Study and Implementation of Patient Data Collection and Presentation for an eHealth Application

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Abstract: This degree project is a part of information and communication technology supported self-care system for the diabetes, mainly in diabetes data collection and visualization. The report is organized in four main sections: investigation and internet search, literature review, application design and implementation, system test and evaluation. Existed applications and research studies has been compared and, a responsive web application is developed aiming at providing relevant functionalities and services regarding diabetes self-management.
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Introduction

Background

eHealth (also written e-health) is a relatively recent term for healthcare practice supported by electronic processes and communication, dating back to at least 1999 [4]. In Sweden, the first known telemedicine trial took place around 1915, in the field of remote reading of ECG signals across the campus at Lund University [5]. Sea-to-shore telemedicine started in the beginning of the 1920s from Sahlgren University Hospital, in Gothenburg, to Swedish vessels around the world, a service that is still operational today [5]. During its brief history, eHealth has often been used for different purposes by physicians and patients. Patients were using eHealth, especially the Internet, in order to obtain more health information than they typically had access to within their patient-physician relationship [6]. After decades’ development, eHealth has been widely used in hospitals and home care, particularly in developed countries; whereas it still lacks of sufficient investment of development and application in third-world countries.

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both [7]. Currently diabetes mellitus are known and classified in two typical types: Type 1 diabetes (β-cell destruction, usually leading to absolute insulin deficiency) and Type 2 diabetes (-ranging from predominantly insulin resistance with relative insulin deficiency to predominantly an insulin secretory defect with insulin resistance) [7]. Diabetes is a common disease happen to all generations which it leads to very inconvenient life and large cost in long term treatment with expensive injection medicines. What makes the situation even worse is that diabetes would further cause a lot of complications such as Heart Disease and Stroke, High Blood Pressure, Blindness and etc.

This project is a part of information and communication technology supported self-care system for the diabetes, mainly in diabetes data collection and visualization. The system architecture and framework will be studied in another project. The idea comes from instructor Dr. Eric Chen’s project proposal, a project developed in cooperation between Kristianstad University and local hospitals. By doing sufficient internet search and comparing the existing applications in this field, an application aim for better self-management of diabetes has been developed. Main techniques involved in the application design are Responsive Web Design, ASP.NET, HTML5, CSS3, data collection and visualization, Cloud Computing, etc. Diabetics are able to use this application to record their measured glucose statistics and other relevant factors; so that they can manage their state of illness by viewing the change of different parameter.

Aim and Purpose

The purpose of this project is to develop a web-based application which could help the diabetics record their daily glucose, weight, exercise and diet, as well as view the data in an ideal presentation. This could be a reference to support them in making self-management decisions. All these could be easily realized both in handheld device and computers due to the responsive web design techniques.

The main part of the project is to collect and present those diabetes-related parameters in a proper way on the basis of the responsive web platform. The design of responsive web
whose layout could automatically adjust different size of screens, the storage of the data in
the cloud database, the proper way to present different types of data, and the secure
mechanisms & access control are required techniques in implementing the system.

Diabetics are very careful on their diet, weight loss, physical exercises and periodic measure-
ment of the glucose. The aim is to provide a system to help them easily do the self-
management. The successful completion of the project needs the cooperation with the
platform group, the professional recommendations from the professionals and the advices &
help from instructor and examiner.

Method and Recourses
From the software engineering point of view, we focus on the preliminary investigation sat
the first beginning. Next we follow the four phases of RUP model to develop our system.
We make clear the requirements of the diabetics so that we could design a well- practical and
operational system with friendly interface. Then we implement the system module by mod-
ule along with basic testing. The testing of the whole system will be done in the end.

In order to develop a real supportive system, we utilize the resources from different as-
pects. Investigation online helps us to know the development of eHealth and diabetes. The
comparison of existing applications let us find out their strengths and weaknesses. Some
relevant techniques are studied by referring to those open sources online. The comparison
among some mainstream techniques helps a lot in selecting the most suitable one. With the
cooperation of the platform group, we could successfully achieve the integration of the
whole system. We also gain many important knowledge and diabetics’ real needs from the
professional researcher and doctoral student of diabetes field.

Report Organization
The report is divided into 10 chapters. The first chapter is the introduction, purpose and
acknowledgement of the project. Then, Chapters from 2 to 4 are mainly focusing on the
study of responsive web design, data collection & visualization and the literature review.
Chapter 5 is the system design and implementation. The investigation and internet search,
techniques we choose, detailed design and the problems we have met are discussed in this
chapter. Afterwards, system test and evaluation, conclusion and future work are involved in
Chapter 6 to 8. At last, Chapter 9 shows a list of references. And Chapter 10 contains the
screenshots of the detail of literature review and system interface.

Acknowledgement
The authors would like to express our great thanks to instructor Dr. Eric Chen. The meetings
with him guide us to accomplish the project better. He gives us a lot of useful and important
advices during the whole development. In addition, he has arranged some meetings with
Kerstin Blomqvist, the Assistant Professor of Clinical Nursing, so that we could get much
professional recommendations and guides about the diabetes and diabetics. Here we
would appreciate to Kerstin and her doctoral student for their great help. Furthermore,
we would also thanks Jun Lu and Song Zhang from the platform group for the coop-
eration and discussion during the whole project. Some ideas and the architecture of the thesis
Responsive Web Design

Introduction
Responsive web design is a concept to give the user an ideal layout for their reading and navigation by using panning and scrolling techniques to automatically adjust to different size of devices such as mobile phones, tablets, PDA and notepad, etc [8]. The original idea of responsive web design is to provide a website which could well adapt to different size of displays of devices [8]. In recent days, more and more people are accessing the websites regularly through the mobile devices, and various mobile devices are commonly used now all around the world. A fixed size website may looks good on PC but may not true on mobile devices. Hence, responsive web design is a global trend with an explosion increasing of hand held devices in recent years.

Background
It is known that smart phone is keeping its dramatic increasing in the global market. A global survey and forecast [23] made at the beginning of 2012 shows that 67 million personal computers have been sold in 2011 and this value is expected to reach 248 million in the following four years. The compound average growth rate is nearly 40% in these four years. Among the market distributions, Asia Pacific area is expected to gain the highest share of both in transportation and sales aspects in 2015. On the other hand, the survey also indicates a fact that more than 450 million mobile phones are sold in 2011, while this value is only 282 million in 2010. Only in Asia Pacific, it is expected that over 1,000 million smart phones will be sold in 2015 [23]. It is sure that Asia Pacific area will be the largest market for both PC and mobile phones in recent years.

Traditionally, if the developers want to establish a site that can be accessed through the mobile devices, a separate set of the websites is needed to adjust the display on the specified kinds of mobile devices. The website should be customized according to the form factor and interaction models of a targeted device or devices. In general speaking, a different structured web design is required to guarantee the availability and good visibility of the website on mobile devices. Suppose if a huge website is needed from a company, there should be developers to create and maintain different designs for the mobile devices.

“One Code Base” is a new trend in recent years in web design field. Developers use the same code to deliver a layout to different device size (such as smart phone, ipad or PC) by taking advantage of latest techniques [7]. This could significantly save development time, labor source and cost as well as code size.

Typical Solution & Related techniques
Fluid grids, media queries and flexible image & media are the three basic techniques [8] for responsive design which those schemes are proposed by Ethan Marcotte, who is the creator of the concept of responsive design. HTML, CSS and JavaScript are three fundamental tech-
Selection and Implementation
The study on responsive web design has been collaborated with the system platform group. In this project, it has been discussed and compared [16] that media query is selected and implemented for achieving a responsive design of the website. Naturally, fluid layout may give a better solution since it can adjust to all different devices with a relative design with percentages rather than fixed size. However, it requires a pre-calculation before real implementation to compute the proportion of all the elements on the website. And the application was initially planned to be responsive for typical mobile devices on the market like iphone, ipad and pc. Hence, media query is selected due to its simple implementation and different set of CSS specifications are structured based on the scope of device width and different orientation.

Data Collection and Visualization

Introduction
Generally, chronic diseases like diabetes need repetitive tests over a long period and generate large amount of data. Nowadays it has been very popular to make web-based application to record, present and share the medical observations [18]. The platform and tools used for data collection and visualization are very important since users may not have enough knowledge regarding the platform and other relevant medical information. Therefore, the collection and data presentation should be easy to manipulate.

Primary Factors
It has been researched that many factors may result in diabetes mellitus such as family history, having a family member who’s suffering type 2 diabetes are increasing their risk of developing conditions; even though diabetes are happen to all generations from younger to older, it’s more likely to happen to the seniors while the age is increasing; lack of enough exercise will seriously damage the health and thus increase the possibilities of pre-diabetes and type 2 diabetes; food diet and high blood pressure are also playing important roles regarding the cause of diabetes [19]. In this project, four primary factors are selected as the foundation of long term self-management of diabetes, which are glucose, exercise, weight, and food diet.

Glucose Level Range
Glucose change is the key factor in deciding the cause and effect of diabetes. Hence, understand the blood glucose level ranges are the key to correctly diagnose the state of diabetes and self-management. However, the standard of glucose level range in each different country or medical organization is different. Moreover, the situation is also differs from person to
person; a person who’s naturally have higher blood glucose may also be in good health state if the blood glucose keeps stably around the same level; females in pregnancy also lead to the change of glucose, etc. Hence, it’s very difficult to formalize a unified standard to indicate an absolute table with the range of the glucose levels.

Table-1 is a suggestion from the National Institute for Clinical Excellence (NICE) in United Kingdom but each individual’s glucose range should be agreed by the doctor or diabetic consultants. According to this specification of ranges and levels, Non-diabetic are normally owning a glucose level between 4 to 5.9 nmol/L and under 7.8nmol/L 2 hours after meals; Type 2 diabetics have a 4 to 7 nmol/L before meal and under 8.5nmol/L 2 hours after meals; slightly different from Type 2 diabetes, Type 1 diabetes has the same level before meal with 4 to 7 nmol/L but under 9 nmol/L 2 hours after the meals; Children with type 1 diabetes have 4 to 8 nmol/L’s range and under 10 nmol/L.

**Table1.** NICE recommended target blood glucose level ranges[23]

<table>
<thead>
<tr>
<th>Target Levels by Type</th>
<th>Before meals (pre prandial)</th>
<th>2 hours after meals (post prandial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-diabetic</td>
<td>4.0 to 5.9 mmol/L</td>
<td>under 7.8 mmol/L</td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>4 to 7 mmol/L</td>
<td>under 8.5 mmol/L</td>
</tr>
<tr>
<td>Type 1 diabetes</td>
<td>4 to 7 mmol/L</td>
<td>under 9 mmol/L</td>
</tr>
<tr>
<td>Children w/ type 1 diabetes</td>
<td>4 to 8 mmol/L</td>
<td>under 10 mmol/L</td>
</tr>
</tbody>
</table>

**Physical Exercise**

People with diabetes are encouraged to do physical exercises since it will lead to better glucose control and reduce the possibility of heart disease. The muscle movement will cause the consumption of sugar taken by the muscle cells and lower blood sugar levels. Other benefits from exercise could be better heart health, better weight control and pressure management. Frequent and regular exercise is good for people in all ages since it boost the immune system and protect against the diseases like Heart disease, Stroke, Type 2 diabetes, Cancer and other major illnesses as shown in table 2. It is also known that exercise can reduce the risk of major chronic illnesses/diseases by up to 50% and reduce the risk of early death by up to 30%. Other health benefits from exercise are shown in table 3.

**Table2.** Major Disease protection

- Heart disease
- Stroke
- Type 2 diabetes
- Cancer and other major illnesses

**Table3.** Benefits of exercise

- Improves mental health
- Boosts self esteem/confidence
- Enhances sleep quality and energy levels
- Cuts risk of stress and depression
- Protects against dementia and Alzheimer's disease
**Weight Loss**

Diabetics, especially with Type-2 diabetes, are very closely relating to the weight, with over 90% of newly diagnosed type 2 diabetics are above the ideal weight. Losing weight could both prevent people from developing diabetes or, help them better manage their disease if they have already been diagnosed with diabetes [24].

**Food Diet**

Appropriate diet plays an effective role in managing the state of diabetes. High in dietary fiber, especially soluble fiber (esp. soluble fiber), and low in fat (esp. saturated fat) & sugar are the recommended nutrition level [32]. What they eat will directly have impact on their glucose.

From the meeting with professionals in diabetes field, we learnt that even in the world of bread, different brand or type gains different proportions of sugar and fiber. So it is a big problem for the diabetic to select a proper kind of bread. Similar situation also occurs in selecting fruits and beverages, etc. Furthermore, there is no best diet for every diabetes patient, so diabetics should plan a specific recipe to meet with their own needs.

**Data Collection**

**Introduction**

Any process of collecting data is known as data collection. The purpose of data collection is to keep the data on record, to analysis and make decision based on the acquired data, or sharing the data with others. Data collection is normally taken under a Data Collection Plan [20], which it contains three fundamental stages to fulfill an integrated data collection process. There are many ways in collecting different type of data with the rapid development of electronic product, communication media and software application. Mainly it can be categorized as two types: automatic collection with the support of electronic devices and wired/wireless communication techniques; and manual collection by inputting personal data into a physical or virtual database; each of the collection methods owns its advantages and disadvantages from different aspects like flexibility, error rate, response time and transmission range, etc.

**Data Collection Plan**

A full data collection plan contains three fundamental steps, starts with a pre-collection activity to decide the definition and collection method; followed by data collection and finally present finding stage to sort and visualize the acquired data.

- Pre collection activity: set and decide the goal of data collection, find and define the target data, the format and definitions of the target data as well as the methods that would be applied in data collection.
- Data collection: the process in applying appropriate method and procedures to collect the required data from the data sources, and further store the retrieved data in a database according to the rules decided in the first step.
• Present findings: usually involves some ways in filtering the mass data, and then sort [11], analysis and/or presenting the achieved data.

Data Collection Method

Paper-based collection

Paper-based collection means data statistics are recorded by humans on paper to keep track of the observation and result. However, it is not so commonly used in IT industry due to its several crucial shortcomings; it may not clearly show the variance if large amount of data is involved and cannot predict the trend by the paper record; it also suffer from repetitious and time consuming since same data need to be recorded over and over, a new copy need to be generated when changes are made to on-record data.

Automatic Collection

Automatic collection refers to collecting data from sources automatically trigged by a certain time period or a specified event, with the support of the electronic devices, communication technologies and related software applications. Therefore, there should be some kind of automatic control design and apply a realizable connection between the hardware component and the data sources (could be physical environment, human or other virtual products can generates data). Automatic collection looms largely in the market due to its intelligence, flexibility and convenience, users don’t have to care the design and do the operation by themselves, and the devices will automatically record relevant data in a specified format. But automatic collection also leads to some errors due to the machine failure and may not be so accurately in analyzing the data. Commonly used devices are outlined as wireless devices, wearable devices, camera, USB, Microphone [27].

Manual Collection

A web-based application design not only provides a visualized interface to the users regarding the presentation of the data, but also a platform for the user to manually tracking and collecting different types of data.

The web application provides rich elements and controls for collecting different type of data. Textbox is used to collect data typically in text and number format or both, user only need to type the input in the given area; Dropdownlist is applied when a number of selections is offered to the users and the users are able to select and collect the specified data entity in the Dropdownlist; Calendar is the element for the user to select the expected date. Checkbox and Checkboxlist can also be used which the functionalities are similar with Dropdownlist, the user just select the corresponding items from the given list.

With the help of other elements like Button or Link, user can execute operations of canceling or storing data into the record storage.

Data Presentation

Introduction

Data presentation aims to show the rules and features inside the data as simple as possible in order to help in decision making. Putt has said “It’s not what you say, but how you say it”.
So a suitable presentation could show the data and the changes directly without any other word explanations [12].

Variables could be divided into two parts: qualitative variables with defined subclasses of states, levels or categories and quantitative variables which are normally expressed in numbers. Qualitative variables can be further divided into ordered and unordered ones, while quantitative values could be discrete or continuous. Different variables should be presented in different ways.

Words, tables, pictures and graphs could be used to explain and analysis the data. Among these, graphic charts such as line, bar, pie charts and histogram are commonly used in data presentation. Using a graphic chart could greatly save reader’s reading and understanding time. Graphic presentation has the feature of simple, clear and understandable and it could arouse readers’ interests to some extent. Readers are more eager to see data presented in a chart so that they could easily find the main points themselves than read hundreds of words about the detail explanation of the data. Thus choosing a proper way to present data is greatly related to the reading and understanding of the data.

**Data Presentation Plan**

An ideal graphic presentation is a kind of art. Providing a readable, understandable and concise presentation is our main purpose. The following points need to be mentioned:

- **Require minimum effort from reader:** The basic and most important measurement in judging whether a graphic is good or not. If the graphic aims to show the changes or trends, the differential parts should be maximized in display.
- **Maximize the information:** Enough information should be shown on the graph so that readers could understand the meaning, measurement units and values. The title, axes labels, legend and scale divisions should be displayed as informative as possible.
- **Minimize ink:** Although the purpose is to put as much information as possible in the graph, it is still important to show them as clear and simple as possible. Those concise texts without any unnecessary words are what readers really need.
- **Using commonly accepted practice:** Presentations should meet the need of reader. For example, normally the origin of the axis is from 0 and the scale division is equal in an increasing way, but these could be change with special requirements.
- **Avoid Ambiguity:** Everything on the graph should be clear and easy to read without leading to any misunderstanding [12].

**Data Presentation Method**

*Line chart*

A line chart is using straight line segments to connect a series of data points [21]. The turning point shows the change or trend in the data. It is commonly used in many data presentation fields. Line charts are widely used in displaying continuous data changing with time. It could clearly show the data trends at equal time intervals.
**Bar chart**
A bar chart is using rectangle bars to show the comparisons in defined categories. The lengths of the bar proportional represent their values. The chart could either be horizontal or vertical. One axis shows the categories which need to be compared, while the other one shows the discrete value of the data [22]. Bar charts are quite widely used in comparing different categories.

**Pie chart**
A pie chart is a circle divided into several sections. Each of the section represents a numerical proportion. It could concisely show how much percentage one part is occupied in the total area. It is commonly used in business area and media area. However, pie charts could be replaced by bar charts in some cases [23].

**Histogram**
Histogram is designed to present the distribution of data. It could show the probability distribution of a continuous variable. The height of the small rectangle gives the frequency density of intervals, and total area of all adjacent rectangles is the number of data. In normal distribution, the whole area equals to 1[24].

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**Literature Review on Data Collection and Visualization**

**Method and procedure**
In order to find qualitative literatures regarding the data collection and visualization of diabetes/eHealth; Google Scholar was initially selected as the tool. However, the searching result on Google Scholar was not so precise and it doesn’t filter the articles well according to the keywords. Therefore, it’s quite usual that Google Scholar presents a number of over 10,000 items for the given keywords; and it’s very hard to select and filter the right articles even different combinations have been tried out.

According to the suggestions from the report [36] of Fohai Tang, a student in home university who studied the similar field in 2012; PubMed will give a higher precision in search the biomedical articles. Even this application is closely relate to the techniques and skills in web development, the focus of the literature review in this project is about the data collection and visualization of eHealth or particularly, diabetes. Hence, PubMed was used as the tool for finding articles.

PubMed is a free database primary provides the abstract and articles on life science and biomedical information [33]. By accessing the PubMed site, the search engine is provided and the search is based on the keyword combination, Figure-1 gives the search process and result in this project based on each query.
As figure 1 shows, the keyword combination of “diabetes self-management AND data collection and visualization” only gives one item found in the database; the same with “diabetes data collection and visualization on web” and “ehealth data collection and visualization on web”, these gives very limited resources which couldn’t be applied in doing a systematic literature review. On the other hand, the relative large topic “diabetes self-management” and “data collection and visualization” give over thousands result; in concrete, the first one gives 5486 search results and the later one gets a result of 1445 results, this will be too many for completing the reviewing and most of them may not relate to the data collection and visualization of diabetes. Hence, those two of “ehealth data collection and visualization” and “diabetes data collection and visualization” were selected as they bring up 16 and 27 articles.

The search query details were translated by the PubMed site. For instance, if “ehealth data collection and visualization” were specified for searching the corresponding result; the actual search command is formatted as ["telemedicine"[MeSH Terms] OR "telemedicine"[All Fields] OR "ehealth"[All Fields]) AND ("data collection"[MeSH Terms] OR ("data"[All Fields] AND "collection"[All Fields]) OR "data collection"[All Fields]) AND "visualization"[All Fields] ] and the site translation of this command was shown in the Figure-2. This search gives a result of 16 articles found from the database.

Another example was the command “diabetes data collection and visualization”, it was formatted into ["diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("data collection"[MeSH Terms] OR ("data"[All Fields] AND "collection"[All Fields]) OR "data collection"[All Fields]) AND "visualization"[All Fields] ] , and the translation of this command is detailed as in figure-3. This search gives a result of 27 articles found from the database. More examples are given in the enclosures.
Totally 43 articles are found from the database. Theoretically, these articles are essential to be reviewed. However, after a roughly review of the abstract; 13 articles were found that almost no-relation with the subject and the purpose of this project, those were purely medical papers. Therefore, 30 papers were finally checked. Figure-4 shows the detailed filtering procedure.

**Figure-4. Paper selection and filtering**

**Analysis**

**Publishing year**

The table below shows the number of published articles in each year. The large-scale researches and development began from 2005. During the previous decades, only 10 related articles had been published. The number of articles has increased significantly since 2011. Even in 2013, three high quality articles have been published in the first five months. It shows that researches and development about eHealth in diabetes fields with data visualizations are very promising.
Table 4. Paper statistics of publishing year

<table>
<thead>
<tr>
<th>Publishing year (until May)</th>
<th>Number of papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>3</td>
</tr>
<tr>
<td>2012</td>
<td>5</td>
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<tr>
<td>2011</td>
<td>4</td>
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<tr>
<td>2009</td>
<td>3</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
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<tr>
<td>2006</td>
<td>2</td>
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<tr>
<td>2005</td>
<td>3</td>
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<td>1997</td>
<td>1</td>
</tr>
<tr>
<td>1995</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 5. Paper statistics of published country

<table>
<thead>
<tr>
<th>Publishing country</th>
<th>Number of papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>15</td>
</tr>
<tr>
<td>England</td>
<td>5</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
</tr>
<tr>
<td>Ireland</td>
<td>2</td>
</tr>
<tr>
<td>Canada</td>
<td>1</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
</tr>
</tbody>
</table>

From table above, it indicates that USA put the most efforts on eHealth in diabetes and data visualization fields among all the countries. Half of the articles are published in USA. The other half is almost published in Europe. UK and Germany has made major contributions in these fields. It shows that western developed countries has done much more advanced researches in combining the medical and computer science fields together to give patients better life. However, it seems like that Asia have not paid so much attention in these fields.

Qualitative findings

Advantage of eHealth

Some significant advantages such as portability, real time, low cost and high efficiency [11] could be found in the articles. And it will be a trend that electronic storage of pa-
tients’ records would replace those paper-based records [14]. Accessibility, saving of the physical resources, the benefits in unified maintenance and the security of patients’ privacy information are what doctors and patients really want. However, eHealth demands a lot on hardware and internet facilities. So it is really hard to carry out this technology into third world country because not every patient could access internet with their mobile devices. This could be a reason for the lack of research and papers in developing countries.

Efficient medical data presentation
Accessing medical information in mobile devices is becoming popular and widespread in recent years. Since different kind of devices do not have the same rendering capabilities as of desk computers, it is necessary to adjust the data presentation to adapt different type of devices [15]. This could also prove the significant meaning of using responsive web design in our project.

General technique concern regarding self-management
It has been shown in one of the papers that most patients they have surveyed show interests in using new technology to support their self-management. Currently, many people get used to take advantage of Internet to help with their diet, to find exercises, and for information on management. And some of the participants said that they would like their tracking journals to be linked to their medical chart [12]. For older people, they have shown the desire for technical support in self-management, but they need some instructions about how to use this technology in mobile devices. In another article, the researchers evaluate the feasibility and get a positive result of diabetes self-management support intervention conducted over the Internet [13]. These researches show that providing a professional self-management platform will make great sense to those diabetics.

Diabetics’ requirements
Main requirements of patients have been summarized in article [12]. Patients want to use social media to interact with others, receive advices and make friends. They are willing to use e-technology to access their medical information. They would like to use internet-based resources to manage their specific health behaviors such as healthful eating and exercises. These practical needs of diabetics have provided a lot of design inspiration.

Project development & Implementation
System Description & Requirement analysis
System Description
The project is able to provide a web application with an interactive interface to track and present the change of glucose, diet, weight and physical exercise via both handheld devices and PC. The system is focusing on general diabetics who would like to record and view their daily data which would support their further decision making. The data would be
visible to the doctor only when it has been permitted by the patient. A forum is provided to all registered users to discussion. Both mobile devices and PC could accessing the website and get a suitable layout due to the responsive web design. It enables users to input their daily parameters and view the changes in any time and place as long as they have internet accessed devices.

**Requirement analysis**

After investigation, literature review and the meeting with professionals, we have analyzed the requirement and listed the following points:

- Responsive web design would be developed to adjust the web size and layout on different end devices like iPhone, iPad and PC, etc.
- Database development is used to store the data from the correct user; secure mechanisms and access control would be implemented to keep the users’ privacies.
- Provide a friendly interface for users to manually tracking and collecting their basic parameter such as glucose, diet, exercise and weight; provide a visualized interface to present the data in suitable graphs according to the period they select.
- Windows Azure cloud platform is used to build, deploy and manage the whole system.

The system implementation is a collaboration result by working together with the platform group. Based on the investigation study and discussion [16]; Responsive web design, Web Server (IIS), Windows Azure have been learnt before development. A lot of relevant preliminary studies help to get familiar with these techniques. Research papers give general ideas, current state and development of the technique. Tutorials and instances are good guides for making practical use in programming. Relevant website provides some advices in solving the problems encountered during the development.

With the rapid development of Internet, a large amount of information could be searched online. Appropriate use of them significantly reduced the time spending in filtering different information. Thus the advantage and disadvantage of different algorithms, techniques, platforms and databases could be easily compared. These results greatly support the decision making in choosing an appropriate method.

**Selection of Tools and Operating System**

The selection of tools and operating system is depending on the system requirement and implementation. To fulfill a web application with consideration features like database, security, access control, and further deploy on the cloud; there are many languages and tools can be used; JSP, ASP.NET, PHP are few examples in making web application; Dreamweaver, Eclipse, Netbeans IDE, Visual Studio can be used for web development. These existing languages and IDE owns its advantage and disadvantages from different perspectives. Hence, some criteria and comparison need to be done before the tools and system is selected. ASP.NET is finally selected due to laconic design and easy implementation, flexible, can support complicated object-oriented design and powerful development environment [27].
**Language and Tool**

**ASP**
Active Server Pages, also short for ASP or Classic ASP. It was the server-side script engine for dynamically generated web pages developed by Microsoft [25]. Its syntax is similar with Visual Basic, can embed script code into the HTML page. Even though it is easy to use ASP, but there have many drawbacks as well. The most important issue regarding ASP is the security concern. Presently Microsoft applied the advantage of Java in ASP.NET while develop .Net framework and, use C sharp as the recommend language for ASP.NET development. It has improved the security strength of ASP, but it is still limited by the platform since ASP/ASP.NET can only run on Windows NT/2000/XP with IIS server rather than Linux, UNIX and etc. Hence, the security concern and operating system have greatly limited the application of ASP in the web development.

**PHP**
PHP, short for Hypertext Preprocessor, is a server-side scripting language used for web development. Unlike ASP, PHP is used for general-purpose programming language [26]. PHP is an internal embedded language, but its syntax has been mixing the syntax of C, Java, Perl and its own syntax. It would be faster than CGI or Perl in executing dynamic web pages.

PHP is fully open source, an important reason why it is widely used. It keeps updating and adding more function libraries so that it will have more features no matter on UNIX or Win32 operating system. PHP provides sophisticated functions which it has better sources when designing the program. The latest version now is 4.1.1, it owns a good performance in Win32, UNIX/Linux and other platforms. PHP has applied new Zend engine after version 4.0, makes it better than CGI and ASP in efficiency.

Even though platform independence is the biggest advantage from PHP, still it has some short coming. If the developers use its own function to connect the database rather than using ODBC, the function name will not be unified since different database are applied. And it further reduces the portability of the program. Overall, its advantages are still obviously as the most popular and widely used back-stage language.

**ASP.NET**
ASP.NET is part of the Microsoft.net framework; it is not only a new version under ASP, but also provides a unified web develop model which it contains all the required servers for the developers in developing web application. The syntax of ASP.NET is compatible with ASP whereas it offers a new programming model and structure at the same time; therefore, it is used for develop application which is more stable and secure. By adding more features of ASP.NET in ASP application, the function of ASP can also be improved. ASP.NET is based on .NET environment, thus can compatible with any other languages compatible with .NET like Visual Basic.NET, C sharp and Javascript.Net. Besides, any application developed in ASP.NET can use .NET framework. Developers are free to utilize the advantages of these techniques such as type security, inheritance and so on. ASP.NET can fully collaborate with other HTML Editor in WYSIWYG style or other
programming tools. These features make it more convenient in developing web application by applying the advantages of all those related tools and specifically, web developers can drag the web control in GUI design of the web pages. ASP can be used for writing well-structured code, and the code can be reused and shared in the future; developers are easy to complete the web application with satisfactory functions.

**JSP**

Java Sever Page (JSP); is the technique that used for creating dynamically generated web pages based on HTML. JSP and Servlet is part of the system in J2EE developed by Sun company, Inc. Since JSP and Servlet are based on Java, they have the biggest advantage of Java which is platform independent and WORA (write once, run anywhere). Apart from WORA, the efficiency and security of JSP/Servlet is pretty good. Even though JSP/Servlet is not widely used now, it can be used very widely in web development in the future.

**Operating System**

Since ASP.NET is selected as the language for development, Microsoft Visual Studio 2010 is selected as the development tool, and IIS server is required for deploying the web application. Thus, Windows operating system is a must for the application development.

**Cloud Platform**

There are a few selections are offered while selecting the cloud platform. Windows Azure cloud is provided by Microsoft and providing the framework and main services developed in Microsoft. Gogrid cloud is developed by Google and providing the platform with its related services. Other selections could be Amazon cloud, Citric cloud and etc.

Since they are developed by different enterprises, the services they provide are different. Windows Azure cloud is selected due to its free trial for three months; and also largely because ASP.NET and Visual Studio is selected as the developing language and development environment, Windows Azure will best suit in developing and deploying the application on cloud.

**Database**

As a consequence after selecting the language, tool and cloud platform, SQL server is selected to be used for database development. A comparison between SQL and MySQL has been made; SQL Server is providing more useful functions which can be applied in efficiently storing and retrieving data under a certain condition. Besides, it is also developed by Microsoft so that it will better compatible with other tools had been selected.

**System Architecture Design**

The system architecture follows the purpose and control flow of the application. This application is developed for diabetes self-management where the users can record and view their glucose, exercise, weight and diet. In particularly, the users can get the food diet tips and use the forum to communicate with other users or doctors; the users can also set permissions
to doctors or other users to share the specified data. Based on the system information and features of the application, the system architecture design can be illustrate as Figure-5.

![System architecture design and control flow](image)

**Figure-5.** System architecture design and control flow

Unauthenticated users will be provided the information of this site and the forum discussion; users can check the relevant information regarding diabetes self-management and external links that may be useful. An unauthenticated user can also go to the correct page to register himself/herself to login the system with the required profile information.

Authenticated users will be verified against their permissions, different role will be guided to different page with certain information. Three roles are set in this website for access control and, account and permission management. Users are normally the diabetics who use this application for diabetes management; doctors also involve in this system to help the patient users; administrators are uniquely given by the developers for mainly manage the accounts, special permissions are granted like checking user profile and delete users who perform malicious actions.

Authenticated Users can access specified information to record their glucose, exercise, weight and diet information; check the historical record or data statistics during a certain time slot; get food suggestions regarding the content of fiber, monosaccharide, disaccharide, sucrose; and set permissions to dedicated doctors to check all or part of their personal data. Users can also post subjects in the forum or response the subject post by others; in this circumstance, they can discuss and communicate with other users who might be the doctors or patient users.
Authenticated doctors will be guided to doctor’s page which contains the relevant information and rules for the doctors. Besides, it lists the users who granted permission to the doctor, detailed data with granted permissions will be plotted in figures when doctor selects a specified user.

When administrator sign up to the system, the administrator can access the list with all registered users, a detailed user profile will be displayed when a user is selected. In case if any users are performing malicious action or deliver bogus information on the forum, the administrator can directly delete the users. Similar to other users, administrator can post global notification on the forum to inform the administration of this site; the information will list and show up in the forum.

**Responsive Web Design**

As it has been introduced in the previous section regarding the concept and solution of responsive web design, main techniques up to day are in three categories. Fluid grid layout, media query and flexible image and media are the three techniques widely used; HTML, CSS and JavaScript are three fundamental technologies for web design. Many factors are deciding how responsive web design would be implemented; different device width is the fundamental factors, different operating system used, different web browser used or different versions of the same browser; they bring a different outcome of the responsive design. According to the comparison of the advantages and disadvantages, the platform group has decided a fixed size design and media query will be used for the responsive design [16].

**Media Query Implementation**

```xml
<meta name="viewport" content="width=device-width, minimum-scale=1.0, maximum-scale=1.0" />
<title>Master Page</title>
<link href="/~/Styles/site.css" rel="stylesheet" type="text/css" />
<link href="/~/Styles/media.css" rel="stylesheet" type="text/css" />
```

Since all the pages designed in this web application inherits the master page; in the master page, the style sheet with media query can be implemented. To avoid the scalable of the mobile screen, the scale has been fixed as the initial size. There is a style sheet file initially
to figure out the content layout of the website on computer, so this layout will be read and loaded when the web application is started.

A second style sheet will be loaded to further check the media type as shown in the following Figure-9. It checks the device width, according to the investigation work collaborated with platform group. The size ranges have been obtained based on the main mobile devices on the market. The mobile screen size and view model are considered when deciding the media category; particularly, iPhone and iPad are selected to be the devices implemented initially. Portrait and landscape modes are considered when designing the application since those two modes are fundamental modes a mobile user will apply.

![Figure-9. Media query in-process implementation](image)

Based with the iPhone mobile device, the portrait mode will have a screen width of 320px. Part of the Samsung and HTC smart phones will have larger size than iPhone, and these has been categorized in a up level with maximum 480px, that is actually the size of landscape mode of iPhone. Normally device with a width over 480px is the tablet like Minipad, iPad or Android Pad; iPad owns a largest width with 768px in portrait mode. All other devices over this size are considered as laptop or desktop size.

### Fixed Size Implementation

With the media query which defines the device categories, fixed size implementation is applied in adjusting a reasonable layout in different category. A separate set of CSS specification is defined in each case. When the application loads the correct CSS specification according to the detected device width, it will load the corresponding CSS style and reconfigure the layout of the web pages. The following paragraphs introduce an example of how fixed size implementation is applied to a “present page”.

```css
//*-------------------Present Page-------------------*/
.presentcontent{max-width:200px;}
.presentglucose{max-width:190px;overflow:scroll;}
.presentexercise{max-width:190px;overflow:scroll;}
.presentweight{max-width:190px;overflow:scroll;}
.presentdiet{max-width:190px;overflow:scroll;}
//*-------------------Present Page-------------------*/
```

![Figure-10. “Present page” on 320px device criteria](image)
In device width under 320px criteria, the content elements in present page are specified in a fixed size according to the page size. By specifying the size of all the elements in this page, the page layout will adjust to this size when this CSS specification is loaded if a mobile phone in portrait mode tries to access the webpage.

```html
/*-------------------Present Page-------------------*/
.presentcontent {max-width:360px;}
.presentglucose{max-width:320px;overflow:scroll;}
.presentexercise{max-width:320px;overflow:scroll;}
.presentweight {max-width:320px;overflow:scroll;}
presentdiet {max-width:320px;overflow:scroll;}
/*-------------------Present Page-------------------*/
```

Figure-11. “Present page” on 480px device criteria

**ASP.NET Web Developments**

**Master Page**

In ASP.NET 2.0, Master page is introduced for writing template outline for the web pages. In this project, master page is applied since web pages in this site should have a same outline. By defining the master page with corresponding controls, the other pages can directly inherit the master page instead of repeating the same implementation on each page. Besides, there could be only few CSS styles directly applied on the master page rather than applying the style sheet in each individual page.

**Cascade Style Sheet**

Cascade style sheet, abbreviate for CSS, is a style sheet language used for describing the look and format of a document in a markup language [28]. It is most widely used in web pages written in HTML or XHTML, and also in XML documents. The newest version now is CSS 4 yet no integrated specification of that has been generated, it just has few modules appear presently. To well structure the web layout and realize responsive web design, CSS 3 is applied in the development of the web application.

The earliest version of CSS 3 drafts were published in June 1999.[9] CSS is divided into separate documents in modules; different module has different stability and statuses [10]. Four of the most important modules published are listed in Table-6.

<table>
<thead>
<tr>
<th>Date</th>
<th>Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-06-19</td>
<td>Media Queries</td>
</tr>
<tr>
<td>2011-09-29</td>
<td>Namespaces</td>
</tr>
<tr>
<td>2011-09-29</td>
<td>Selectors Level 3</td>
</tr>
<tr>
<td>2011-06-07</td>
<td>Color</td>
</tr>
</tbody>
</table>

**ASP.NET Web Page**

ASP.NET has been introduced in the previous sections with its conception, advantage and disadvantages. It has been selected as the development language in this project design. The development of ASP.NET pages were guided with the official API and open...
SqlDataSource. This is the control used for formalizing the data source from database by using SQL. When a SqlDataSource is created, it can be modified by specifying a connection string and database table, and further the SQL used for finding corresponding data. After the data source has been specified, the data source can be applied or used by other presentation control.

GridView. GridView is a control used for generating and presenting table format data. By specifying or binding a list format data source, the GridView control can present the data in rows. The page capacity and paging features of GridView can be set in property window to adjust the layout. And the command field can also be added to this control to select, edit or delete row.

DetailsView. DetailsView is normally used when a certain row is selected in the GridView, then the details information of that entity could bind on that DetailsView.

Chart. Chart is used when the data sources need to be plotted in a chart layout. There are 35 types of chart defined in ASP.NET include the line chart, bar chart, column chart, pie chart and so on. The data source in different dimensions needs to be specified before the chart can correctly present the change and trend of the data. By using chart, users are easy and apparent to see how the trend varies and predict a future value.

Iframe. There’s always some videos need to be embedded into the web page for user interaction, and possibly a map for users to check the geographical location. In this project, video and Google map are applied in the application design, where iframe controls are used for realizing the features.

**JavaScript**

JavaScript is an interpreted computer programming language [29]. It is originally executed on the web browser in client side for user interaction, controlling the browser, or doing other process with a given purpose and logical implementation.

In this project, JavaScript is used both in front-end and back-stage development for dynamically updating the page or trigger an event by time or action.

**XML**

Extensible Markup Language, short for XML, is a markup language that defines set of rules for encoding documents in a format which is both human-readable and machine-readable.[30]

XML is in a well-structured format. Hence, it is easy to use in case of storing data in XML. And users can define his own tags if necessary. In this project, XML is used in the application for storing the image data for AdRotator where several images will substitute when
user tries to access the webpage and the possibilities of the images are specified in the XML document as well.

**C Sharp**

<table>
<thead>
<tr>
<th>Version</th>
<th>Language specification</th>
<th>Date</th>
<th>.NET Framework</th>
<th>Visual Studio</th>
</tr>
</thead>
<tbody>
<tr>
<td>C# 1.0</td>
<td>ECMA</td>
<td>January 2002</td>
<td>NET Framework 1.0</td>
<td>Visual Studio .NET 2002</td>
</tr>
<tr>
<td>C# 1.2</td>
<td>ISO/IEC</td>
<td>April 2003</td>
<td>NET Framework 1.1</td>
<td>Visual Studio .NET 2003</td>
</tr>
<tr>
<td>C# 2.0</td>
<td>Microsoft</td>
<td>October 2003</td>
<td>NET Framework 2.0</td>
<td>Visual Studio 2005</td>
</tr>
<tr>
<td>C# 3.0</td>
<td>August 2007</td>
<td>November 2007</td>
<td>NET Framework 2.0 (Except LINQ/Query Extensions)</td>
<td>Visual Studio 2008</td>
</tr>
<tr>
<td>C# 5.0</td>
<td>August 2012</td>
<td>NET Framework 4.5</td>
<td>Visual Studio 2012</td>
<td></td>
</tr>
</tbody>
</table>

Figure-12. Version history of C Sharp [34]

C Sharp language is used for back-stage development. Since Visual Studio 2010 and .NET Framework 4 is used as the development platform, C Sharp 4.0 is used for the back-stage program development. Most of the back-stage processes are focusing on the fundamental logical process and database regarding the selection, deletion, updating of the data stored in the database.

**MS SQL Server & Database**

MS SQL Server is a database management system developed by Microsoft. Database is used by the software application for storing and retrieving data. For better database management and further deploy on the Windows Azure Cloud, SQL Server 2008 is selected as the platform in this project to create the database with related tables.

Figure-13. Glucose Database       Figure-14. UserAccount Table
The database contains 8 tables based on the requirement and categories of data need to be stored in this application.

1. **Breadtable** contains attributes of bread Name, Fiber, Monosaccharide, Disaccharide, Sucrose; current 13 typical kinds of breads are stored in the database.

2. **ForumText** table defines a subject by storing the Username, Role, Time, TextContent, Id, and Subject.

3. **Fruittable** is the same as Breadtable, it defines the fruit Name, Fiber, Monosaccharide, Disaccharide, Sucrose; current 13 typical kinds of fruits are stored in the database.

4. **Permission** table stores the record Id, Dname (Doctor’s name), Uname (Username) and the Permission the user have granted to the specified doctor.

5. The table **Persondata** stores all the personal data recorded by the user, which includes glucose, exercise, weight, diet, recordtime, username, recorddate.

6. **Replytable** defines and stores the reply from the users to any subjects in the forum; each reply is defined by four primary properties of Id (subject Id), Username, Time, TextContent.

7. **SecurityQuestionIndex** stores a reflection between the string format Security question and number form security question.

8. **UserAccount** table is defined to have Username, Password, Email, Age, SecurityQuestion, SecurityAnswer, Role, CreatedTime.

For instance, UserAccount table is defined as Figure-17, where each of the attributes has a data type and a property to indicate whether it can be null or not. And a unique field Username is selected as the primary key in this table since this application will not allow two user accounts with the same username.

**Web Server (IIS)**

Even though this application is placed on the Windows Azure Cloud, where the web application and the database are all deployed on cloud platform, there should be a substitute method in deploy the web application on web server. Simply because of two limitations, the Windows Azure Cloud only offers a free trial for three months with limited usage capacity; if the application is deployed on cloud at the early time of the development, the capacity and resource would soon be used up. Secondly, when the application was updated, there need to be updated on cloud as well. However, the application keeps updating and need to be test over and over; it is not a good solution to deploy the application on cloud at very beginning.

Instead IIS is offering its service before the application is ultimately deployed on cloud. IIS, short for Internet Information Services, it is a web server application developed by Microsoft with the use of Windows operating system. It supports multiple protocols like HTTP, HTTPS, FTP, SMTP and etc. To deploy the local web application on IIS and bind the IP address, port on IIS, the web application can be accessed remotely by others. It is often used during the development for test purpose.
Data Collection

Blood glucose collection with meter

Normally, a diabetic needs to test his daily blood glucose and record it. The timing and frequency to test the blood glucose should be discussed with care team. Enough tests could give a better overall trend so that it would be meaningful and useful in determining the management and where adjustments might be helpful. And researches showed that keeping blood glucose levels in an acceptable target range can help prevent the complications associated with diabetes [31].

There are several ways to do this kind of self-testing. In Sweden, most diabetics use electronic blood glucose meter (as Figure-15 shows) to test and collect his data.

![Figure-15. Electronic blood glucose meter](image)

The main steps of blood diabetes testing are as follow:

- Mount the disposable needle on the equipment, adjust the needle length and stab it into the side of the finger which has been washed and dried carefully.

![Figure-16. Step one: blood test](image)

- Insert the Contour chip into the blood glucose meter and collect the blood to one side of the chip. The blood glucose level will be shown on the screen of the meter after a short while.
Figure-17. Step two: glucose analysis

- The user could either record the value on notebook or use the USB on the meter to export them to the computer.

Figure-18. Step three: data export

**Specification**
The users need to manually input their daily parameters. Glucose, exercise, weight and diet are the four basic factors which will affect the diabetics’ state of illness. Figure 19 shows the general data collection page.
A calendar allows them to choose the date of the record information. This will help to draw the periodical graph later.

Glucose is the key factor in diabetes. The level of glucose is important in determine the progress of the diseases. The measurement unit of glucose is quite different from each country. In Sweden, “mmol/L” is the most common measurement in the medical field. The threshold of glucose level is 5.2mmol/L before meal. Lifestyles including exercise, weight and diet always directly affect the glucose level. It is quite necessary to record all these glucose-related factors for the diabetics in self-management to see what will cause the change or could keep the glucose level so that they could find the most suitable lifestyle of their own.

Exercise is the first factor which will affect the glucose level. There is no standard applies to everyone. So diabetics could record the time they do physical exercise every day. Then they could find a benefit exercise mode by contrasting the changing trend of glucose and exercise in graphic presentation. The measurement unit of exercise is “minute”. No matter what kind of exercise they do, how long they do it is what we are concerned.

Weight is another factor which will have impact on glucose level. Maintaining the weight in a proper range is important in keeping the glucose level. Those overweighted diabetics could have to lose weight under the doctor’s advice. The measurement unit of weight is “kilogram”. Similarly, they could find the relationship between glucose and weight in periodical graph presentation.

What one eats will directly influence the level of glucose. So the record of diet is particularly important. Different food has different content of fiber and sugar even they belongs to same category because of the different receipts from different brand or type. Inputting the diet into textbox is better than selecting from the list, because it is a heavy workload to update all type of food with all brands. In our project, two tables of fiber and sugar proportion are provided in another page for users to check when they are choosing food.

**Implementation**

Users need to input all these data into the textbox in the interface. What they input could be read by backstage. When they press the “SUBMIT” button, all information will be stored into the database. All these contents in textboxes are of “string” type. The glucose, exercise and weight will be converted to “int” before storing.
Data Presentation
All the input data are required to present in clear and concise ways. The user could choose to see the general graphs of glucose and its related factors all together in one page or select the individual factor and view its graph of a specified period.

Graphic presentation
The general visualization of glucose, exercise, weight and diet are presented together in “present page” (as Figure 20 shows) so that user could clearly compare or contrast the trends and changes among all of them. It would help them to know which kind of lifestyle will influence his glucose level and how it influences. The glucose and weight statistics are presented in line chart. The exercise statistics are presented in bar chart. And the diet records are presented in a table with time and content.

Figure-20. General data presentation page

The glucose and weight statistics could also be viewed in line chart with a specific time period, respectively (as Figure 21 & 22 shows). The reason for choosing line chart here is that these two parameters are continuous data changing with time.

The title of the statistics is on the top of chart. The x-axis represents the date, while the y-axis represents the value of the parameter. The origin of y-axis is 0. In the chart, the green points are the record value in each day. Straight line segments are used to connect them to show the changes and trends.

At first, the chart on the right shows all the data without. User could select the time period in the calendar on the left. When they press “CHECK” button, the corresponding line chart will display on the right. The scale divisions will be adjusted automatically.
The physical exercise is presented in a bar chart (as Figure 23 shows). It is not a continuous parameter, so bar chart with date has been chosen for the presentation here. The title of the statistics is shown on the top of chart. The x-axis represents the date, while the y-axis represents how long they do the exercise. The origin of y-axis is 0. In the chart, each green bar represents the minutes of exercise one has been done in the corresponding day. User could clearly find the changes of exercise time by comparing the lengths of the rectangles.

Similarly as the glucose level and weight, user could use the calendar to select a time period and see the required part of data when pressing “CHECK” button. The scale division and width of each bar are adjusted automatically to give a best layout.
Table presentation
The records of diet are presented in a table (as Figure 24 shows) because they are text records rather than quantitative values. The table has two columns which are date & time and diet. Each row displays a record of diet.

Users are allowed to read a specific record of diet by selecting the date & time in the left table. They are also allowed to view records according to date by selecting a day in calendar in the middle. The result will be shown on the right. And they could use scroll to view all parts of the table.

Figure-24. Diet record presentation page

The experts in diabetes fields bring a requirement that diabetics are confused in choosing food with correct nutrition. Fiber and sugar are the two main factors which they need to take into consideration. Providing a table with food name, fiber, monosaccharide, disaccharides and sucrose would support them in choosing a suitable food. Two individual tables of fruit and bread, the most common kinds of food, are shown in Figure 30. User could select one of the foods to view its nutrition bar chart on the right. These professional data could give diabetics some recommendations in making decisions. The data source is Swedish national food agency website (Livsmedelsverket).

Figure-25. Food information presentation page

Security
Authentication
For security reasons, authentication is the most powerful method to ensure the safety of the privacy of diabetics and their personal data. Only registered user with correct username and
password could login his personal account. Security questions and email alert will help him when he forgets the password.

**Access Control**

Diabetics, doctors and administrator are the three roles in the system. Each of them has different permissions.

- Administrator has right to login the admin page to manage user. He could delete illegal user and publish a notification in the forum.
- Diabetics are the main users of the system. They could login their account and record their daily glucose level, exercise, weight and diet. They could also view the presentation of each factor to support their self-management. They can also publish a topic or reply to an existing post in the forum. Because of the patients’ privacy, a diabetic could decide if his doctor is allowed to view his record. He could achieve that by giving specified permissions to a doctor by inputting his name. Or his data could only be viewed and managed by himself.
- Registered doctors have rights to post or reply in the forum. And one doctor could only view the records with patients’ corresponding permission.

**System Test and Evaluation**

**System test method and test result**

The test part can be divided into two main categories, the black box testing and white box testing. The black box testing is more concentrating on the function test whereas the white box testing is focusing on the potential bug lies in the logic of code implementation.

The white box testing is mostly done in parallel with the programming. When a code section is done, different situations according to the code structure and logic need to be test to see if any potential flaw existed in current implementation; modify or add more process mechanisms if bugs were found. In this project, a formal testing was mainly carried out after the application has been finished with black box approach. The following table shows the considerable testing issues in this project and the outcome of the testing.

<table>
<thead>
<tr>
<th>Test number</th>
<th>Description</th>
<th>Expected outcome</th>
<th>Pass / Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Successfully access the web application</td>
<td>The web application is successfully loaded with the home page as the first sight</td>
<td>Pass</td>
</tr>
</tbody>
</table>

1) Open the web browser on mobile device or pc, type the URL of this site.
<table>
<thead>
<tr>
<th></th>
<th>Navigation between different pages with correct content</th>
<th>Whenever a page link is clicked, the site view is directed to that specific page with all the expected contents.</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1) Click different pages according to the menu list</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>Register an account.</td>
<td>The register page is shown up with the label information and textbox, dropdownlist to insert related information. And the information can be successfully submit by clicking the submit button</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Go to the account page and click the register link</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Login an normal User account</td>
<td>The default page show up with the record page, and the menu list contains the record, present, glucose, exercise, weight, diet, food, permission, setting pages with the expected content</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Go to the account page and login with a registered user account</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Login a Doctor account</td>
<td>The default page for doctor shows up with a list of users who granted permission to that doctor, and granted data can be plotted in visualized chart if a user is selected from the list</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Go to the account page and login with a registered doctor account</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Login an Administrator account</td>
<td>The default page for administrator shows up with a list of all registered users, select the user will bring up the details of the user and the user can be deleted. Besides, there should be controls for the admin to send global notification to the whole site</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>1) Go to the account page and login with a registered admin account</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Post subject on forum

1) Go to the forum page and post a subject or reply a selected subject on the forum list.

Any operation like post subject or reply would be rejected if no user account has login, then it will be directed to the login page. The login user can directly post a subject on the forum and the forum list will be updated; reply a subject will update the reply table of the subject.

### Function test on Iphone

1) Repeat from 1-7 by using iphone with internet connection.

The functions achieve expected outcome as on the computer, the functionalities work as predefined.

### Function test on Ipad

1) Repeat from 1-7 by using ipad with internet connection.

The functions achieve expected outcome as on the computer, the functionalities work as predefined.

### Function test on Android platform (Sungsum Galaxy)

1) Repeat from 1-7 by using Sungsum with internet connection.

The functions achieve expected outcome as on the computer, the functionalities work as predefined.

### Application test on IE, Chrome, Firefox, Safari, UC Web

1) Repeat from 1-7 by using the web browsers mentioned above with internet.

The functions achieve expected outcome as on the computer, the functionalities work as predefined.

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**System evaluation method and test result**

In this project, the evaluation methods are comparing with similar apps in the market, discussing with other students instructor, listening to the opinions from the instructor and professional researchers.
Comparison with similar apps

Some similar apps such as glucose buddy, Bant, Diabetes App Lite could be searched in app store. We have made an objective and fair evaluation to the project by comparing these apps.

Some strength is listed as follow:

- Most of the diabetes self-management applications are software which needs to download from the app store or Android market. But our system is web-based. Everything is deployed and stored on the cloud. User could access the website only with an internet-enabled device such as mobile phone, iPad and PC in any place & at any time. Because of this feature, we put user authentication to guarantee the security and privacy of user. Only registered user with correct username and password could login the personal data. Even in most existing offline applications, the lack of authentication is a big problem. We believe that no patient wants others to view his illness data.

- Most existing apps present each factors individually. It is clear but difficult for users to find the relationships and trends among them. Our project provides such a page to show all the graphs and tables together so that the user could easily contrast and connect these factors. This could help them to understand the impact of each factor and support them to determine their proper lifestyle.

- Seldom apps provide the nutrition information about food. But these information means a lot for diabetes in choosing the food. Our project provides two tables of different kinds of breads and fruits and lists their fiber and sugar. This could be a reference for the diabetes in choosing a proper food among all kinds of similar food.

- Our project provides a forum for the users to post and reply. They could exchange their experiences and discussing in this platform. The forums are commonly provided in some diabetes association website. It seldom appears in those offline self-management applications.

- Most diabetics don’t want the doctors to view their daily record, or they may cheat in the record. Because of this kind of attitude, our project gives them the rights to decide whether the doctor is allowed to view his data and which part is visible to him. Thus they will record the real data trustingly. This is an important point that other applications have ignored.

Some weakness still exists in the system which may need to be improved in the future work:

- The project has only designed responsive web page to adjust PC, iPhone and iPad. Due to the limitation of time and too many sizes in Android phones, the layout in Android has not been designed. Thus the using range of devices is small.

- Although the layout in mobile phone could be adjusted in to a proper way, the aesthetic appearance of the interface is not good enough.

- The glucose level before or after meal is quite different. But we don’t distinguish them in our project. So the timing and frequency of glucose testing should be controlled by the diabetics himself so that the presentation result will be more meaningful and useful.
Recommendations from instructor, professional researchers and classmates

The system is user-centered, so we get a lot of feedback from different people. The meeting with instructor has given us many guides in designing and implementing the project. The professional researchers have proposed some useful ideas and requirements from the patients’ point of view. Moreover, our classmates have given a lot of creative advices after they use the system.

Summary

This project aims at making a diabetes self-management application by applying the information technologies. The application should enable the user to tracking and viewing their diabetes statistics, the data collection and presentation is studied as the most important concern. By completing this project, the web application with expected functionalities has been completed and deployed on windows azure cloud platform. Related investigation and internet search has been carried out; a systematic literature review has been done. After the completion of the application, the system test and evaluation were processed to test the system availability and reliability. We have learned quite a lot from this project work, mainly narrowed as the following subjects.

Web development

Web development is the real code implementation of this project to achieve the application with given purposes. HTML5, CSS3, JavaScript, ASP.NET was the techniques how we have realize this application. During the development of the web application, those skills have been practiced and improved a lot.

Responsive web design

Responsive web design occupies a large work load in this project especially in the early development stage. Different strategies had been discussed and a solution is implemented in the application design. Media query and fluid layout were something we have learned in the responsive web design. This would be very useful in the future web development as well as in our career since more and more people are using mobile devices regularly and responsive design is a global trend.

IIS (Internet Information Services)

Due to the limitation of the free trial of the cloud platform, the database development was not initially developed on the cloud. Instead the web application was tested and deployed on IIS. At the beginning, a lot of problems in deploying IIS have been raised regarding the permissions and firewall protection. We have learned how to successfully deploy the web application on IIS server and deal with the problems appeared on IIS.

SQL database and SQL

Due to the limitation of the free trial of the cloud platform, the database development was not initially developed on the cloud. Instead, a local SQL database was established with specific-purpose tables. Hence, we have worked much on establishing SQL database on SQL
server and working with different SQL statements with C# programming in Visual Studio. Concretely, there has been a problem existed while remotely connecting to the SQL database; several approaches had been tried out and finally fixed.

**Cloud Computing and Windows Azure Cloud**

In this project, we have a deep insight of the windows azure cloud platform, especially in deploying web application and SQL database. We have learned how to publish a local web application to the cloud and how to establish a SQL database on the cloud.

**C# Programming**

Even though C# is no longer new when doing this project, we have learned and practiced much on C# programming. C# language is used for developing the back stage process of the web request in this application. Approximately we have written back stage program for 19 pages in this website and 5 C# classes used. The experiences in writing C# programming has brought us the ability in writing C# formatted logic; especially in database management, cookies and working with the front-end server control.

**Literature Review**

A systematic literature review has been done in this project. In prior to the literature review stage; large amount of investigation and internet search has been done to process the literature review and its related work. From those processes, we have learned the method and procedure of literature review, how we could efficiently find useful resources from the past researches done by others.

**System Evaluation**

System evaluation is processed after the application was finished. It mainly evaluated the application from two strategies. First, interview and discuss others from users’ perspective. Secondly, performance testing in the code implementation to get different target parameters of the application like response time, error rate and process capacity.

**Team Cooperation**

According to the group setting, data collection and visualization group and platform group are two independent research groups with different direction. But we have been working together in doing the investigation and making the application. During the project work, we have cooperated in contributing to the project design and finally get the application done.

**Conclusion**

By taking this degree project work, we have been studying something new like responsive web design, data collection and presentation of eHealth application as well as some medical information, particularly on diabetes. Apart from the study of different technologies, we have done a systematic literature review which we haven’t ever experienced before. Cooperation is also very important in this project since two groups are working together and
some other medical groups are also involved. From those aspects, we have improved ourselves much during months of project work.

Moreover, applications on ehealth self management could make important sense in our society since people are facing or suffering variety kinds of diseases and may need long-term health care or treatment. Self management application will save a lot of medical resources and cost; and on the same time the patients can use it for a better and more convinient management of their illness, especially for those who need long term observation and lacks of sufficient medical supports.

On the other hand, mobile devices are more popular than before and most people now are using the mobile devices regularly for accessing different services. Hence, the development of ehealth application on mobile devices would solve a lot of problems as well as better serving the community with different kinds of diseases. Therefore, our work could be important and beneficial for those who need them. Meanwhile, the potential market in this field could be large as many people over the world may need it.

The application itself is developed with expected functionalities and features in the current step. However, a future development could be assigned as to improve the application from different perspectives.

**Recommendations for Further Work**

Even though this project has fulfilled the application with expected purpose for diabetes self-management, there are still several critical concerns can be improved or added. Basically, this application has realized a responsive web design on iphone, ipad, and the web pages enable the user functionalities of authentication, data tracking and viewing, and discussion forum; in particular, access control is implemented in this site to enable the role management. Different roles are granted separate set of permissions and pages for given purposes. However, the web pages can be always improved to get a better view for the user; scalable responsive web design is a crucial point in order to adjust the web layout on various kinds of mobile devices; point-to-point communication is another optimal design to enable a direct communication between doctor and normal patient user; security protection of the user data and other site info would be required to keep the user privacies.

**GUI Design**

The current web GUI design is adjusted and decided by us as developers, the site view looks fine according to the meeting with the medical group and our classmates. However, the layout can be always modified and the content can be adjusted to make the site a better intuitive view. Besides, the main color used in this site is light green; the medical group had ever given a suggestion that there might be some users who are Red-green color blindness. These will be the fundamental concerns in the future work improvement.

**Responsive Web Design**

The current responsive web design is to some extent dynamic since more categories of the mobile devices can be added, but there requires a new CSS specification whenever a new category is added. There could be some solutions to get a single design that could be adopt-
ed in different situations. A proposal could be that using media query plus fluid layout; use a relative size design to define the web layout rather than using fixed size. Another proposal could be writing a computation algorithm to firstly detect the device width, and then automatically compute and assign an optimal size and position to configure the web layout. Even though the responsive design in this project has been realized on mobile devices like iphone, ipad; there would have other concerns in considering the other mobile devices, different web browsers and different operating systems as well.

**Point-to-Point Communication System**

Initially it was planned to establish a communication system in this site to enable the communication between doctor and patient users. In this case users will have the chance to discuss with the doctors and get help from them. But this purpose has been deviated from the initial purpose that establishing a tool for diabetes self-management which mainly focuses on the patients rather than the doctors. However, this could be an optional design in the future development.

**Security Protection**

Security protection of the user data can also be included in the future work to keep the user privacies. User data is very serious since the patients may not want the others to know about their personal data, this is also a crucial concern in making other kinds of self-management tool. The user privacy needs to be guaranteed. Any data uploaded should be encrypted during the transmission and in the storage.

**Literature Review**

In prior to this project design, we have already taken some paper seminars during the course study yet not very systematic approach in doing literature review. A better and more efficient literature review could be done to improve the design, especially in data collection and visualization part, which is recognized as the core part in this project.
References

Books
Sorting Data: collection and analysis By Anthony Peter Macmillan Coxon ISBN 0-8039-7237-7

Articles
AMERICAN DIABETES ASSOCIATION, Diagnosis and Classification of Diabetes Mellitus, DIABETES CARE, VOLUME 29, SUPPLEMENT 1, JANUARY 2006
Jun Lu, Song Zhang, E-health Web Application Framework and Platform Based On The Cloud Technology, 2013.06
WWW

LeanYourCompany.com, Establishing a data collection plan, 2013-05-06
Enclosures
<table>
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<th>#</th>
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<th>country</th>
<th>title</th>
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<th>literature related to</th>
<th>Full text</th>
</tr>
</thead>
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Enclosure 2

1 ("Diabetes Self Manag"[Journal] OR ("diabetes"[All Fields] AND "self"[All Fields] AND "management"[All Fields]) OR "diabetes self management"[All Fields]) AND (("data collection"[MeSH Terms] OR ("data"[All Fields] AND "collection"[All Fields]) OR "data collection"[All Fields]) AND "visualization"[All Fields])

2 "Diabetes Self Manag"[Journal] OR ("diabetes"[All Fields] AND "self"[All Fields] AND "management"[All Fields]) OR "diabetes self management"[All Fields]

3 ("data collection"[MeSH Terms] OR ("data"[All Fields] AND "collection"[All Fields]) OR "data collection"[All Fields]) AND "visualization"[All Fields]

4 ("telemedicine"[MeSH Terms] OR "telemedicine"[All Fields] OR "ehealth"[All Fields]) AND ("data collection"[MeSH Terms] OR ("data"[All Fields] AND "collection"[All Fields]) OR "data collection"[All Fields]) AND "visualization"[All Fields] AND web[All Fields]

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Enclosure 3
Typical Solution and Implementation of Responsive Web Design

Fluid Grid Layout
Fluid Grid Layout technique uses media queries (enables text to adapt the predefined conditions with different media features such as width or height) to determine where to put the break points so that the site could properly resize variety of elements. Fluid Grid Layout allows the user to have specific experience of the website by using different devices. The structure of the website could be used for both PC and other handheld devices [8].

Instead of using fixed size elements with pixel measurement, fluid grid layout is commonly constructed by the percentage of each element used which gives a good integration view. Firstly, developers are required to get a fixed size design with specified size of each element. Secondly, by considering the proportion of each element in the design, the percentage of the width and height of the element can be calculated, and the percentage will be adopted when different size of devices is detected. For a simple instance, an element with 100px width in an 800px’s container will be defined to have a 12.5%’s width rather than fixed number. Figure-a indicates the difference between fixed size design and fluid grid layout.

![Figure-a. Comparison between Fixed Layout and Fluid Layout [8]](image)

Media Queries
A media query includes a media type and at least one expression to define the condition of the style sheets. Those media features such as width, height, orientation and resolution could be used to give the boundaries. This technique enables the web contents to adapt to devices with different sizes such as notepad, iPad and mobile phones [8]. Developers are using media query to specify different design for different device width, according to the different device width and view mode, a separate layout design can be structured in CSS. The code framework in Figure-b indicates how media query is implemented.
Responsive graphics and other media
As it has been introduced in the previous techniques; by using fluid layout, the web content will be reconfigured while the device width or orientation varies, but it only regenerates the text layout rather than the other media like images or embedded videos. A large image on a computer may not be contained on for a mobile device with even smaller screen width; it’s the same that a relatively small image on mobile devices may not be cleanly shown up on the computer with relatively larger screen. Then the problem raises that how to resize the images or videos according to the device width. The solution could be just replacing the fixed dimensions with relative measurements or percentages and then boom, flexible responsive images. Figure c gives an example that implies how the graphics and other media are resized according to the device width.
Encountered problems and solutions

The project development was mainly focus on four sections, responsive web design, ASP.NET development, Database and Cloud Computing. In each section of the development, there have been raised a lot of problems and difficulties in the design and implementation. Completely new to responsive web design, insufficient knowledge regarding the remote access to the SQL Server database and deployment on cloud platform have all lead to problems which slowing the development process. Selected problems are considerable issues appear in the development and related solutions are listed.

- Subject: How to successfully deploy the local web application on IIS.
  Problem 1. No permission in accessing the application directory Solution: Make sure the application is placed in the directory which the program has right to access it; otherwise place the application into other directory can be fetched. Furthermore, change the permission of the application on IIS, grant full control permission to the users/ systems if necessary.
  Problem 2. Can access the web application locally but not remotely when the web application is deployed on IIS; bind it to the correct address. If it could be viewed locally, it means the application has been successfully deployed. Try on another computer remotely, it may not be accessible. In this case the firewall needs to be turned off to allow the external request.

- Subject: Failure in remote accessing the SQL Server database.
  Problem 1. SQL Server Services cannot correctly runs in SQL Server Services Configuration Manager.
  Solution: Try not to update the tool or reinstall the SQL Server Service Configure Manager; try to locate the file named “Microsoft SQL Server 2012LocalDB” and delete it, the problem is then fixed.
  Problem 2. Failure in remote accessing others’ SQL Server database. Solution: Go to the SQL Server Configuration Manager tool, enable the TCP/IP protocol and modify the setting to correct IP and port number, and then restart the SQL Server Services.

- Subject: How to deploy a web application on Windows Azure Cloud
  Solution: Create a new web application on Windows Azure Cloud, and go the DASHBOARD page. There the PublishSetting file of the web application can be found. Download this file and add it to the application directory. Right click the application to publish and then add this file as the configuration file. The web application will be successfully published on cloud.

- Subject: How to get a database design on Windows Azure Cloud
  Solution 1: Create a new SQL database on windows Azure, to do this it will be required to register a unique account with its password. Login to the database management page and there could create tables and other information. When the database is created, get to the
dashboard page and fetch the connection property, it will have the connection string for different frameworks. Choose .NET will get a copy of the connection string which it can be applied in ASP.NET web application in Visual Studio. Regarding the connection string, the username and password need to be modified to the correct account that has been previously registered.

Solution 2: If the database is locally created in SQL Server, the database can be exported in a script language. And use this file as the source file to create database on cloud, then the database is established on cloud with the same structure. Followed the same with the final step in solution 1; try to locate the connection string and correctly apply it to the application.