Body Temperature Sensor is analog voltage, which include voltage (+) and voltage (-) pin. Those two pins need to be connected to our analog signal receiver.

5. Pulse and Oxygen in Blood Sensor

5.1 Sensing Mechanism

Pulse and Oxygen in Blood sensor is more complicated. The LEDs in this sensor send out two waves which are red light spectra and infrared light spectra with 660 nm and 940 nm in wavelength respectively. These two waves go through the finger and measures the absorption coefficients of oxygenated Hemoglobin and Deoxyhemoglobin. The absorption coefficients is calculated when two light waves reach to the photo-detector which is integrated in this type of sensor. According to the fact that oxygenated hemoglobin has higher absorption rate at 940 nm compares to the 660 nm for a higher absorption rate of Deoxyhemoglobin, the sensor calculates the arterial oxygen saturation and the pulse from the information collected by photo-detector.

5.2 Data Processing Mechanism

Figure four illustrates the how analog signal from Pulse and Oxygen in Blood Sensor converts into digital form.

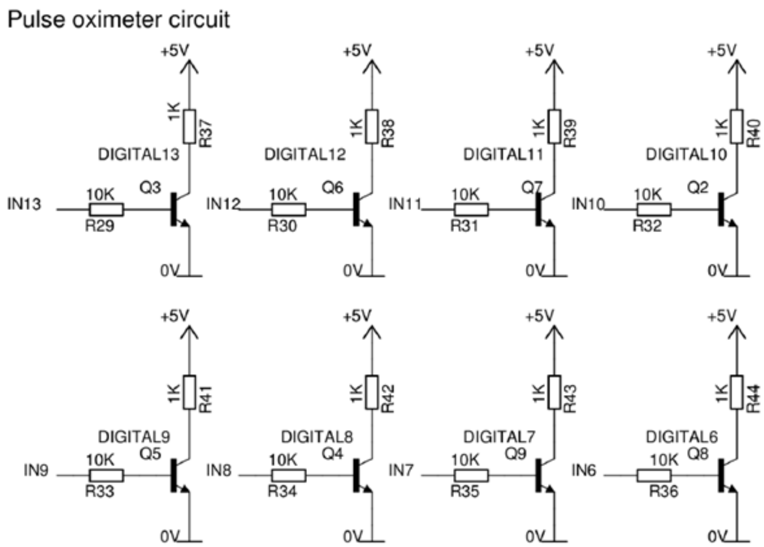

Figure 4: The digital switch circuit for Pulse and Oxygen in Blood Sensor [3]

Figure 4 illustrates the circuit for converting the analog signal to digital signal by BJT transistors, which perform as switches.

6. Galvanic Skin Sensor

6.1 Sensing Mechanism

The working principle of Air Flow Sensor is also just measurement of voltage because of the resistance change of semiconductor due to the change in the rate of airflow.

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6.2 Data Processing Mechanism

Figure 5 is the voltage amplifier Circuit of Airflow Sensor.

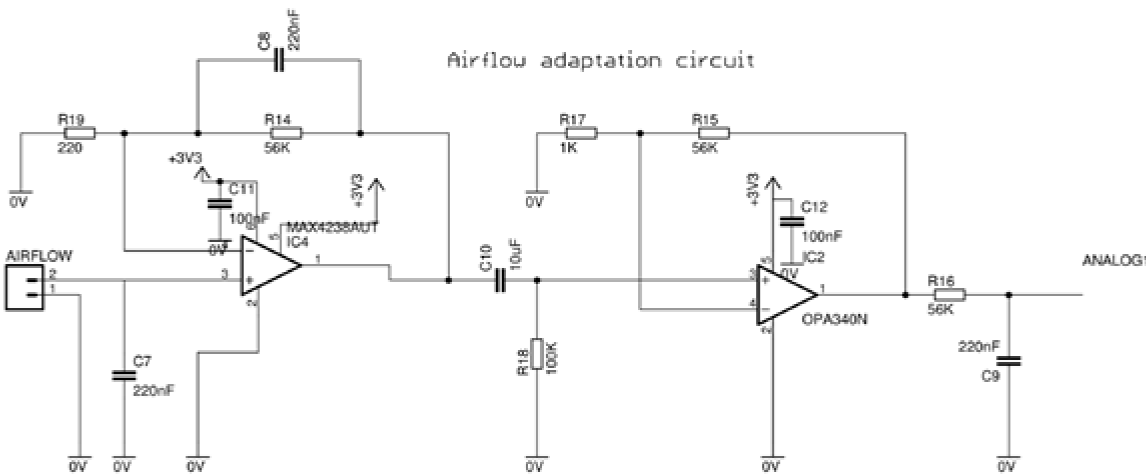

Figure 5: The voltage amplifier of Airflow Sensor

Because the output voltage of airflow sensor is not high enough for transferring to the A/D converter, therefore we need to apply the amplifier to amplify the voltage.

7. Air-Flow Sensor

7.1 Sensing Mechanism

Galvanic Skin Sensor is working by measuring the conductance change of the skin due to the change in skin moisture level. Also, the analog output is voltage.

7.2 Data Processing Mechanism

Figure 6 is the voltage amplifier Circuit of Galvanic Skin Sensor.

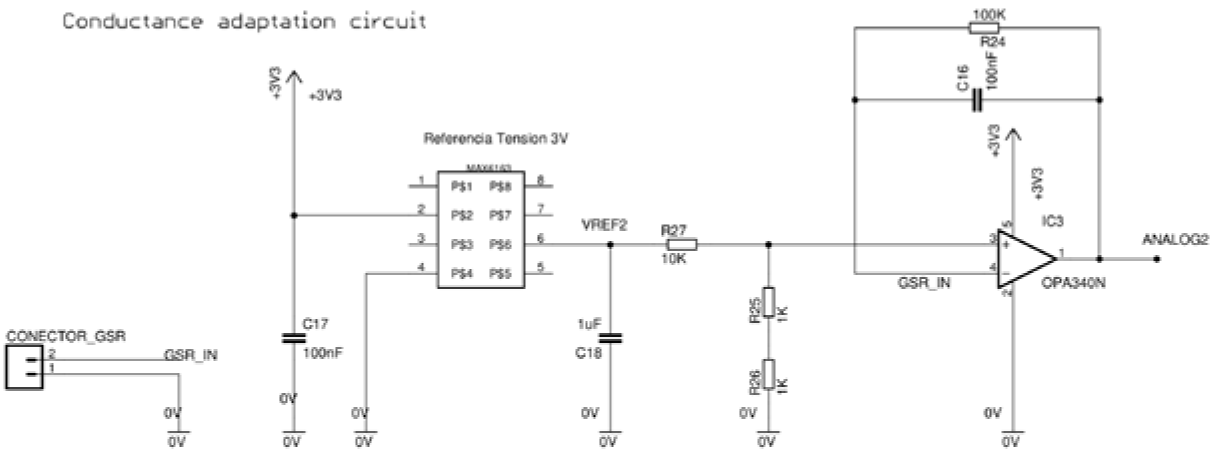

Figure 6: The voltage amplifier of Galvanic Skin Sensor [4]

The circuit shown in figure six amplifies the voltage output and eliminates the possible fluctuating noise from the measurement.

8. Patient Position Sensor

8.1 Sensing Mechanism

Patient Position Sensor contains a triple axis accelerometer to determine whether the patient is falling down or not. It contains its own algorithm analyzes the value in x, y and z axis from triple axis accelerometer.

8.2 Data Processing Mechanism

The data processing mechanism is the same as Figure 3, the Health Reporter has BJTs inside function as digital switch in order to convert analog signal to digital signal.

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9. Analog Signal Processing Unit

This unit contains a microcontroller with different types of connection pins in order to have a variety of sensors attach to it. Also, it has output pins to connect to A/D converter and this gives the possibility for other devices with only digital signal processor to utilize the data provided by analog device.

This unit includes two significant analog signal processing stages. The first stage is the analog signal amplification, the output signal of sensors are always voltages with low peak value, which are often not enough for other units or chips to perform analysis. Therefore we need to perform analog signal amplification before goes to other data analysis stage.

Another important stage is signal filtering. Because the signal is analog, there will be fluctuating noises happen during the measurement. Therefore, bypass capacitors are needed for several analog signal sensors.

10. Analog to Digital Converter Unit

This unit contains three XBEE RF OEM modules and one LTC2309 in order to convert analog signal to digital. This A/D Converter Unit takes the amplified and filtered signal and converts them into digital form. Then it transfers the digital data to the digital signal processing unit in order to perform further analysis.

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11. Digital Signal Processing Unit

In Health Reporter, Raspberry Pi model B+ was selected to be the digital signal processing unit because raspberry pi is a single board computer with enough processing speed for the data analysis for the project.

11.1 Control Hardware

11.1.1 GPIO Overview

Figure 7 illustrates the GPIO pins layout on Raspberry pi B+

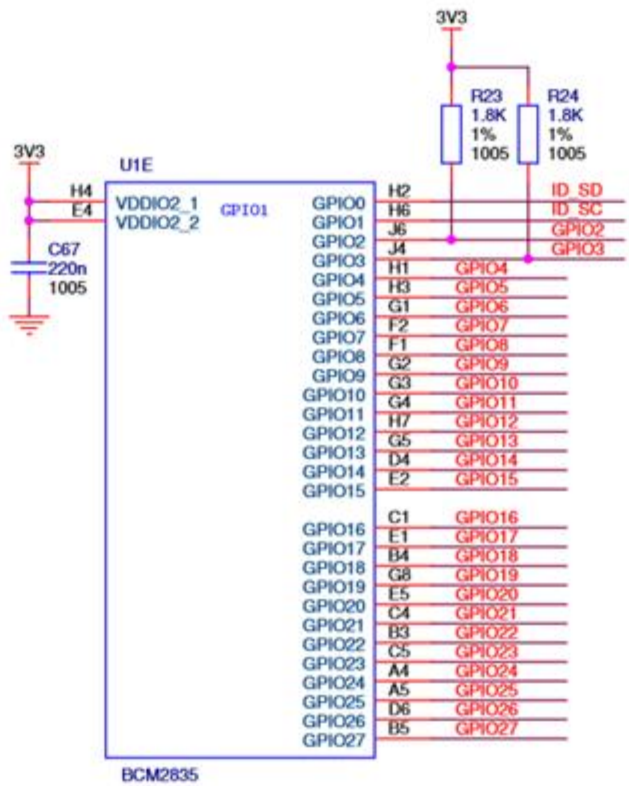

Figure 7: GPIO layout on Raspberry pi B+[2]

General-purpose input/output often refers as GPIO is a software-controlled digital signal, which are provided by a variety of chips. Each pin represents one associated bit in data sequences.

GPIO is the approach for embedded system to communicate with other devices through digital data sequences. GPIO only takes two possible readable values which are 1 and 0. When the pin receives voltage higher than 66% of the supply voltage connected to the pin, the GPIO takes the input value to be 1 and any voltage lower than 66% will result in 0 [3]. Additionally, the maximum supply voltage for GPIO on raspberry pi is 3.3V. Therefore, any voltage higher than 3.3V may results in faulty behaviors from GPIO pins. Also, the maximum current draw from power supply pin is 500mA. Any current higher than that results in the breakdown of the board.

11.2 Control Software

GPIO pins are hardware on board, it is necessary to utilize GPIO driver in order to get all data into software. Individual GPIO pins are identified by unique hardware number associates with each GPIO pin. Additionally, those hardware numbers are encrypted inside driver to make sure other programs cannot mess around GPIO pins[5].

Apart from unique hardware number associates to each GPIO pin, it also needs a global number in GPIO namespace in order to be identified by legacy GPIO interface.

After the identification process. Then we need a structure to manage the GPIO pins, which is “struct gpio_chip” with members described below:
1. Approaches to set up GPIO direction
2. Approaches used to collect GPIO values
3. Method to return the IRQ number associated to a given GPIO
4. Configuration flag saying whether calls to its methods may sleep
5. Debugfs dump method (showing extra state like pullup config)
6. Base number (each chip has a base number by default)
7. Label for diagnostics and GPIOs mapping using platform data

The GPIO driver needs to configure each gpio chip with adding or deleting gpio chip. But in real cases, deleting a gpio controller is rare.

Read/Write instructions can access the most GPIO controllers without sleep function needed. Also, hardware IRQ handlers. However, some GPIO controllers need to be accessed by SPI or I2C, which are message based buses. To deal with message based buses, it is necessary to have sleep function included because commands for reading/writing GPIO values need to be at the head of queue. Additionally, sleeping function cannot be done from hardware IRQ handlers[6].

With all the functions implemented above, GPIO pins can be accessed without crashing problems.

12. Server

Server is implemented to receive data from Raspberry Pi, store data to database server, process and format data using back-end Java application, and send the requested data back to the end user. The user are able to view the data if they have access privileges. The website includes three-tier applications, with web, application and database tier [7].

12.1 Client-Server Communication

An HTTP server is used to connect to HTTP client (e.g. web browser) via HTTP request over TCP/IP protocol. Apache Tomcat will be installed as web server. In additional to HTTP server, Tomcat also implements several Java Platform such as Java Servlet and JavaServer Pages (JSP) [8].

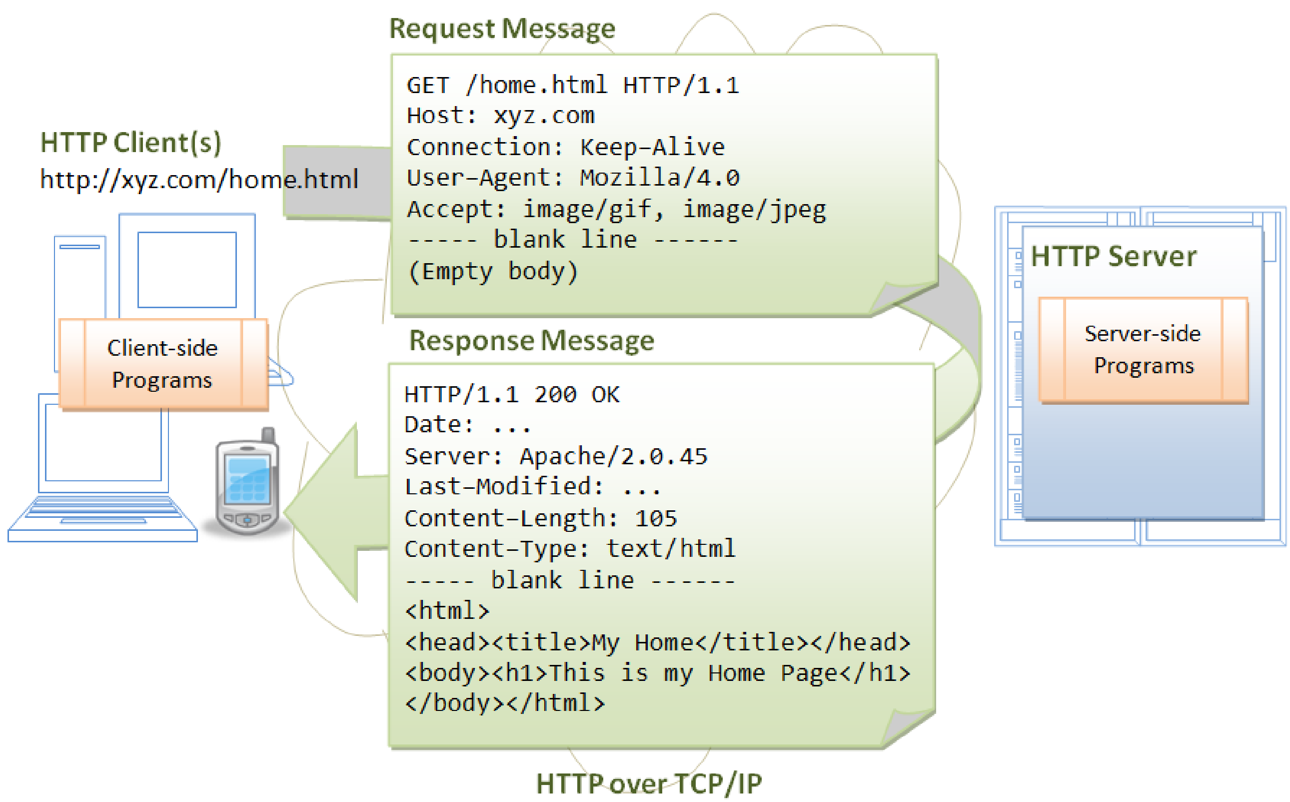

Figure 8. Client-Server Communication via HTTP

Figure eight above describes HTTP protocol running over TCP/IP. A client sends a request message to the server. The server then returns a response message to the client so that the client gets the page they requested.

12.2 Database Design

Database server is needed to store user data. In this project, MySQL database is implemented as a database server. Web server and database is connected using JDBC [9]. JDBC is a Java Database Connectivity Technology, which is a Java API to define how a client may access a database.

Database schema is used to describe relational database system structure. The figure shown below lists the database schema for storing user data. The user table stores basic information of the user, such as name, age, etc. as well as the emergency contact information such as doctor, hospital and relative. The critical_state field lists the current state the user undertaking, which can be used as a flag to notify the associate doctor and relative[10].

The record table stores record for each report, including user ID, date, and the corresponding measurements. The record can be accessed by joining user table and record table with user_id and can also be filtered by date, description etc[11].

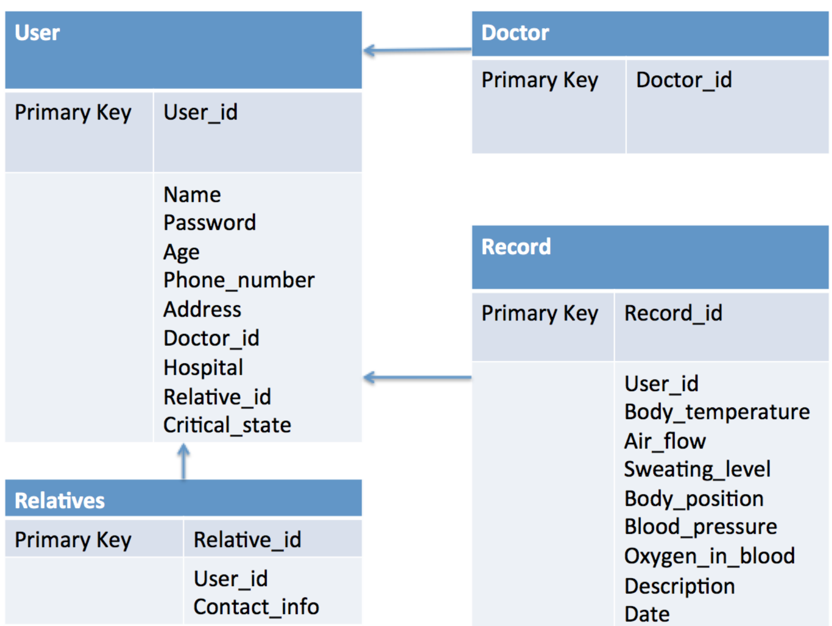

Figure 9. Database schema for application database

13 User interface software

The software will receive the data from the sensors and analyze them. The results involving users' healthy status and feedback will be displayed on the software applications.

13.1 Web Application

One software version is web application. Figure 8 shows a brief concept of web application. The home page will provide detail information of product to let users clearly understand product's functions [12]. Moreover, home page also includes a registration system so that users will be able to either sign up a new account or login an exist account. Users will go into the personal interface after login their own accounts. In the private space, users will be able to see their own healthy status with both digital and graphical representation and feedback [13].

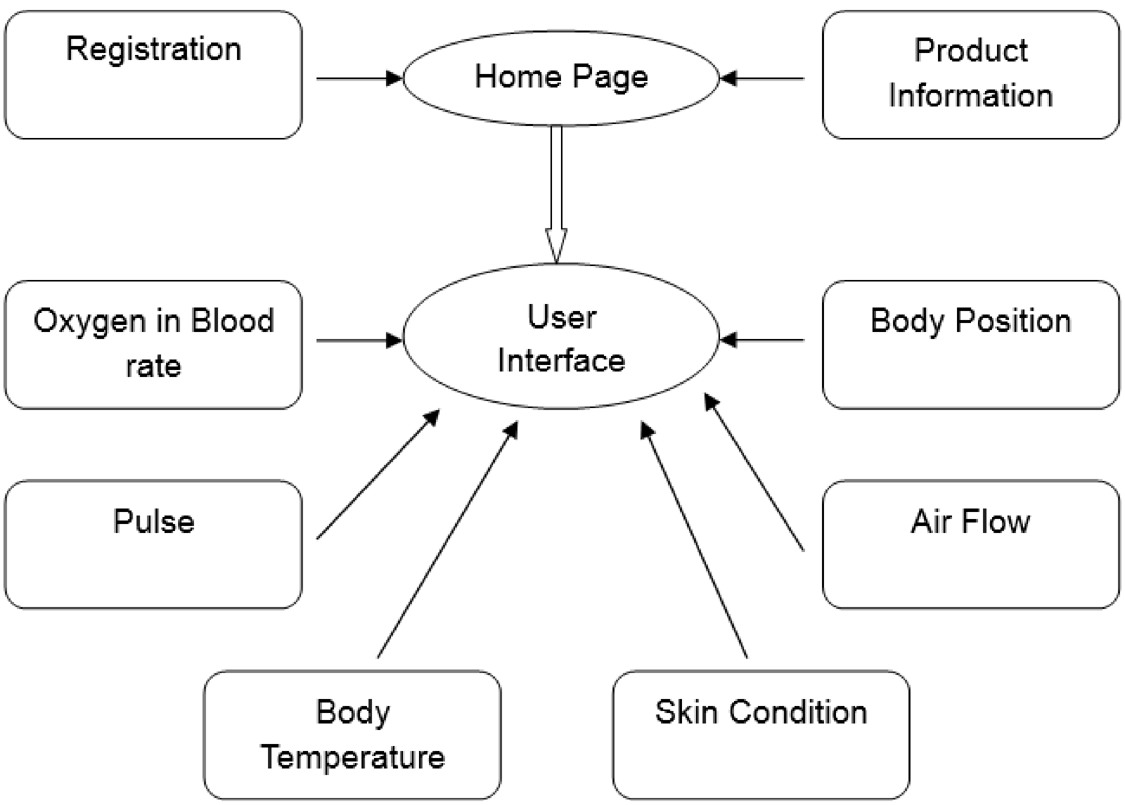

Figure 10: Overview diagram of web application

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13.2 Mobile Application

Another software version is mobile application. The features of mobile application are similar with web application but it will be convenient for users to check their healthy status in anytime and anywhere [14]. Figure 8 shows the detail information of mobile application. Login interface will let users sign up a new account or login an exist account [15]. As long as users login their accounts, main screen will provide different options for users to check the status they want. Below each option, users will be able to see all data and feedback. Moreover, mobile application will have a help center for assisting users to operate the application and a setting interface for managing the application [16].

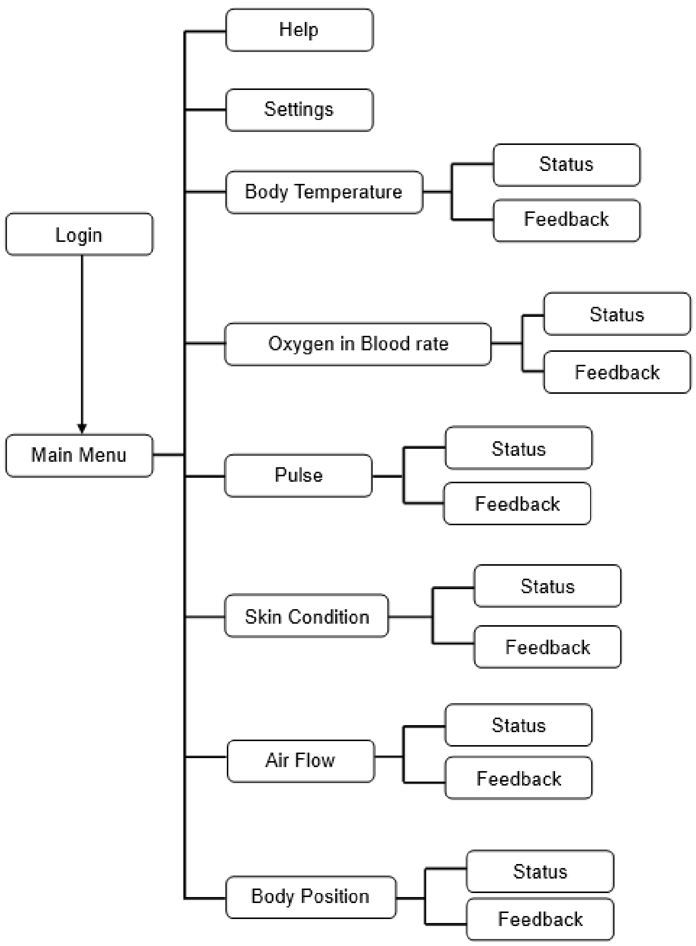

Figure 11: Flow Cart of Mobile Application

14. User Interface Verification

In order to ensure all the user interfaces are working properly, we are planning to perform the following test.

1. Led light indicates whether Health Reporter is working or not in an easily readable manner.
2. Push notification on mobile app while the client requires an extended care/attention.
3. Able to view the client’s data on web and mobile application.
4. Depending on client’s permission, other people might be able to access her/his data.
5. Each buttons on web and mobile applications performs according to their primary functions.
6. Time required to obtained the data is fairly short.
7. The designs must be clear, concise and easy to use.
8. Both web and mobile applications has to be stable enough to perform these features.
9. All the parts shall work consistently and properly without bug.
10. Ensure everything is connected and able to send the data properly [17].

15. System Test Plan

In order to make sure the positive feedback from the user after putting the Health Reporter into production, there are several test procedures need to be done before final release, including individual module testing and system testing.

15.1 Unit Testing

The first section will be the physical characteristics of our sensors. Due to the fact that all sensors are needed to be attached to the human body, we need to make sure that all materials for making sensors should not causing allergy in general cases. We first make sure the materials we utilized are generously accepted by public and then we will have some patients carry those sensors for a specific period of time and report whether there are unexpected feeling or not.

Additionally, all sensors are required to be waterproof. Those sensors will be putting into several level of watery condition in lab situation. After we have reached the pre-set level of waterproof for our sensors, we will need actual human to carry those sensors in raining or swimming condition. This procedure gives us the feedback of waterproof ability in excess physical motion of our sensors.

Because of the fact that wires are coming up with the design of our sensors, we will need to proceed to the strength test of different wires according to sensors individually. This test will be in performed in lab condition because it is easier to test the upper limit of the strength which can be exerted on our wires.

For our main platform which is the analysis platform. We will add the outer case for it when we enters into final production. Also, the case will be conducted to have three type of testing, which includes waterproof testing, bearing capacity testing and physical motion testing. However, before all those testing, we need to make sure the design of our outer case is outstanding over our competitors like Apple and Garmin. We will have our mechanical design team and marketing team carry out this task. After our case has positive feedback from users, we will carry out the waterproof testing and physical motion testing first because those two are general day-to-day usage cases. For physical testing, we will need to shake the platform which is sealed inside our case randomly in different orientations and still remain functionality. Waterproof testing is straightforward as its name. We will put the device under water with sensors attached to it and our device should perform as usual without any out-of-range failure. We will also carry out the bearing capacity testing for our cases in order to simulate some edge cases when users accidentally sit on our device or put some excessive mass on it. The bearing capacity should at least be 100kg in order to put main platform of Health Reporter excludes sensor platform into production.

After all those individual tests have been passed successfully, we need proceed to the system testing. There will still be same sorts of testing areas demonstrated above including waterproof testing, bearing capacity testing and physical motion testing. But in this testing level, we will put the whole system together both in our lab or carries by users. This procedure will make sure that our whole system will perform properly in daily usage with some edge cases included.

Because of the fact that the self-error handling system is integrated in our Health Reporter, we will also create some dummy error cases in our testing procedure in order to make sure that the self-error handling system works as expected.

15.2 Normal Case 1: All sensors are attached to patient's body correctly

User Input: Patient boots up the Health Reporter

Conditions: Patient's mental and physical condition is fit to wear sensors. All sensors have been attached to the patient's body correctly. Patient opens the Health Reporter website or mobile application.

Expected Result: There are data and analyzed results show on website and mobile application.

15.3 Normal Case 2: Sensors are not placed at the proper position

User Input: Patient boots up the Health Reporter

Conditions: Patient's mental and physical condition is fit to wear sensors. All sensors have been attached to the patient's body incorrectly. Patient opens the Health Reporter website or mobile application.

Expected Result: There are unexpected data and error messages show on website and mobile application.

15.4 Normal Case 3: Sensors are placed closely to each other

User Input: Patient boots up the Health Reporter

Conditions: Patient's mental and physical condition is fit to wear sensors. All sensors have been attached to the patient's body. Patient opens the Health Reporter website or mobile application.

Expected Result: There are data and analyzed results show on website and mobile application. There should not be any interference between sensors.

15.5 Extreme Case 1: Sensors are placed in a thin layer of water.

User Input: None

Conditions: Before putting into water, testing shall be done to verify whether sensors are working properly or not.

Expected Result: Utilize the Multimeter to measure the functionality of sensors. There should be no current leakage.

15.6 Extreme Case 2: Shake the sensors by specialized testing machine

User Input: None

Conditions: Before putting into machine, testing shall be done to verify whether sensors are working properly or not.

Expected Result: Utilize the Multimeter to measure the functionality of sensors. There should be no current leakage or other damage to sensors.

15.7 Extreme Case 3: Let the Health Reporter and associated applications running for 72 hours

User Input: Patient boots up the Health Reporter

Conditions: Patient's mental and physical condition is fit to wear sensors. All sensors have been attached to the patient's body correctly. Patient opens the Health Reporter website or mobile application.

Expected Result: There are data and analyzed results show on website and mobile application.

16. Conclusion

This Design Specification is proposed according to the requirements in Functional Specification of Health Reporter. All listed descriptions in design specification shall be carried out during the whole development cycle. During the test cycle, all required and extreme test cases will be performed in order to ensure the functionality of Health Reporter under normal circumstances. This design specification demonstrates all required details for the whole development of Health Reporter.

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Appendix A: System Schematics

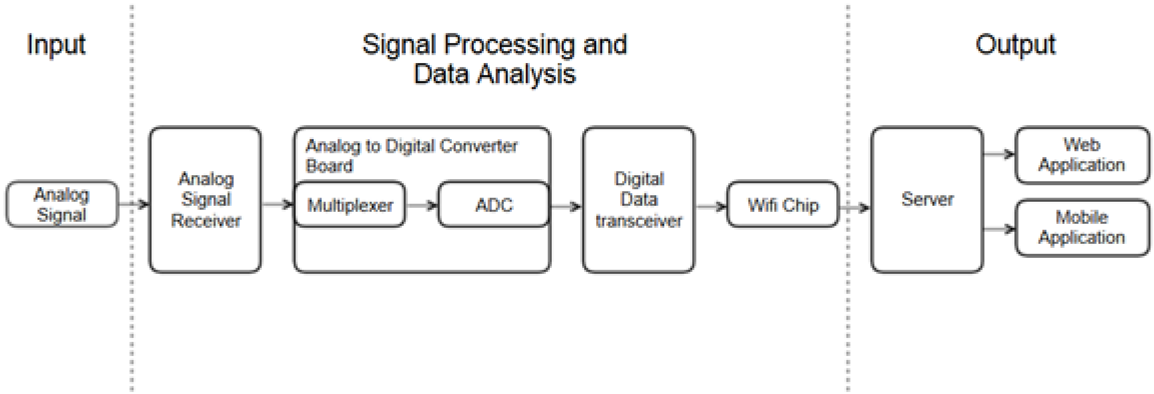

Figure 12: System Overview

Appendix B: Data Flow Diagram

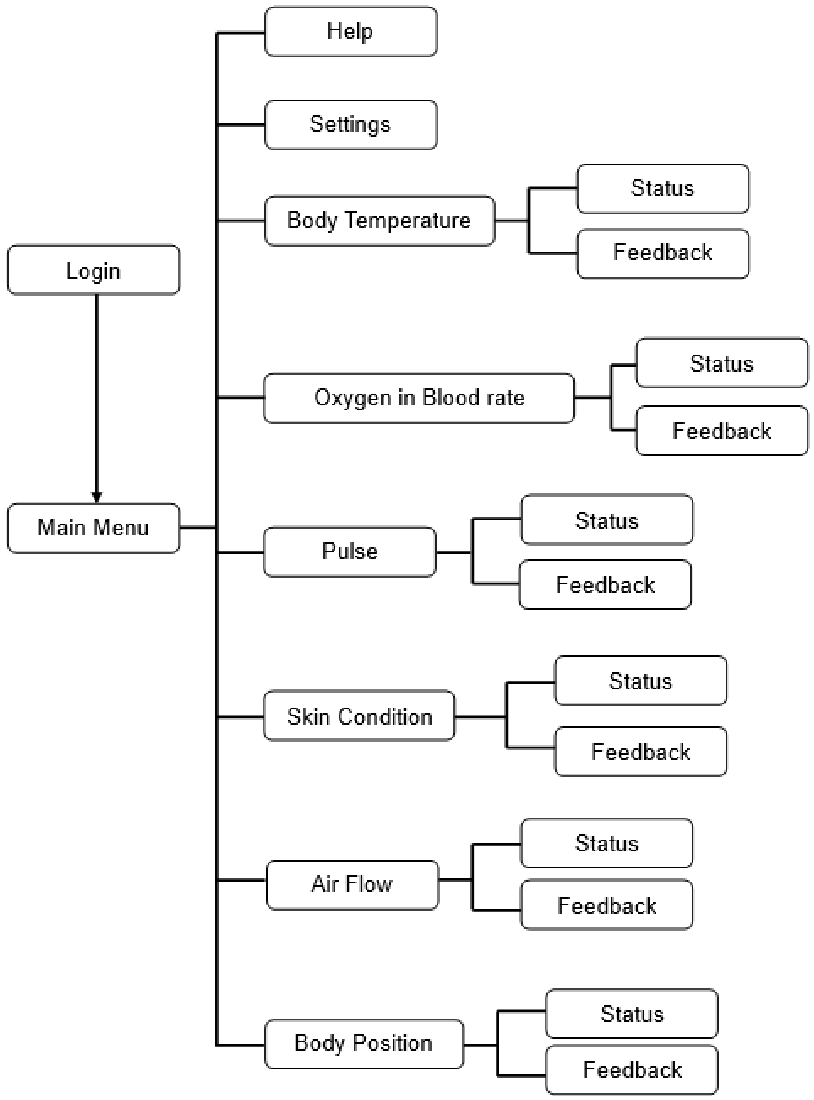

Figure 13: Mobile application Flow Chart

Appendix C: Test Plan

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Pulse and Oxygen in Blood Sensor	
Max load capacity: 500g ☐ Yes ☐ No	Comments:
Functionality: ☐ Yes ☐ No	

Patient Position Sensor	
Max load capacity: 500g ☐ Yes ☐ No	Comments:
Functionality: ☐ Yes ☐ No	

Temperature Sensor	
Max load capacity: 500g ☐ Yes ☐ No	Comments:
Functionality: ☐ Yes ☐ No	

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Air Flow Sensor	
Max load capacity: 500g ☐ Yes ☐ No	Comments:
Functionality: ☐ Yes ☐ No	

Galvanic Skin Sensor	
Max load capacity: 500g ☐ Yes ☐ No	Comments:
Functionality: ☐ Yes ☐ No	

User Interface test cases	
user login with valid username and password ☐ Yes ☐ No	Comments:
user can only access the data if they have privilege ☐ Yes ☐ No	
data shown correctly ☐ Yes ☐ No	

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General Tests	
Raspberry Pi receive data from sensor ☐ Yes ☐ No	Comments:
Server receive data from Raspberry Pi ☐ Yes ☐ No	
Server sends information to end user ☐ Yes ☐ No	

Reliability and Performance Tests	
System running for 24 hours continuously ☐ Yes ☐ No	Comments:
Support at least 20 user ☐ Yes ☐ No	
Store at least 20 reports for each user ☐ Yes ☐ No	

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Safety Tests	
Sensor can be easily detached ☐ Yes ☐ No	Comments:
Sensor will not cause allergy ☐ Yes ☐ No	
All wires are electrically isolated ☐ Yes ☐ No	

