Bachelor Thesis

Spring 2012

School of Health and Society
Department Design and Computer Science

A Mobile System for Vital Sign’s Data Collection and Data Presentation

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Examination:
This graduation work on 15 higher educations credits is a part of the requirements for a Degree of Bachelor in Computer Software Development (as specified in the English translation).

Title:
A Mobile System for Vital Sign’s Data Collection and Data Presentation

Abstract:
This degree project deals with vital sign’s data collection and data presentation on mobile devices. The report consists of three main parts: analysis, design and implementation, and evaluation. Literature review and internet search are main methods for making an investigation on existing systems and related works. A prototype is developed by using PHP, Android and HTML5 technologies. The system test and evaluation is made to show the system’s usability.

Language:
English

Approved by:

_______________________________________
Daniel Einarson Date
Examiner
Abstract

The purpose of this project work is to make research on vital sign’s data collection and data presentation on handheld devices. With the development of smart phones and tablets, more and more people prefer accomplishing their daily tasks on mobile devices. Additionally, the awareness of personal health care increases at the same time. This report consists of three main parts: analysis, design and implementation and system evaluation. By studying literature and searching related works on the internet, general design guidelines are documented. The result is that a prototype is implemented with the functionalities of data collection and data presentation. The system test and evaluation are also completed.
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</tr>
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<td>10.</td>
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<td>34</td>
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</tbody>
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1. Introduction

1.1 Background

With the rapid development of mobile internet, more and more industries are being influenced and transformed. Recently, the IT Company Apple Inc. announced the new version of iPad. The new iPad has been proved to support 4G, the new-generation wireless technology. From user point of view, it will be faster and more convenient for downloading and uploading data through hand-held devices. This project is about data collecting and data presentation in a personal healthcare system. The idea comes from instructor Dr. Eric Chen’s project proposal. A related work has been done in the year of 2009. Two students from home university have developed an e-healthcare subsystem for chronic renal failure patients. ASP.NET was the main technology being used for building the system. However, by the time goes by, the role of mobile devices becomes more and more vital in the personal healthcare field instead of web applications. A totally new research needs to be done on mobile platform.

1.2 Aim and purpose

The purpose of the project is to help patients remotely interacting with the healthcare system, by inputting data through hand-set devices and viewing visual presentation of the health data.

The project work’s core parts are data collection and data presentation for the end users (patients), the patient vital signs are collected and sent to the central server for remote storage. The data can then be used by the healthcare personal for diagnosis and disease management (it is not part of this project), or by the patients and their relatives to support self-care.

Considering limitation of project time, on one hand, data collection’s application is developed as a native mobile application which runs on a specific operating system. On the other hand, application in the purpose of data presentation is developed as a web-app or browser application. Both native app and web-app have their strengths and drawbacks. What’s more, mobile users also have different preferences. Some feels comfortable with native app, whereas others choose to work with help of web-apps. In the future, another data collection’s web-app and data visualization’s native-app are going to be carried out.

1.3 Report organization

The report is divided into 10 chapters. The first chapter is about this project’s aim and acknowledgement. Next, from Chapter 2 to Chapter 4, it is mainly focusing on the study of primary vital sign’s types, data collection methods and related works have been done before. Then, Chapter 5 is about the prototype’s design and implementation. The investigations on client side and server side programming are also discussed in this chapter. Afterwards, system test, evaluation, conclusion and future work recommendation are included from Chapter 6 to Chapter 8. Lastly, Chapter 9 contains a list of references.
Screenshots of literature review’s details, GUI design details and abbreviations which are used in the report are attached in the Chapter 10.

1.4 Acknowledgement

The author would like to express my special thanks to instructor Dr. Eric Chen. The weekly meetings with him guide me to achieve a better system design and gain deeper understanding of degree project work. In addition, he helps me to order full-text reports which are needed for literature review from library. The whole project work would not be done without his patience and his support.
2. Study on vital signs

2.1 Introduction

Vital signs are vital measurements of physiological statistics and widely used by healthcare institutions [32]. In this project, the system retrieves primary four vital signs data from user and display past data in a simple and easily understood way.

2.2 Primary four vital signs

The primary four vital signs are as follows:

Pulse
The pulse is “the physical expansion of the artery” [32]. It is closely related to heart rate and cardiovascular disease. Small change of pulse rate indicates various medical conditions. For example, an infection or dehydration can be detected from a fast pulse rate [33].

Blood pressure
Blood pressure is “the pressure exerted by circulating blood upon the walls of blood vessels” [23]. High blood pressure or hypertension affects the kidneys, arteries, heart or endocrine system [27]. Low blood pressure or hypotension can leads to serious heart, disorders of endocrine and neurological [28]. In addition, severely low blood pressure can cause shock [28].

Respirations
Respiration rate, or breathing frequency is “the number of breaths taken within a set amount of time, typically 60 seconds” [30]. It helps to diagnose abnormal state of lung. Tachypnea or rapid breathing can be caused by carbon monoxide poisoning, haemotherax or pneumothorax [31]. Dyspnea or shortness of breathing is caused by “asthma, pneumonia, cardiac ischemia, interstitial lung disease, congestive heart failure or chronic obstructive pulmonary disease” [25].

Temperature
Temperature stands for body temperature. Fever or high temperature can be a symptom for infectious disease, immunological diseases, skin inflammations, tissue destruction, and cancers [26]. Hypothermia or low temperature’s risk factors are chronic disease, hypoglycaemia and trauma [29].

2.3 Variations by age

Age is a main factor for defining normal state of vital signs. Human in different period of lifetime have diverse normal state of pulse rate, blood pressure, respiration rate and body temperature. In the following, three vital signs tables are used to illustrate variation on normal range of these vital signs.
2.3.1 Pulse rate

Table 1. Table for regular range of pulse value[22]

<table>
<thead>
<tr>
<th>Pulse</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>60 to 100 beats per minute</td>
</tr>
<tr>
<td>Children - age 1 to 8 years</td>
<td>80 to 100</td>
</tr>
<tr>
<td>Infants - age 1 to 12 months</td>
<td>100 to 120</td>
</tr>
<tr>
<td>Neonates - age 1 to 28 days</td>
<td>120 to 160</td>
</tr>
</tbody>
</table>

Adult’s regular range of pulse rate is various from 60 to 100 beats per minute. Children who are between 1 year old and 8 years old have 80 to 100 beats per minute. Infants and neonates have a higher value compared to adults and children, 100 to 120 and 120 to 160 respectively.

2.3.2 Blood pressure

Table 2. Table for regular range of blood pressure value[22]

<table>
<thead>
<tr>
<th>Blood pressure</th>
<th>Systolic</th>
<th>Diastolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>90 to 140 mmHg</td>
<td>60 to 90 mmHg</td>
</tr>
<tr>
<td>Children - age 1 to 8 years</td>
<td>80 to 110 mmHg</td>
<td></td>
</tr>
<tr>
<td>Infants - age 1 to 12 months</td>
<td>70 to 95 mmHg</td>
<td></td>
</tr>
<tr>
<td>Neonates - age 1 to 28 days</td>
<td>&gt;60 mmHg</td>
<td></td>
</tr>
</tbody>
</table>

For the blood pressure, adults’ normal systolic pressure varies from 90 to 140 mmHg. Children’s systolic pressure can be 80 to 110 mmHg. When it comes to infants and Neonates, the value is lower. The systolic pressure for the infants is 70 to 95 mmHg, and for neonates, it is greater than 60 mmHg.
2.3.3 Respiration rate

Table 3. Table for regular range of respirations value [22]

<table>
<thead>
<tr>
<th>Respiration</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult (normal)</td>
<td>12 to 20 breaths per minute</td>
</tr>
<tr>
<td>Children - age 1 to 8 years</td>
<td>15 to 30</td>
</tr>
<tr>
<td>Infants - age 1 to 12 months</td>
<td>25 to 50</td>
</tr>
<tr>
<td>Neonates - age 1 to 28 days</td>
<td>40 to 60</td>
</tr>
</tbody>
</table>

Normal respiration rate for an adult is 12 to 20 breaths per minute. The value increases by the decreasing of age. For a child, it is 15 to 30 breaths per minute. And for infants and neonates, it is 25 to 50 breaths per minute and 40 to 60 breaths per minute respectively.

2.3.4 Temperature

Infants and neonates usually have higher body temperature than adults and children. Females also have a higher value compared to males. Normal range of human body temperature is from 36.2°C to 37.2°C.

2.4 Vital sign data types

Considering implementing healthcare system, vital sign data requires being represented in general programming data types. Based on the discussion above, following data types can be used.

a. Integer
The type integer can be used for primary four vital signs’ data storage.

b. Boolean
Use type boolean for storing data that determines if patients have one specific kind of symptom.

c. String
Use type string for storing text data.

d. Float
Float type can be applied for the other vital signs type except the primary four vital signs, since some vital types need more float point to realize accuracy.
3. Vital sign data collections

3.1 Introduction

Data collection means to retrieve vital signs data from user. There are lots of data collecting ways available on the market. These methods can be divided into two major categories: collecting data automatically and inputting data by user manually. Each of them has its own advantages and disadvantages.

3.2 Automatic data collections

Collecting data automatically is good for increasing efficiency. Users don’t need to type data by themselves. However, the drawback is that data’s accuracy is not guaranteed for some specific ways of automatic data collection. Discussions about methods for collecting vital parameters automatically are listed below.

3.2.1 Wireless device

Bluetooth
On 16th of March, 2012, Apple Inc. launched the new iPad which supports Bluetooth 4.0. It is the first time that tablets implement this latest version of Bluetooth. Bluetooth 4.0 is known for its Low Energy Technology [24]. It guarantees a Bluetooth device longer battery life compared to previous versions. Additionally, the standard for Bluetooth 4.0 includes two new data types: the Health Thermometer Profile and the Heart Rate Profile. It makes monitoring and sending vital sign’s data more easily.

The advantages of Bluetooth technology are low cost, flexible ranging and low power consumption [21]. The devices don’t have to be really close for the purpose of configuring the line of sight during data transmission. Even though pairing enforces security of device communication, however it also ends to a long setup time. Bluetooth hacking is still a security problem.

Zigbee
In order to build wireless sensor network, Zigbee is considered to be low cost, low power consumption and easy network building and configuration. Low data rate is the main drawback, typically less than 250 kbps.

3.2.2 Camera

With the improvement of cameras on mobile phones, more and more innovative ways of data collection have been revealed. On November 17, 2011, Philips released a Vital Signs Camera app. The app provides an easy way to measure heart rate and breathing rate by just looking at camera. No optional sensors are needed.

Another technology, OCR (Optical character recognition) can also help user input data by simply taking a picture of hospital’s lab report. The downside of collecting data by camera is accuracy and fixed range. It’s hard to guarantee data’s accuracy. User need to keep a certain fixed range for capture picture or keep capturing with camera.
3.2.3 USB

Nowadays, USB is the most widely used way for communication between a device and a computer. The transmission speed is really high. The negative side is that a USB cable is needed and it has fixed short range.

3.2.4 Microphone

Voice recognition has been spotlighted again with the launch of Siri. Siri isn't just voice recognition technology, but voice comprehension [19]. However, accent difference and accuracy are still the problems that need to be solved.

3.3 Manual collection

The alternate way to enter data is to type manually. It reduces efficiency but on the other hand, it raises the accuracy. The following part discusses available data collecting GUI components’ usage on common mobile devices. Seekbar controls, Textfield controls and Spinner controls are often used for obtaining input texts from user. Seekbar controls help a user to pick a value from a certain range. One thing that concerns about Textfield controls is that most present smart phones provide an auto-complete feature. Users save a lot of extra typing time because of this function. When it comes to dropdown list role, on the mobile phone it is typically performed by Spinner controls. Usually, Buttons, Check Boxes, and Radio Groups are implemented for the purpose of accepting user’s choices. For retrieving time and date, DatePicker controls and TimePick controls are being used quite frequently.
4. Literature review

4.1 Method and procedure

In the first place, PubMed database has been chosen for this literature review study’s data source. It is widely used in the health research study and maintained by United States National Library of Medicine (NLM) at the National Institutes of Health. The main references of research papers in PubMed come from MEDLINE database. Compared to Google scholar, it has a better precision on both overall search and full-text search [2].

Secondly, it is required to find out proper searching keyword. For topics for data collection and user interaction, the key word is “("user interaction" OR "data input" or “user interface") AND (mobile OR handset OR "cell phone" OR tablet OR smartphone OR ipad OR “android” OR iphone OR "handheld") AND ((healthcare) OR ("health care") OR "medical") AND "english"[Language]”. 50 hits have been found.

Next, when searching for data presentation related topics, “(visualization OR "data presentation") AND ("mobile" OR "cell phone" OR tablet OR smartphone OR ipad OR iphone ) AND ((healthcare) OR ("health care") OR "medical") AND eng[Language]” is used as search criteria. 61 hits show on the screen.

Thirdly, filtering the result is essential during literature review. From the figure that shows in the next page, after reading the abstract and reducing duplications from two search result sets, 64 papers have been eliminated. Then, another 6 papers have been taken out from study result set. The reasons are one paper mostly focuses on heart rate monitor’s usage for personal wellness, one mainly discusses about decision support system, one more has a study on Nightingale tracker technology’s education, another one considers mobile phone’s usage on point of care instead of personal health care field, then two more results serve for CT datasets and the last one study on animals’ health data. Afterwards, lacking of full-text, 6 results has been omitted. In the end, with the help of instructor and home university’s library, 35 reports have been collected for detailed review and analysis.
4.2 Analysis

1. Publishing year

<table>
<thead>
<tr>
<th>Publishing year</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>3</td>
</tr>
<tr>
<td>2011</td>
<td>6</td>
</tr>
<tr>
<td>2010</td>
<td>6</td>
</tr>
<tr>
<td>2009</td>
<td>2</td>
</tr>
<tr>
<td>2008</td>
<td>9</td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
</tr>
<tr>
<td>1998-2005</td>
<td>6</td>
</tr>
</tbody>
</table>

The table above shows the count of reports in each publishing year. The attention on mobile health rises from year 2006. Then the peak appears in the year of 2008, there are 9 reports which is the largest number for the total numbers of publications per year. Next, in the following year, only two results have been found. Lastly, the rate of 6 reports per year remains until now.
2. Publishing country

Table 5. Table for count of each country’s article

<table>
<thead>
<tr>
<th>Publishing country</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>3</td>
</tr>
<tr>
<td>Finland</td>
<td>1</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
</tr>
<tr>
<td>Greece</td>
<td>1</td>
</tr>
<tr>
<td>India</td>
<td>1</td>
</tr>
<tr>
<td>Italy</td>
<td>3</td>
</tr>
<tr>
<td>Japan</td>
<td>1</td>
</tr>
<tr>
<td>Korea</td>
<td>1</td>
</tr>
<tr>
<td>Norway</td>
<td>5</td>
</tr>
<tr>
<td>Portugal</td>
<td>1</td>
</tr>
<tr>
<td>Spain</td>
<td>1</td>
</tr>
<tr>
<td>Sweden</td>
<td>2</td>
</tr>
<tr>
<td>Turkey</td>
<td>1</td>
</tr>
<tr>
<td>UK</td>
<td>1</td>
</tr>
<tr>
<td>USA</td>
<td>13</td>
</tr>
</tbody>
</table>

From the table above, it indicates that USA put the most efforts on e-health among all countries. 13 related reports are published in USA. It can be seen that Norway and Germany also work hard on mobile health, with 5 research reports respectively. The number of reports which published in Europe and UK is 23. Especially Nordic countries have made a major contribution to improve mobile health system, 8 published research papers. However, looking back to Asia, only 4 results are found in the result set.

4.3 Qualitative findings

With the fast pace of mobile device’s development, an increasing number of people are being comfortable using mobile phone, tablet to accomplish their daily life tasks. As well people are willing to integrate these devices to capture their health status [8]. With the help of touch screen, it is easier to collect vital sign data at any time as long as device is in the reach of their hands. From user’s point of view, it is also straightforward to learn and becoming familiar with inputting health data on mobile device [8]. Yet there are still some major distinctions between elder people and young people.
4.3.1 Youth vs senior people

Senior people prefer text in large font and input data without typing manually [10]. Also a simple and straightforward user interface design is significant factor for older user [1]. Furthermore, unlike youth, they are not adapting to common user interface’s usage for navigation and actions. Such as, iOS’s dock navigation is more suitable for elders instead of common web page navigation structure. In addition, they have another problem using Drag-and-drop action which is quite intuitive for younger users. The reason they said is that they thought that after dragging one item to the other place led to making item disappear from the former position [10].

One important thing for youth, is that childish graphical user interface is really uncomfortable in their point of view [11].

Despite those points mentioned above, both young people and old adults would rather to have iconic images combined with text in the application [11], [10]. In my point of view, it can not only help users easier to learn how to use the application, but also delight users instead of just plain text in front of them.

4.3.2 Sensor network and wearable devices

By means of sensor network and wearable devices, personal health data collection becomes easier and lower-cost. What’s more [5], it signifies it is possible that monitoring respiration rate is performed by embedding optical fibers into textiles. Yet it requires certain breathing technique and body posture from user point of view. A noise filtering algorithm and making T-shirt (with sensor on it) easier to wear is needed to improve the usage. In the report [12], the system uses Zigbee for building sensor network and collecting vital parameters. Then with the help of Bluetooth, it achieves communication with server and stores data on the server. It is implemented on J2ME mobile phones. As the author mentioned in the article, there are two primary security concerns in this architecture, “mutual authentication between each sensor node of the BAN and the MBU” and “secure data exchange in intra-BAN communication” [12]. The security problems still need to be carefully configured in sensor network architecture’s design.

It can be a reason that the usage of the sensor network and wearable device is still low in the real world [6]. Especially on the iOS platform, the main reasons are insecure data transmission and lacking of official support [6]. In contrast, NFC and RFID are being thought as more secure.

4.3.3 NFC and RFID

There are more and more hospital integrating RFID technology into patient identification and tracking [3], [13].

Acquiring data by applying near field communication (NFC) technology, enhances improved portability, better integration with RFID, usability and learnability [9]. Inputting data can be simply performed by using a RFID tag to touch mobile device.
4.3.4 Security

In the present, data transmission on mobile device is still quite risky. [4] If a user uses open operating system such as: Android, which the source code is open to everyone, may leads to various insure situations. As well as that other application can be grant permissions to interfere or stop the target application. On the other hand, if user chooses a proprietary operating system such as iOS, it constrains developing progress, such as without Jailbreaking, developer is not able to access the serial interface. Particularly third party application probably cannot be able to cooperate with developer’s application.

To enforce safety, the system uses two-tier authentication in the report of [7]. On the client side, a unique security code, username and password are needed. On the server side, (UDID unique device ID) is used. UDID usually identifies the unique of each apple device. After certain inactivity period of time, the system will pop up a window to ask a user if he wants to keep the session alive. The user needs to reenter the security code to reactive the session, otherwise the application will exit automatically in 30 minutes. In my point of view, it protects data’s authenticity. However, the transmission between server and client is not guaranteed.

Talking about NFC, it limits short-range communication. In particular with the help of unique RFID tag, it achieves enforced safety and avoids faking.
5. Design and implementation

5.1 Introduction

In this chapter, design and implementation of the system are two main topics. Firstly a brief system’s description, general design guidelines are presented. Then how to select proper tools and operating system both on the client side and server side programming consideration are discussed. Next the system’s design and implementation section includes whole system architecture, database and functionality of system. Lastly, several encountered problems and solutions during project work’s progress are discussed.

5.2 System description

The system is able to collect vital sign data and present data in a chart view. Two applications are implemented for data collection and data presentation, respectively. The project is focusing on general user who would like to record and view personal health data in their daily life. The data can also be used for hospital personnel to monitor patients’ health status. Mobile devices (such as smart phone, tablet) are mainly used for accessing the system. It enables users to input health data in any place and any time as long as internet enabled mobile devices near them.

5.3 General design guidelines

Design guidelines are important, and can have a core impact on achieving expected results which is decided in the start of project work. Keeping them in mind during the whole progress of project development, makes sure we are on the right track. Some general design guidelines are listed in the below, after literature review and internet search.

- Keep GUI design simple because of limitations on mobile devices, such as screen size and battery’s consumption.
- Font size and graphical components’ size shall not be too small for senior people. Senior people prefer iOS’s dock item design instead of normal web page design.
- The graphical user interface needs to apply for various screen size of mobile devices.
- Keep appropriate gaps between graphical components and group these components in a meaningful way.
- Use different color for represent different types and ranges of vital sign data. User can identify whether the sample of data is in a normal range or not.
- Provide touch feedbacks on mobile device for better user interaction.
- Keep writing style simple, short, important things come first and friendly [17].
- Avoid childish graphic presentation for teenager user. Teenagers are quite sensitive to it.
- Apply user experience’s and user interaction’s knowledge during design of system.
• Don’t add too much interaction on mobile application, because it may lead to bugs and conflict on distinguishing gestures.
• Deal with interrupt of other applications or incoming calls on the mobile phone.

5.4 Selection of tools and operating systems (HTML5, Android)

5.4.1 Android vs iOS

Android is the platform used in this project work’s data collection part. The reasons why we choose Android instead of iOS are presented as follows:

1. Choosing Android platform is good for a lower cost for developing app and no need to buy external devices, for example a Mac and an iPhone.

2. Since the app is mostly used for communication between patients and healthcare system, the amount of user is the main consideration. The project work is intent on letting more users involve experiencing the app. Consequently, android which has a larger user group is chosen as the programming platform.

3. Android has a better support for integrating with Google’s tools and services, such as Gmail, Google map, Google search, Youtube, Google Goggles and Google translate.

4. Android is based on Linux operating system. The app is easier to improve with embedded Linux in the future. However, because of lacking knowledge, embedded Linux will not be involved in this project work, even though it is so common and popular in the real world.

5. To continue project work on the Android platform, developers have more programming rights and permissions on mobile device compared to iOS.

5.4.2 HTML5

In the beginning of project, the whole system is supposed to be built on Android platform. However, after we take close look at Android’s charting library, we found that android didn’t have a standard charting library. There are various third parties’ graphing library, such as ChartDroid, AndroidPlot and AChartEngine. Still, these libraries don’t offer rich user interaction and good support for various screen size.

Considering better user interaction and user experience, client-side programming languages come to our mind. We decide to create our data presentation application with cutting-edge technology HTML5. In the developer point of view, HTML5 enables apps with more functions, better performance, higher speed and closer experience to desktop application [15]. From user point of view, user can simply type a web address in the browser or click an icon to run the application instead of downloading app first, then installing and running the application. At the same time, users don’t need to be worried about updating and configuring the right version of the application. All of personal data is
synchronized and not limited to one specific device or platform. Whether you are using a
desktop or mobile device, iOS or Android, HTML5 works perfectly in various platforms
and devices.

5.5  Data presentation tools

5.5.1  Sencha touch vs other HTML5 mobile frameworks

Along with increasing speed of mobile internet, numerous mobile frameworks are being
developed. They all have their own positive and negative sides. In the following, I will
just compare three popular ones: Sencha touch, jQuery Mobile and Dojo.

1. Licensing. Dojo offers quite liberal license. It is free whether you built your
applications for open source or commercial purpose. JQuery Mobile is under
license of GPL or MIT, so it is also free to use. However, Sencha touch’s
licensing is more complex. The latest version 2.0 of Sencha touch requires
purchasing its commercial license in order to distributing your application.
Whereas the version 1.0 is under GPL v3 license.

2. Performance. Sencha touch and Dojo have much better and more reliable
performance then jQuery Mobile during app’s running time, but have a longer
initial load time [16]. In my own tests, Sencha touch has faster graphic rendering
speed and better integration with iOS operating system compared to Dojo
framework.

3. Documentation. Sencha touch’s documentation is extensive and has examples in
frequent using classes compared to another two frameworks. Source code is
directly link to each class’s documentation. Yet there are still some typos and odd
holes in the documentation.

4. UI components. Sencha touch offers a wider choice, better interaction and better
looking UI components and widgets.

5. In practice, Sencha touch is suitable for small teams, in contrast, large team can
choose Dojo for better codebase maintaining [18].

Finally, Sencha touch version1.0 is used in this project since it offers better user
interaction, performance, outlook of UI components, good documentation which abounds
examples and GPL license.

5.6  Server side programming consideration

In the web development, there are a variety of options for the server side programming
language. The debates on choosing the most suitable language for specific project work
have never been stopped with the improvements of each language and framework. All of
them have their own advantages and disadvantages. In the following part, PHP, RUBY
and ASP.NET will be mainly discussed about.
5.6.1 PHP, RUBY, ASP.NET comparison

1. Maintenance
   During the development of one project work in the real world scenario, the original author of project development work is always not the one who will maintain and modify the code in the future. Thus when choosing a server side language in the beginning, the factor of maintenance should be keeping in mind. In addition, measurement of maintenance is various in different contexts. For instance, if the scenario is developing a website which sells products, Ruby is not a good choice, since support is usually not provided in commodity web hosting [14]. On the contrast, PHP is generally used anywhere and more familiar to other programmers.

2. Cost
   As we know, PHP and RUBY are open source, whereas ASP.NET is an Microsoft’s product. When it comes to web hosting, LAMP (Linux, Apache, MySQL and PHP) are quite popular. Mainly the reason is that purchasing and upgrading of Linux operating system, Apache server, MySQL server, PHP are free. As well, there is no need for paying extra licensing cost for backup server. So maintenance cost for load balancing and server clustering is reduced. Particularly, compared to PHP and RUBY, ASP.NET needs IIS and Microsoft SQL as web server and database server running on Windows operating system. Consequently, cost for purchasing and upgrading operating system, and server are added to company’s budget externally. In addition, by increasing amount of servers, licensing fees have also to be charged from Microsoft.

3. Support
   Developing with each of three languages can all have good support, since any of them is popular in web development. The main difference can be that, on one hand support for PHP and RUBY is mostly coming from open source community. On the other hand, Microsoft takes responsibility for technical support.

4. Performance
   For database accessing and modification, PHP has a long history working with MySQL server. Until now, the performance for communicating between PHP and MySQL is still faster than ASP.net and Microsoft SQL server [20]. For accessing file system, compared to Windows’ NTFS file system, Linux’s ext4 file system has a better performance [20]. Moreover, Windows system is considered as more cumbersome which leads to less available CPU and more RAM using rather than Linux.
5. **Ease of prototyping**
   PHP is easier to learn and has less time to deploy a website. As a price, you have less knowledge about low-level computer science concept and thinking skill in object-oriented design.

6. **Security**
   PHP, RUBY and ASP.net can all achieve enforced security of website building. One thing to notice is that PHP allows bad programming practices. It results in more bugs and security risks if developers don’t have a thoughtful design and coding style.

7. **Popularity and usage**
   Each one has their own large using groups as developers or companies. Some examples are given in the following: Facebook, Wikipedia, WordPress are built with PHP, Twitter, Hulu and Groupon uses Ruby. MSN.com, Live.com construct with the help of ASP.NET. However, LAMP (Linux, Apache, MySQL and PHP) is still much more popular than the other ones in web hosting.

To sum up, PHP has been chosen as the server side programming language. Quick deployment, low cost and wider popularity are the major reasons why it has been selected among three options.

### 5.7 System architecture design

![Figure 2. Figure for system architecture](image)

The whole system is divided into two core parts: data collection and data presentation. Two stand-alone applications are developed.
5.7.1 Data collection

The client application used for getting user’s vital sign data is developed on Android platform. After the client application receives data input by user, it sends an HTTP POST request with user’s data to a PHP web page which runs on the server side. Then the server inserts data into a MySQL database. Finally, the PHP page sends back the result which indicates whether the operation is successful or not.

5.7.2 Data presentation

By using HTML5 technology, a browser is the major user interface to the system. Firstly, after a user enters the web address of the application, an HTTP GET request is sent from the Sencha touch chart application to the same PHP web page which mentions in the data collection part. Secondly, the PHP page gets data from the database by a SELECT SQL operation and sends these data in JSON format back to the client application. Finally, the client application plots these data in a chart view or block view.

5.8 Database design and implementation

To let users be able to retrieve their health data from anywhere and anytime, a central database for storing data is designed in this system. The database contains one table named “vitalsign”. In the following describes this table’s columns:

1. Id
   “Id” column is primary key of “vitalsign” table. It increases automatically when new row has been inserted into table. The data type is int(8).

2. Value
   “Value” column stores value of vital sign data. The data type is smallint. Representing the value of body temperature in smallint data type is not mean that the system ignore the value after decimal point. To minimize storage space of data, data type “smallint” with storage size of two bytes is used rather than data type “float” in four bytes. In order not to lose the accuracy of data, before inserting body temperature data into database, the PHP page which handles database operation, multiply the data by 10. Next when data presentation application sends request for receiving data, the same PHP page divided data which get from database by 10.

3. Date
   “Date” column represents recorded data’s date. The data type is varchar(10). The date’s format is YYYY/MM/DD. The reason for choosing this format is to sort date easier by using ORDER BY Sql operation.

4. Userid
   “Userid” column is used for identifying specific user. The data type is int(10).
5. **Type**

“Type” column stands for type of vital sign data. The types are: TEMP shorts for body temperature, RP shorts for respiration rate, BP shorts for blood pressure and PULSE shorts for pulse rate. The data type is varchar(10).

6. **Note**

“Note” column keeps track of user’s note when recording health data. Possible note can be the food he eats before measurement, feelings and so on. It can be helpful for hospitals to identify patients’ symptom. The data type is varchar(200).

**5.9 System functions and implementation**

The system’s functions can be mainly divided into two categories: collecting data and presenting data.

**5.9.1 Data collection**

![Figure 3. Figure for data collection GUI](image)

The figure above shows the graphic user interface for data collection application on the Android platform.

1. **Seekbar and EditText**

Seekbar and EditText android graphical components are used for retrieving vital signs data from users. Depends on a user’s preference, he can choose input data whether by scrolling the Seekbar or typing manually. Seekbar is much easier and intuitive for users to enter data in the user experience perspective. However, sometimes people may want to input data by keyboard. Therefore, both methods remain in the implementation. The note text field gives users an ability to write down feelings or things when recording vital parameters.
2. Buttons
After fulfilling the form, users can decide whether to send data to server by clicking Submit button or clear data fields by clicking Reset button. Considering better user interaction, enlarging button animation is developed when a user clicks on one button. Consequently, a user can make sure he pressed the button. Next, a confirmation dialog pops up in order to let the user change data before submitting data to the central server. It can not only enhance the user experience, but also enhance data’s authenticity.
Additionally, Client side data validation is performed to check if a user enters valid data or fulfills all the required data fields. The required data fields are all input text fields except note text field. The reason that why note text filed is mandatory is considering from user point of view. It is usual that a user may not want to write any note about measurement. In the end, an error message will display if data’s value is not in the correct range by inputting data from keyboard.

3. Padding and size
Padding between Seekbar and left side of screen is to achieve better user experience. Users are more comfortable when scrolling Seekbar rather than no padding. The size of Seekbar is longer than EditText because of better usability and outlook.

4. Data’s color differentiation
Vital signs data which are inside or outside regular range for one specific data type will end in different EditText control’s background color. It reminds user his health status when he is sending vital parameters to server. If one type of vital sign is out of normal range, the user can find it out immediately and ask for help from doctors or family members. In certain situations, this feature may save a person’s life, since time is a vital factor for emergency.

5. Grouping components
A line is used to separate two groups of graphic components. One group is for inputting value and the other one is for submit and reset functions. This line keeps simplicity of design and helps users to identify functionality of graphic components more easily.
5.9.2 Data presentation

Figure 4. Figure for data presentation GUI on mobile phone in portrait mode

Figure 5. Figure for data presentation GUI on mobile phone in landscape mode
The four screenshots show data presentation application’s look in smart phone’s portrait mode, landscape mode, tablet’s portrait mode and landscape mode respectively. The application primarily focuses on presenting data in a well-structured and ease-interaction way. It offers following features and functions:

1. Adapt to different mobile device
   As you can see from above screenshots, data presentation application is suitable for various mobile device and different operating system. Especially on tablets, data presentation application has a better performance and visual view.

2. Plot data
   Four data types (pulse rate, body temperature, blood pressure, respiration rate) can be plot as line charts individually or together on the screen. The reason for this design is based on different contexts and user preferences. For example, doctors need to view two or more vital signs’ trends when they identify a patient’s symptom. In this context, multiple line charts display in the shared canvas is necessary. Another example is: sometimes, users or doctors only want to view one data type’s chart without distraction of the other ones. Display line chart for individual data type can be considered as the best solution.
What’s more, to gain less confusion and better view of data presentation, on the chart, each day will only have one data point value for each vital sign. The value shows on the chart is the average value which calculate from a predefined SQL statement in the PHP web page. The reason for that personal healthcare is the main purpose of this project. In the user point, one data point per day is enough at the user side. More data points increases distractions and confusions. However, in the central database, multiple users’ samples per day can still be retrieved by hospitals and health institutions.

3. Line chart and block table
Two types of data presentation are provided in this application. One is line chart, the other one is block table. On one hand, observing data’s trends and relations between different data type is major purpose for line chart design. The Y-axis represents value of vital sign data, measurement date is displayed in X-axis. On the other hand, display each date’s data in individual block, is in order to view inserting data’s history and take a quick look of one specific date’s data in a plain text view. Some users prefer chart view, yet there are still one group of users would rather view data in plain text.

4. Help button
A help button is placed on the dock with a question mark icon. This button is mainly used for showing help information about the application’s functions and instructions. User can learn how to use this application more quickly with the help of this button.

5. Zooming in and out
Zooming function is really important for smart phone’s user, since the screen size of mobile phone is rather small. In this application, users are able to zoom in and out both horizontally and vertically. Additionally, after zooming in, users can switch between zooming mode and viewfinder mode. Zooming mode means users can continue zooming out or zooming in by pinching and spreading. Viewfinder mode is mostly used when users want to move the view under a zoomed screen by dragging on the screen. It is valuable when users just want to move a little around the zoomed screen.

6. Display individual point’s value
From tapping on each data point, user can view this data point’s value clearly on a pop up window. Further information about this data point is also included, such as whether the value is inside or outside a regular range. The data in different range ends in different color which is the same as the function mentioned in the data collection’s app part.
5.10 Encountered problems and solutions

5.10.1 How to get each average value of four vital sign data type per day?

Solution: Instead of query database four times to retrieve average value for each vital parameter, I use one SQL statement to enhance system’s performance. The statement combines four result sets of different health data first and then reduces the redundancy by add a condition for date’s coherence. The SQL statement is showed below:

```sql
SELECT * FROM ( SELECT AVG(  `value` )  AS BP,  `date` AS DATE FROM `vitalsign` WHERE  `type` =  'BP' GROUP BY  `date`)a, (SELECT AVG(  `value` ) AS TEMP ,  `date` FROM `vitalsign` WHERE  `type` =  'TEMP' GROUP BY  `date`)b, (SELECT AVG(  `value` ) AS RP ,  `date` FROM `vitalsign` WHERE  `type` =  'RP' GROUP BY  `date`)c, (SELECT AVG(  `value` ) AS PULSE,  `date` FROM `vitalsign` WHERE  `type` =  'PULSE' GROUP BY  `date`)d WHERE a.`date` = b.`date` AND b.`date` = c.`date` AND c.`date` = d.`date`.
```

5.10.2 Problems when studying Sencha touch document.

Solution: during reading Sencha touch official document on the website, there are some typos in it. Since I use the text editor for programming, it takes a lot of time to finally find one typo in the example’s code. Typos are rarely appearing in major programming language’s document, such as Java, C#’s API. My recommendation is to carefully observe the code even if it is provided in the official document. Another solution is to take a look at latest version of framework’s document even though you are developing program on previous version. It may helps you to find out reasons for strange bugs.

5.10.3 Display problem about line chart’s graphic component for data type selection

As the picture shows below, when the application runs on smart phones, the graphical component for data type selection has overlays on the other button which serves for switching between zooming mode and viewfinder mode. I tried different ways to overcome this problem, such as moving components position, yet failed. The reason is that the position of data selection’s bar and mode switching’s button are pre-programmed horizontally in the framework. In the end, I go back to read API and find one useful property: dock. This property minimizes the selection bar into one button. The outcome is showed in the following screenshot.
Because of limitation on mobile phone’s screen size, I recommend group different functions into buttons to obtain better visual presentation.

5.10.4 Problem working with Android Seekbar

Android only supports seekbar’s value range in decimal values. When we want to use it for float body temperature value, we encounter this problem. After searching solution on the internet, I found the solution. Firstly I configure Seekbar’s range to 80. Then convert data into proper float value when display the value in EditText’s text field.

The code is present below:

```java
//convert value to valid temperature value
String tempVal = Float.toString((float)(progress+350)/10);
//bind value dynamically to EditText field
tempTextField.setText(tempVal);
```
5.10.5 Problem with Android EditText’s text validation

Android API predefines three methods in the EditText’s listener. They are beforeTextChanged (CharSequence s, int start, int count, int after), onTextChanged (CharSequence s, int start, int before, int count) and afterTextChanged (Editable s). First method is used for changing existing texts in the EditText control. Second and third method can be used for observing texts which just have been changed. The main difference among them is edibility of new texts that have been just input to the EditText control. The second method is unable to edit the new texts, whereas the third one allows you to edit the texts.
6. System Test and Evaluation

6.1 System test method and test result

Black box testing and white box testing are applied during the development of project work. Black box testing is primarily used for testing the functionality of the system. On the other hand, white box testing is mainly used for observing codes.

Data collection black box testing:

Table 6. Table for data collection black box testing

<table>
<thead>
<tr>
<th>Test nbr</th>
<th>Description</th>
<th>Expected outcome</th>
<th>Pass / Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Submit data with all data field fulfilled</td>
<td>A successful message shows on the screen, indicates submitting data successfully.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Input the data in all EditText controls or scroll all Seekbars to a certain value</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Press Submit button</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Submit data without all data field fulfilled</td>
<td>An error message should pop up on the screen that indicates submitting data unsuccessfully.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Input the data in one EditText control or scroll one Seekbar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Press Submit button</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reset data fields</td>
<td>Seekbar’s and EditText’s values need reset to default values.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Click reset button</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Reset data field</td>
<td>Seekbar’s and EditText’s values need reset to default values.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Input value in one of the data field or scroll one Seekbar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Click reset button</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Observe EditText’s background color changing</td>
<td>If input data is in the regular range, the background color is green. Otherwise, it is red.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Input data or scroll data inside regular range</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Input data or scroll data outside of regular range</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Data presentation black box testing:

**Table 7. Table for data presentation black box testing**

<table>
<thead>
<tr>
<th>Test nbr</th>
<th>Description</th>
<th>Expected outcome</th>
<th>Pass / Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plot data</td>
<td>Four lines will display on the same chart.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Run appication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Zooming in and out</td>
<td>The x-axis and y-axis will zoom in and out with pinching and spreading on the screen.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Pinch and spread on the screen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Get one data point detail information</td>
<td>After tapping on the data point, a window pops up. It contains details about this data point</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Tap on one specific data point on the screen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Viewfinder mode</td>
<td>You are able to move view by moving your finger.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Zoom in by pinching</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Click switch mode button to Viewfinder mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3) Tap press and move your finger on the screen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Select plot data type</td>
<td>Specific data type’s line on the chart will appear or disappear according to taping on the data type.</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Click selecting data type button</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Enable or disable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table: Desirable data types by tapping

<table>
<thead>
<tr>
<th></th>
<th>Get help information</th>
<th>A help window will pop up with help information in it.</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1) Click help button on the dock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6.2 System evaluation method and result

In this project, the evaluation methods are comparing with similar apps in the market and discussing with classmates and instructor.

#### 6.2.1 Comparison with apps in the market

E-health is a hot topic nowadays. More and more apps have been developed recently.

The system strengths are as follows:

To start with, as mentioned in the literature review part, there are not so many research projects using Android or iOS as their main developing platform. HTML5 technology is not found in the result set of literature review. It proves that my project work is on the cutting edge. With the benefits of HTML5, cross-platform feature can be the point that my application shines among existing apps. Secondly, with the help of Sencha touch framework, data presentation app is able to dynamically change graphical layout corresponding to device’s screen size. Many applications don’t offer this feature when I am examining the app market. Thirdly, the lack of zooming function on the chart is found on many comparable apps, yet my project work implements this important function. Finally, for inputting data on the mobile phone, most apps uses text field, whereas in this project, both scrollbar and text field have been provided for better user experience.

On the other hand, there are still some weaknesses in the system.

In the first place, compared to the other apps, the security factor is not considered much in this system. Four digits code is usually required for enhancing client side security. Then the functionalities are not as rich as other apps on the Apple’s app store or Android market. In the end, in this project, the system focuses on single user, which makes the application lacks of multi-user functionality.

#### 6.2.2 Discussion with classmates and instructor

User-centered method is applied on discussion among classmates and instructor. Each week, I collect feedbacks on system’s design mainly from instructor Dr. Eric Chen and then make changes on the development of system. Classmates also make reviews after using the prototype. They make system more adaptive to different users’ preferences.
7. Conclusion

The purpose of this report is to make investigations on vital sign data types, overview available data collection and data presentation methods on mobile devices. Finally, it designs and implements a prototype application based on the user interaction design guidelines. Test and evaluation are also done.

After finishing this project work, I have gained knowledge on several points which list below.

1. I get a deeper understanding of UI design on mobile devices. Mostly it is related to Android and HTML5.

2. To be honest, I have no literature review experience before. Now I am more familiar with general procedure of literature review and structure of formal research paper.

3. Before the beginning of the project, I am new in the field of e-health. At the present, not only my English vocabulary for medical terms is increased, but also my perspective on e-health is raised to an upper level. I am glad to work on a project which can really improve people’s daily life.

4. As well my programming skills are enhanced on client-side, server side and framework. Rare JavaScript and PHP knowledge has been taught before the start of this project work. At the same time, Sencha framework and HTML5 knowledge was new for me in the beginning.
8. Future work

Since this project only produces a prototype, there are several things that I would like to implement in the future.

First of all, mobile data security is still a main risk for smart phone and tablet applications. Enhanced security function is needed for protecting users’ privacy. The client side authentication can use combination of user name and password. In addition on the server side, server can use device’s unique ID to perform user identification. Last but not least, communication between client and server needs encryption for avoiding sniffing.

Secondly, adding multi-user feature can make system more practical to real world scenario. Since several family members may want to use the same mobile device for recording their own vital signs data. Then the privacy between family members can be protected with multi-user functionality implemented.

Thirdly, concerning the hospital usage, if a doctor wants to monitor a sudden change of individual patient, an alarm or a reminder in the system is necessary on the server. After the server receives data sent from the patients, it can compare the received data with previous records and then send an alarm or a reminder message to hospital or log this sudden change into the server document.

Lastly, integrating sensor network and wearable device into system, can make data collection to be automatic, low-cost and convenient from user point of view.

All these works are in the purpose of providing user a pleasing user experience and great user interaction, at the same time, persuading people embracing the benefits of new technology is quite important too.
9. References

List of References

Articles


10. Enclosures

Enclosure 1 Articles for literature review


45: Sanjo Y, Yokoyama T, Sato S, Ikeda K, Nakajima R. Ergonomic automated


<table>
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<th>#</th>
<th>Year</th>
<th>Country</th>
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Enclosure 3 Abbreviations

ASP - Active Server Pages
BAN - Body area network
CPU - Central processing unit
CT - Computed tomography
GPL - GNU General Public License
GUI – Graphical user interface
HTML5 - Hypertext Markup Language
J2ME - Java 2 Platform, Micro Edition
JSON - JavaScript Object Notation
MBU – Mobile base unit
NFC - Near field communication
NTFS - New Technology File System from Microsoft
OCR - Optical character recognition
PHP - Hypertext Preprocessor
RAM - Random access memory
RFID - Radio-frequency identification
SQL - Structured Query Language
UDID - Unique device identification
UI – User interface
USB - Universal Serial Bus
Enclosure 4 GUI design

Details about GUI design.