mHealth Support System for Researchers and Participants

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mHEALTH SUPPORT SYSTEM FOR RESEARCHERS AND PARTICIPANTS

by

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ABSTRACT
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With the proliferation of mobile technologies, there is a significant increase of research using mobile devices in the medical and public health area. Mobile technology has improved the efficiency of healthcare delivery effectively. Mobile Health or mHealth is an interdisciplinary research area which has been active for more than a decade. Much research has been conducted and many software research tools (mHealth Support System) have been developed. Despite the time length, there is a significant gap in the mHealth research area regarding software research tools. Individual research groups are developing their own software research tool though there is a significant similarity among them. Most of the research tools are study or disease specific. Some of the tools are device specific (desktop/laptop, mobile phone, and tablet) and some are platform specific (web, android, iOS, and windows). This costs each research study their precious time, money, and workforce to develop similar service or software research tools. Based on the mHealth research characteristics, it is possible to design and implement a customizable generic software research tool. In this thesis, we have proposed, designed, and implemented a customizable generic mHealth software research tool. It has most of the common software research modules that are needed for an mHealth research study. These include real-time data collection, research participant management, research staff management, role based access control, research data anonymization, customizable surveys, report generation, study forum, and activity tracking. This software research tool is responsive and HIPAA compliant which makes it device independent, privacy-aware, and security-aware.

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LIST OF ACRONYMS

PDA	Personal Digital Assistant
GPS	Global Positioning System
mHealth	Mobile Health
ICT	Information and Communication Technologies
WHO	World Health Organization
GOe	Global Observatory for eHealth
SMS	Short Messaging Service
GPRS	General Packet Radio Service
PDF	Portable Document Format
URL	Uniform Resource Locator
CSV	Comma-Separated Values
HIPAA	Health Insurance Portability and Accountability Act
PHI	Protected Health Information
ePHI	Electronic Protected Health Information
HTTPS	Hypertext Transport Protocol Secure
SSL	Secure Socket Layer
ERD	Entity Relationship Diagram
PHP	Hypertext Preprocessor
HTML	Hypertext Markup Language
Yii	Yes It Is
MVC	Model View Controller

CSS	Cascading Style Sheet
JS	JavaScript
RDBMS	Relational Database Management System

CHAPTER 1: INTRODUCTION

The mobile technology is referred as a technology which is used for cellular communications. Due to its adaptive and portable features, mobile technology has become popular among the people. Nearly a decade ago, only business executives were seen carrying smartphones. Nowadays, mobile technologies such as smartphones, laptops or tablets are easily available. According to new research, from the Pew Research Center's Internet & American Life Project, “64% of American adults now own a smartphone of some kind, up from 35% in the spring of 2011” [1]. Earlier, mobile device users would use their cell phone, PDAs (Personal Digital Assistants), MP3 player, e-book reader, camera or GPS (Global Positioning System) device individually. These days, a smartphone puts all of these functionalities along with a Wi-Fi adapter and a high definition touch-sensitive screen into your pocket.

The use of mobile and wireless technologies such as smartphones, Wi-Fi, and Bluetooth is becoming very popular in the healthcare area, popularly known as mHealth (Mobile Health). Lower cost and pervasive use of mobile devices are the main reasons that make healthcare faster, better and affordable. Recent research shows that mHealth has, and will continue to have a remarkable impact on the delivery of healthcare services.

Extensive research has been focused on developing mHealth system. Mobile communication and smart devices help to improve the quality of life by bringing healthcare services to the remote user [2]. Modern smart mobile devices are the target devices for the mHealth applications. Most of the mHealth applications are device specific. These applications can work on either iOS platform or android platform [3]. Mobile technology, especially smart phone-based applications, improved the efficiency

of healthcare delivery, and ultimately made the healthcare more effective [2], [3]. Developing device dependent applications need more time and more resources which are expensive. Most of the study collects only participants' data. Then researchers study and generate reports from the collected data. Researchers collect pre and post data using different tools like survey monkey but those tools do not give real-time access to data. Usable mHealth interface for the researcher is a long-awaited facility. Also developing the generic system is more time and cost effective than disease specialized tool [4]. There is no such solution or study, which covers all the above-mentioned features. The goal of this thesis is to develop a system which will cover all the above-mentioned functionalities. We have discussed the research objectives in the following section.

1.1 Objectives

The objectives of this thesis are the followings:

- Generic research tool for healthcare research
- Provide researchers a device independent tool
- Provide participants a device independent tool
- Easy collaboration between researcher and participant
- Provide researchers a real-time accessible data collection tool
- Provide reports from the collected data

1.2 Our Contribution

The major contributions of this thesis are as follows:

- Developed a device independent mHealth system.
    - Participants and Researchers will be able to use same application on different devices

  - Cross-platform
  - Cost effective
  - Mobile
- Proposed an architecture and developed mHealth tool which is generic for any disease.
- Developed a continuous tracking system.
  - Monitor participants involvements and activities on assigned mHealth tools
  - Automatic reporting for lack of involvement based on defined activity thresholds by researcher
  - Track assigned milestones
- Developed a data collection tool.
  - Get current status of the participants
  - Get feedback from participants on assigned tasks and activities
  - Collect participant's response during the treatment
- Incorporated and customized forums for a support group.
  - Easily customizable based on requirement
  - Easy to configure
  - Getting support when anyone needs it
  - Networking opportunities
  - Building communication between participants and experts
  - Increasing knowledge
- Developed email notification sending to participants as a reminder.

- Designed and developed a well-organized secured database.

1.3 Organization of The Thesis

The rest of this thesis is organized as follows:

- Chapter 2 introduces and describes different terms related to this research.
- Chapter 3 investigates existing works in the mHealth research field.
- Chapter 4 analyzes the required components of the mHealth research tool.
- Chapter 5 discusses the important design considerations of the system development.
- Chapter 6 highlights the features of the proposed system.
- Chapter 7 presents the details of the proposed system.
- Chapter 8 concludes the thesis with a summary and suggestions for the future works.

CHAPTER 2: BACKGROUND

2.1 mHealth

The use of mobile and wireless technologies in the healthcare area is popularly known as mHealth (Mobile Health). mHealth is used to improve health outcomes, healthcare services, and health research. It is not a separate industry, rather it is the future of the healthcare industry. Lower cost and pervasive use of mobile devices are the main reasons that make healthcare faster, better, and affordable. Recent research shows that mHealth has, and will continue to have a remarkable impact on the delivery of healthcare services.

2.2 Responsive Web Design

The responsive web application can automatically adjust for desktops, laptops, tablets or smartphones. It needs to build once, which can run across all devices. It is cost and time effective. A single application can serve multiple purposes for all devices. It helped to make the system works perfectly and looks good for any size of any device. Nowadays, smartphones occupy people for a large portion of their daily time. They browse almost everything by using these devices. So, it is essential to have a mobile based application for business purposes. As developing different kind of applications (android, iOS, web app) to serve a single purpose is not time and resource effective, IT industries moving towards responsive designs. In the near future, most of the web design will be responsive.

2.3 Forum

Any person can be benefitted and motivated by participating in a healthy group discussion or forum. Different researches [5] [6] have shown that focus group discussion

is helpful for a group of people with similar experiences. They can discuss on a specific topic guided by a moderator or researchers. The generic mHealth tool can have a generic customizable forum rather than a focus group discussion board. Moderator or researchers will be fully in charge.

2.4 Role Based Access

Role-based access is an approach to restricting the unauthorized access to the system. It determines which user has what type of permission to access the system. Using the same application, different users can view different contents or perform different types of tasks.

2.5 Privacy and Security

When planning a digital healthcare application, security and privacy are two essential design issues. Whereas the HIPAA (Health Insurance Portability and Accountability Act) Privacy Rule deals with Protected Health Information (PHI), the HIPAA Security Rule deals with electronic Protected Health Information (ePHI).

To protect health-related data which are created, received, maintained or transmitted electronically the system must follow HIPAA Security Rule [7]. According to U.S. Department of Health & Human Services, "The Security Rule requires appropriate administrative, physical and technical safeguards to ensure the confidentiality, integrity, and security of electronic protected health information". All data transaction between a participant and the online system or a researcher and the online system should be secure and encrypted when it comes to the human subject. In a research study, there can be different types of personal information of participant. Using some secure protocols like HTTPS (Hypertext Transport Protocol Secure) security can be achieved. HTTPS utilizes

SSL (Secure Socket Layer) over HTTP in general. Host servers which are HIPAA compliant are also another way of achieving security. For example, participant's name, address, phone number etc. Participant's health related data is also private for that participant. User's credentials are also private information. All of this information should be encrypted while storing into the database.

While working with human health data, privacy is an important concern. Medicine and health related study should maintain HIPAA Privacy Rule [8]. According to U.S. Department of Health & Human Services, "The Rule requires appropriate safeguards to protect the privacy of personal health information, and sets limits and conditions on the uses and disclosures that may be made of such information without patient authorization. The Rule also gives the patient's rights over their health information, including rights to examine and obtain a copy of their health records, and to request corrections".

CHAPTER 3: RELATED WORKS

3.1 mHealth

The term “mobile health” or “mHealth” describes the numerous applications of mobile technologies in healthcare and public health area. This word was introduced around a decade ago [9]. The term “eHealth” describes the use of information and communication technologies or ICT in health. The services under eHealth include patient treatment, conducting research, educating healthcare provider and workforce, disease tracking, and public health monitoring [10] [13]. According to World Health Organization (WHO), mHealth is an integral part of eHealth. The Global Observatory for eHealth (GOe) defined the mHealth as the medical and public health practice offered through various mobile and wireless devices. These devices include mobile phones, patient monitoring devices, personal digital assistants, and computers [11]. Besides these devices, smartphones, and other portable mobile devices like iPod, tablets have significant applications in mHealth [9]. According to WHO, “mHealth involves the use and capitalization on a mobile phone’s core utility of voice and short messaging service (SMS) as well as more complex functionalities and applications including general packet radio service (GPRS), third and fourth generation mobile telecommunications (3G and 4G systems), global positioning system (GPS), and Bluetooth technology” [10]. Nowadays, numerous wearable devices and smartphone applications are an important part of the mHealth. This became possible because of the technological advancement and ubiquitous adoption of the smartphone. According to a report [12] on the state of the mHealth app publishing, there are around 100,000 mHealth apps are available in the two major smartphone application stores (Apple’s App Store and Android’s Google Play).

The same study also reported that the annual revenue of this market is projected to reach more than US $26 billion by next year (2017).

3.2 mHealth Research

In the last decade, from its early adoption in 2000, mHealth has been growing continuously [13]. The applications of mHealth are able to aim different stakeholders in health and healthcare industry. These stakeholders include physicians, nurses, patients, and healthy people [13]. There have been many research using mobile technology or mHealth. Few examples are: smoking cessation, physical activity, pain recognition and management, weight management, osteoporosis and bone health, mental health, and various disease management [18] [14] [15] [16] [17]. One of the advantages of using mobile devices is they are personal, have good computational and communication power, intelligent, connected to the internet, and always with the user [19] [20]. Hence it is possible to support or intervene patients continuously whether they are in hospital or rehab, or day to day monitoring in everyday life [13].

3.3 mHealth Research Tool

Due to an increased demand in mHealth research studies, there has been a lot of development of different research tools. These tools accommodate different requirements of the research study [23] [21] [22]. The mHealth researches are multidisciplinary. Therefore the system design, development, testing, and evaluation of the mHealth tools need experts from respective fields [25]. The system design needs to be performed by healthcare researchers. The development and testing need to be done by software engineers. The evaluation of the system needs to be performed by extensive collaboration by researchers, physicians, participants, and business experts.

Different studies develop different tools based on their respective study requirements. Most of the research studies have common sets of tasks that need to be performed through mHealth tools [25] [24]. These tasks include managing research participants, collecting numerous data from the participants, track participant's activity, motivate participants, manage research data, generate meaningful information from research data, preserving security and privacy of the research study (participant's personal information and health-related data), discussion group for participants, etc. [24]. Each research study is independently developing mHealth tool to perform these tasks. A significant budget has been used to develop the same set of tools that can be generalized and then customize based on specific needs. This is going to help in minimizing development cost and time, save valuable time interacting researcher and developer. Also, different studies have developed the same tool for different devices (for example, desktop or laptop computer, website, android application, iOS application, Windows application). This can be also reduced by developing a responsive application which will work on any device.

CHAPTER 4: REQUIREMENTS ANALYSIS

From previous and ongoing researches, we have identified key requirements. Those are discussed below:

4.1 User Enrollment

To identify data collected from participants and to keep track which researcher is working on those data, user enrollment is important. During enrollment, generally, personal information of the user is being collected. Privacy and security of user's personal data are discussed later in this chapter. It is a key requirement that the system will be able to separate user's personal data with the data collected from the surveys through the whole study. During the enrollment process, all users have a separate account with unique username and password.

4.1.1 Researchers

Mainly researchers will have the administrative control of the system. Based on responsibilities and accessibility to the system, researchers can be divided into different roles.

4.1.2 Participants

Participants can be divided into groups based on the necessity of the mHealth study.

4.2 Static Contents

According to ExSite WebWare, static contents are the fastest and most efficient way to deliver any content [26]. In the mHealth study, researchers may provide static contents to participants which will be helpful for them. For instance, the recipe of calcium enriches food, how to improve diet plan, videos of physical exercises etc. A

static content can be either a PDF (Portable Document Format) file, or doc (word processing document) file, or simply a URL (Uniform Resource Locator).

4.3 Surveys and Forms

A set of predefined questions which helps to collect data from participants. A question in a survey can depend on the answer from the previous question. Again, the answer can be calculated from another answer. For example, if a participant provides his or her date of birth, the system will calculate his or her age and put the number on the answer field automatically. Questions and answers in a survey can be categorized into different types like:

- Predefined Choice
    - Single Choice
    - Multiple Choice
- Yes/No Choice
- Number Range
- Text/Comment

Researchers may need different types of forms such as user enrollment form. Surveys and forms can be useful in multiple ways:

4.3.1 Determine Eligibility

Researchers will enroll all participants who are willing to participate in the study. Forms can be created with predefined questionnaires based on the required criteria of the particular research area. Eligibility can be determined using those forms. If participants are not eligible for the study, they cannot participate in it.

4.3.2 Data Collection Tool

Primarily the data collection tool will be used to get the current status of the participants, get feedback from the participants on assigned tasks and activities and collect participant's response during the study. Data collection process can be done by two ways:

- Directly by participants
- Through researchers

Data will be collected from eligible participants using different types of surveys. The study may require that participants will complete these surveys within a specific range of time. The same surveys can be used for multiple times to collect data from the same participants according to requirement.

Researchers will examine participants and store data into the system. There will be an option for researchers that if any participant is unable to complete surveys or submits a paper copy of surveys, researchers will be able to enter data using surveys on behalf of that participant.

4.3.3 Eliminate User

Researchers will be able to eliminate participants using forms. There can be multiple types of elimination like:

- Participant who completes his or her study
- Participant who does not want to continue the study anymore
- Participant who does not concentrate or complete surveys timely
- Participant who is irregular or inactive for a long time

4.4 Continuous Monitoring and Tracking

Researchers will be able to monitor participant's involvement and activities in assigned tasks. There will be an automatic reporting system for lack of participant involvement based on defined activity thresholds by researchers. The tool or system will keep track of the participants' application activities:

- Activity Tracking: It will keep track of the user navigation in the app.
- Time Tracking: It will keep track of the time participant spends on each survey. It will also keep track of the total time spent on the application.

4.5 Motivate Participants

Research [27] shows that motivation keeps participants active in the study. If the system has an option to send gift cards to its participants after completion of any milestone, they will be motivated towards the study. For example, researchers can pre-schedule gift cards according to the requirement fulfillment. When participants will complete required surveys or exercises, the system will send them gift cards automatically.

4.6 Forum or Group Discussion

Different researches [5] [6] have shown that focus group discussion is helpful for a group of people with similar experiences. They can discuss on a specific topic guided by a moderator or researchers. The generic mHealth tool can have a generic customizable forum rather than a focus group discussion board. Moderator or researchers will be fully in charge.

4.7 Reports

Analyzing data is important to get useful information through the process of data cleaning and transforming. In mHealth researches, data analysis have a key impact. Reports can help researchers to analyze data. Researchers can use two types of reports:

4.7.1 Primary Report

These type of reports will provide raw data to the researchers from the database. There will be no computed value or data. Researchers will be able to export data in a CSV (Comma-Separated Values) or Excel file.

4.7.2 Processed Report

These type of reports will provide both raw data and some computed data. For instance, the system can have a report which will display the start date, end date and days of participation of a participant. Days of participation is a calculated field where other two fields are retrieving from the database. The system can deliver the reports in a web page and/or CSV or Excel file.

4.8 Security and Privacy

When planning a digital healthcare application, security and privacy are two essential design issues. Whereas the HIPAA (Health Insurance Portability and Accountability Act) Privacy Rule deals with Protected Health Information (PHI), the HIPAA Security Rule deals with electronic Protected Health Information (ePHI).

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While working with human health data, privacy is an important concern. The health-related study should maintain HIPAA Privacy Rule [8]. According to U.S. Department of Health & Human Services, "The Rule requires appropriate safeguards to protect the privacy of personal health information, and sets limits and conditions on the uses and disclosures that may be made of such information without patient authorization. The Rule also gives the patient's rights over their health information, including rights to examine and obtain a copy of their health records, and to request corrections".

CHAPTER 5: SOFTWARE DESIGN CONSIDERATIONS

Designing means expressing creativity, giving a structure to an unorganized plan. A good software design can assure the development of a successful software. Following sections discuss a few good practices of designing a software [28].

5.1 Development Process

The importance of choosing an appropriate development lifecycle process for software development is to deliver a quality product for business success and to get the best use of time and money. Based on the functional requirements and delivery requirements developers need to select their desired process. The regularly used methodologies enclose direction about how to execute the development process.

One of the popular methods is Agile. Agile is a variant of lifecycle where deliverables are submitted in stages [29].

Developers should always keep in mind that it is important how well a method is executed rather than what method is executed.

5.2 Requirements

Gathering, analyzing and agreeing on requirements is vital for a successful project. It is not necessary to fix all the requirements before any architecture or design or coding are done. But a clear understanding of overall requirements is essential before designing a system. Documentation can be helpful for both stakeholders – developers and clients. Requirements can be two types:

- Functional Requirements

  What the system should do can be defined as a functional requirement. For instance, functional requirement

can be like display the full name or take input from a customer or print the invoice or audit tracking etc. Mike Perks discussed in an article on best practices for software development projects that “A good way to document functional requirements is using Use Cases”.

- Non-functional Requirements

  Non-functional requirements specify how the system should behave or work. It can also be defined as quality attributes for a system. Few non-functional requirements are scalability, capacity, data integrity or manageability.

To meet client’s needs, requirement analysis is necessary. The stronger the foundation the smoother it will go when development begins. Developers can follow few techniques [30] to gather requirements:

- One-to-one Interviews

  Sit down with the client and ask open-ended questions.

- Group Interviews

  Same as one-to-one, but with a group of people. One user may express his or her opinion, others may expand or correct that.

- Questionnaires

  This will be like taking surveys; the developer will provide a set of questions to the client. Clients will fill out before approaching to an in-person interview.

- Use Cases

Sometimes managing non-technical clients becomes difficult. They cannot visualize what will be best requirements for their product. Use case is like story telling; it expresses how a certain process in the software should work. It may be helpful for clients to communicate clearly.

5.3 Architecture

The system architecture is an organization, behavior, and views of a system. Selecting an appropriate architecture for developing a system is very important. Applying well-known industry architecture is the best practice.

5.4 Database Design

A properly designed database is essential to achieving the goal while developing a software system. Certain principles guide the database design process. In an article of Microsoft, it is stated that while designing a database we should keep in mind the following processes [31]:

- "Determine the purpose of the database"
- 'Find and organize the information required"
- "Divide the information into tables"
- "Turn information items into columns"
- "Specify primary keys"
- "Set up table relationships"
- "Refine the design"
- "Apply the normalization rules"

5.4.1 ER Model

According to Margaret Rouse in an article [32] ER model states the following: “The entity-relationship model (or ER model) is a way of graphically representing the logical relationships of entities (or objects) in order to create a database.” Database design without an ER model is similar to build a house without having a building plan. Designing and developing a system without having an ER diagram is doable. However the moment somebody else takes the responsibility for the project there will be a confusion.

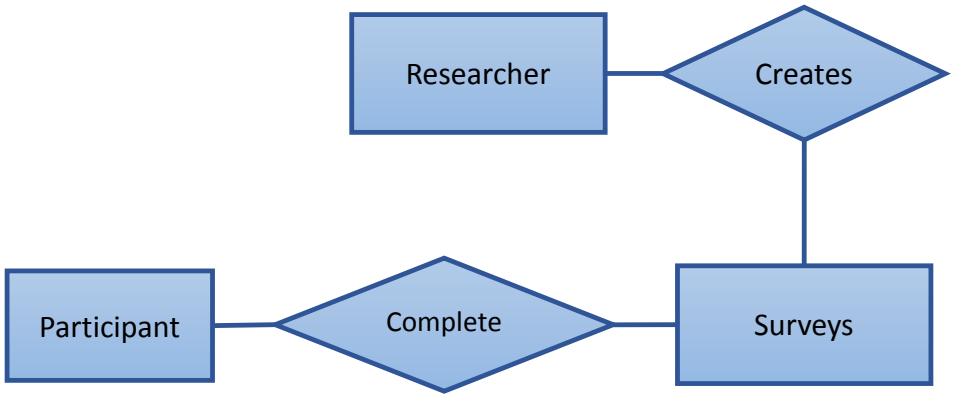

Figure 5.1: An example of ERD

An example is given in Figure 5.1. The elements researcher and participant are described using ER diagrams. The elements inside rectangles are called entities while the items inside diamonds denote the relationships between entities.

5.5 Peer Review

It is always helpful to review other's effort and gather experience. It is also time and cost effective. Reviewing other's work may eliminate challenges they faced. Sometimes, peer review is more effective than testing. It motivates developers and helps them to choose their desired path.

5.6 Testing

After development or during development, testing is an integral part of software development. By testing, developer can evaluate whether the system meets all the requirements, responds correctly, performs functions within expected time. In a summary, it helps to determine whether the system meets all the criteria which were desired. Some popular software testing methods [33] [34] are following:

- Black-Box Testing

  This is an approach of testing which can be done without having any knowledge of interior implementations and without seeing the source codes. The tester is not aware of the system architecture. Developers may seek help from the end user. For large code segments, black-box testing is suitable. But some cases it is inefficient as the tester has only limited knowledge about the system.

Figure 5.2: Black-Box testing approach

- White-Box Testing

  White-box testing is the technique which tests internal structures or working of a program. It investigates details of interior logics. White-box testing is also well known as open-box testing, glass-box testing, transparent-box testing, and structural testing. The tester must need to have a knowledge of source code to find out which part of the code is not working correctly.

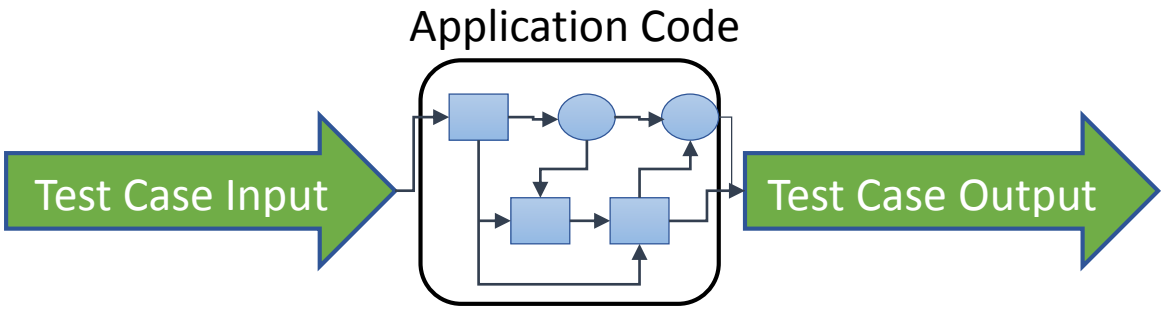

Figure 5.3: White-Box testing approach

As tester knows the interior structure of the code, it helps him to identify which data are helpful for testing the system. This testing approach needs a code analyzer and debugging tool. The cost of white-box testing is very high as it needs a skilled tester. End users can not test the system using this approach.

- Grey-Box Testing

  Grey-box testing is the combination of Black-box and White-box testing. This technique needs limited knowledge of the internal data structures and algorithms.

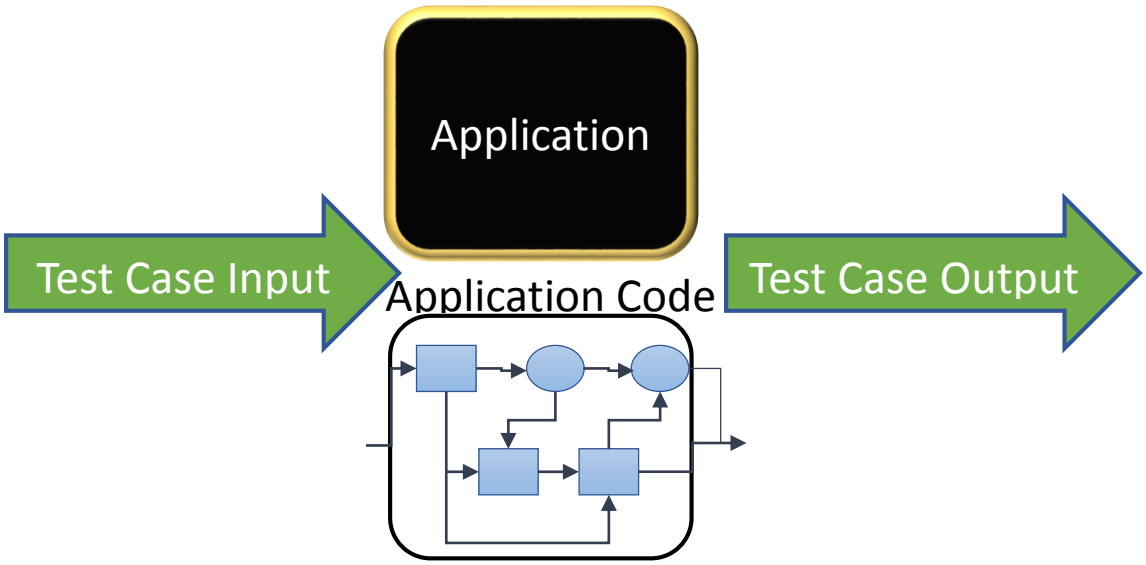

Figure 5.4: Grey-Box testing approach

It offers collective benefits of black-box and white-box testing. This type of test is done from a user point of view, not the designer.

- Unit Testing

This approach tests individual software components. It is done by the developer not by the testers. The unit testing developer can find problems or error comparatively early. It requires full knowledge of program structure.

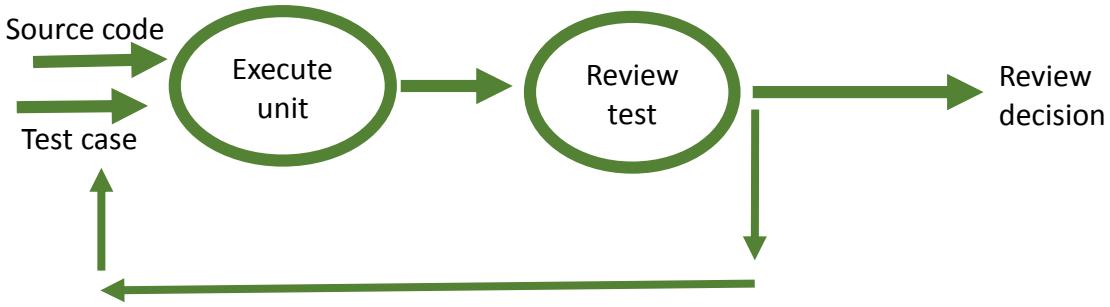

Figure 5.5: Representation of Unit testing

CHAPTER 6: FEATURES OF OUR SYSTEM

We have discussed the features of the system in this chapter.

6.1 Role Based Access

In our developed mHealth system, there are two major panel – one is admin or researcher panel and the other is participant panel. The system can adapt different types of users with different roles. Access to the system can be controlled by using this role. Admin or "Super User" will have the main control power of researcher panel. "Super User" registers all other users and assigns access level based on their role or given tasks.

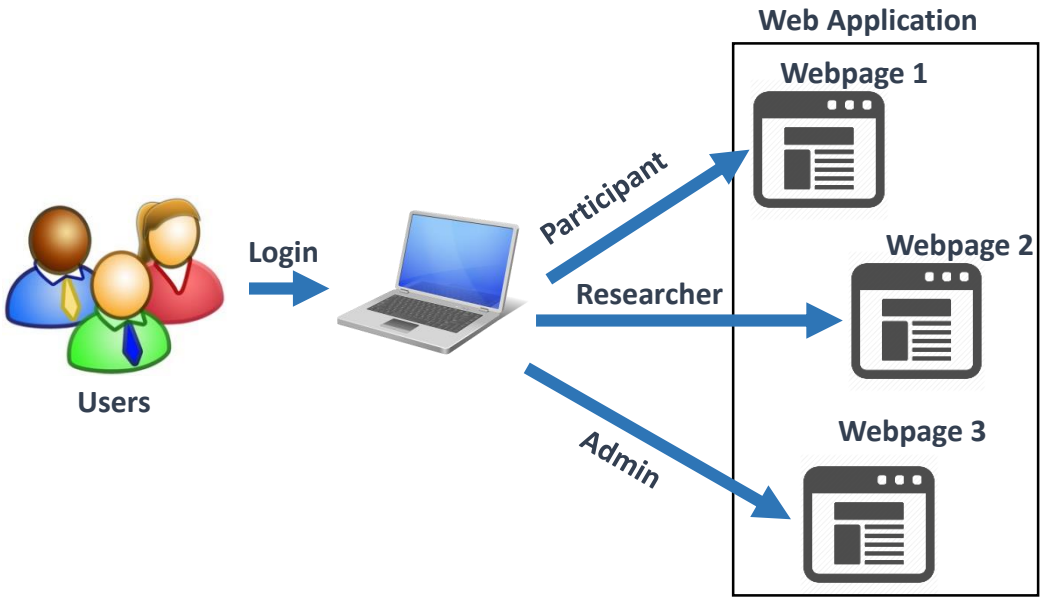

Figure 6.1: Representation of role-based access system

6.2 Responsive Design

The responsive web application can automatically adjust for desktops, laptops, tablets or smartphones. We have developed the mHealth web application in such a way

that it will support any device. It is cost and time effective. A single application can serve multiple purposes for all devices. To make our system responsive we have used Twitter Bootstrap. It helped to make the system work perfectly and looks good for any size of any device.

6.3 Generic mHealth System

Most of the healthcare applications are disease specific [35] [36] [37]. Developing a disease specialized system is both resource and time consuming. We have developed the system in such a way that it will work for any disease. Researchers will be able to set surveys or forms according to their research study. Survey questionnaires may vary based on the study requirements.

6.4 Data Collection

Data collection is a most important part of any research study. In our research tool, data collection tool is used to get the current status of the participants, get feedback from the participants on assigned tasks and activities and collect participant's response during the study. The most useful data collection process is taking surveys. Data collection process can be done by two ways:

- Directly by participants
- Through researchers

Data can be collected from eligible participants using different types of surveys. Participants are able to take surveys from their interface. The study may require that participants will complete these surveys within a set time period. The same surveys can be used multiple times to collect data from the same participants according to the requirements.

Researchers will examine participants and store data into the system. If any participant is unable to complete surveys for a valid reason, there is an option to activate their surveys. There is another option for researchers that if any participant is unable to complete surveys or submits a paper copy of surveys, researchers will be able to enter data using surveys on behalf of that participant.

6.5 Tracking System

Most of the research studies want to track the progress of the participants. This progress is the significant indicator of the participant's performance. Research studies have a timeline consisting of different milestones at the different timestamps. The researcher wants to track the progress of the participants at every timestamp to see whether they reached the milestone or not. In our system, we have the provision to track the participant's current status based on the research timeline.

user_id Identify user without personal info	logtime when visited the page	controller controller of the page	action action of the page	active_time how long user keeps active in this page
resaercher1	2015-12-15 13:39:25.000000	create	user	20
researcher1	2016-02-01 08:01:00.000000	update	user	30
guest	2016-04-06 04:21:00.000000	site	purpose_of_tool	45
9234	2016-04-27 11:22:13.000000	site	survey	653
1234	2016-05-04 00:00:00.000000	site	forum	120

Figure 6.2: User activity log

This tracking system is customizable. The researcher will be able to customize timeline, timestamps, and milestones for their research study. Based on their requirement the system will track the milestone of the respective timestamp.

6.6 Forum

Healthcare forums provide interaction between participants and researchers (participant-participant and participant-researcher) and facilitate knowledge sharing between users. We have developed a generic forum tool and incorporated it with our web application. The forum tool is easy to configure and customizable. It covers specific to generic functionalities.

Figure 6.3: Forum for participant and researcher

Participant or researcher can start a topic and others can participate. As we maintain the privacy of the users, no personal information, like the name, will be disclosed. Every participants and researchers will be known as their unique “Id”. Users will be able to vote or report any particular post. Researchers will be able to monitor all the activities.

6.7 HIIPAA Compliant

Data protection is important to make sure that the personal information is not disclosed without the knowledge of that individual. While a research study works with human subjects, it needs to maintain HIPAA compliance. Participant's personal data is private as well as his or her health data. HIPAA provides guidelines when and how participant's personal information can be shared, including data collected from them.

Our system is HIPPA compliant as it has access to participant's information. We have designed our data storage in such a way that participants, as well as researchers, will be identified by their unique study id. Participant's personal data and research data will be stored separately, making research data anonymous. Research data will be accessible by participant's study id.

CHAPTER 7: IMPLEMENTATION AND SYSTEM DESCRIPTION

This research focuses on developing a modern, responsive and generic mHealth architecture to support researchers and participants in the healthcare area. In this chapter first, we will discuss the tools we have used for implementation. Secondly, we will describe our system.

7.1 Tools Used

Using different types of tools we have developed our system. Among those, few of them we have highlighted in this section. Those are:

- PHP

  PHP means Hypertext Preprocessor. It is a server-side scripting language. Originally PHP is created by Rasmus Lerdorf in 1994 and initially stood for Personal Home Page [38]. The main purpose of designing PHP is for web development. PHP code can be embedded embed into HTML (Hypertext Markup Language) code, or it can be used in combination with various web template systems, web content management systems and web frameworks [39]. In our system, we have used PHP in a web framework.

- Yii Framework 1.1

  Yii (Yes It Is!) is a high-performance, component-based PHP framework [40]. Building an actual web application is not as simple as writing “Hello World” in PHP. As soon as developers want to manage security or MVC (Model View

Controller) pattern, they look for a framework. Yii is used for rapidly developing modern web applications. There are other good PHP frameworks like Symfony, Cake, Zend, CodeIgniter. For developing our mHealth support system we have used Yii as it is mature, time-tested and stable. It has MVC architecture. Creating forms are very easy using Yii. It has built-in support for form input, validation and Ajax [41]. Incorporate extensions can be done easily. Another feature of Yii is, it has good documentation and great developer community.

- Twitter Bootstrap 2.3.2

  Bootstrap is free, open-source and most popular HTML, CSS (Cascading Style Sheet) and JS (JavaScript) web framework for designing responsive web application. According to Twitter developer Mark Otto: "A super small group of developers and I got together to design and build a new internal tool and saw an opportunity to do something more. Through that process, we saw ourselves build something much more substantial than another internal tool. Months later, we ended up with an early version of Bootstrap as a way to document and share common design patterns and assets within the company." [42]. Bootstrap is compatible with the latest versions of the Google Chrome, Firefox, Internet Explorer, Opera and Safari

browsers. It contains nothing but CSS. That means there is no superfluous images, Flash or JavaScript.

- MySQL

  MySQL is an open-source RDBMS (Relational Database Management System). MySQL is a popular choice of database for use in web applications. Between two editions – the open-source MySQL Community Server and the Proprietary Enterprise Server, we have used Community Server in our system.

7.2 Server Configuration

One of the popular web servers on the internet is Apache. Because of having Multiprocessing Modules, Apache is able to run in a process-based, hybrid or event-hybrid mode. It has scalability and flexibility. Apache supports SSL which is helpful to secure web application. We have used Apache Web Server to host our system.

7.3 System Description

The purpose of our generic mHealth support system is to serve researchers and participants a standard and modern application for healthcare area. We can divide our system into two major interfaces: researcher and participant. While the website's visual interfaces look similarly for both, the functionalities are different and programmed based on the researcher's requirements. To get access to the private sections users must need to log in with their credentials. Based on user's role system permit to visit web pages which are applicable for that particular user.

Figure 7.1: Static Content of the System

Figure 7.2: Researcher's Interface

Figure 7.3: Participant's Interface

On researcher's side, there are different types of functionalities. The researcher can create users and provide access level. One of the researcher's pages is shown in figure 7.2. As an administrator, researcher is able to manage or update user's profile excluding password. There are different types of forms for researchers to manage participants. Forms are for the researchers to enter participants' information, to decide whether participants are eligible to participate, to store participants' examination data, and to remove the participants from the system when they completed their study. Moreover, researchers are able to monitor participant's activities like whether participants complete their required surveys within a fixed timeline. Researchers can also track every user, what they are doing and when they do it. By analyzing raw and processed reports researchers determine participant's progress.

Participants' and researchers' interfaces are different based on their role and assigning tasks. From figure 7.2 and 7.3, we can see that navigation bars are different from each other. On participant's interface, there are multiple surveys based on the timeline, exercise videos, quizzes, and few static contents. Participants need to complete surveys within the timeline electronically. Researcher defines the timeline. When the timeline passes, the surveys will be removed from participant's web interface. The researchers have the option to complete surveys on behalf of participants, so that if any participant is unable to submit or submits a paper copy of surveys, researchers can enter data directly into the system via the website. If a participant has a valid reason for not completing surveys within the time period and researchers accept that, then there is a way to activate the removed surveys which are not completed.

There is a common forum (group discussion) for both researchers and participants. Besides observing what participants are discussing, the researchers are also able to create, moderate and participate in the discussion if needed. To remind participants to take surveys within time, the system has notification sending service. Notification is also sent if any participant remains inactive for a long time. We run a script every night and check whether any participant needs any reminder.

CHAPTER 8: CONCLUSION

8.1 Summary

In this thesis, we have proposed, designed and developed an mHealth software research tool which provides responsiveness and generic mHealth support for researchers and participants. The goal of the system is to help researchers to manage healthcare research efficiently.

8.2 Intellectual Merit

For this thesis, we have a contribution in: real-time data collection, research participant management, research staff management, role based access control, research data anonymization, customizable surveys, report generation, study forum, and activity tracking. This software research tool is responsive and HIPAA compliant which makes it device independent, privacy-aware, and security-aware.

8.3 Broader Impact

Mobile communication and smart devices help to improve the quality of life by bringing healthcare services to the remote users. Although there are research studies which collect data of participants and help to improve participants' health, to best of our knowledge there is no solution or study which is device independent and generic, offers similar interface for both researcher and participant, collects data electronically, provides researcher real time accessible data, reminds user by sending email notifications and most importantly which stores user information with security and privacy. We have designed and developed our research tool which supports all these areas.

8.4 Future Works

Mobile technology has improved the efficiency of healthcare delivery effectively. So, it is obvious that the number of research using mobile devices in the medical and public health area will be increased day by day. Incorporation of the text messaging service as notification sending and reward sending service to motivate participant is a future work. User feedback plays a key role to evaluate a system. In addition, evaluation of the proposed research tool using pilot data is a future work.

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APPENDIX A

Description of few terms related to this thesis are following:

- mHealth

  The use of mobile and wireless technologies in the healthcare area is popularly known as mHealth (Mobile Health). mHealth is used to improve health outcomes, healthcare services, and health research. It is not a separate industry, rather it is the future of the healthcare industry. Lower cost and pervasive use of mobile devices are the main reasons that make healthcare faster, better, and affordable. Recent research shows that mHealth has, and will continue to have a remarkable impact on the delivery of healthcare services.

- PHP

  PHP means Hypertext Preprocessor. It is a server-side scripting language. Originally PHP is created by Rasmus Lerdorf in 1994 and initially stood for Personal Home Page [38]. The main purpose of designing PHP is for web development. PHP code may embed into HTML (Hypertext Markup Language) code, or it can be used in combination with various web template systems, web content management systems and web frameworks [39]. In our system, we have used PHP in a web framework.

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writing “Hello World” in PHP. As soon as developers want to manage security or MVC (Model View Controller) pattern, they look for a framework. Yii is used for rapidly developing modern web applications. There are other good PHP frameworks like Symfony, Cake, Zend, CodeIgniter. For developing our mHealth support system we have used Yii as it is mature, time-tested and stable. It has MVC architecture. Creating forms are very easy using Yii. It has built-in support for form input, validation and Ajax [41]. Incorporate extensions can be done easily. Another feature of Yii is, it has good documentation and great developer community.

- Twitter Bootstrap 2.3.2

Bootstrap is free, open-source and most popular HTML, CSS (Cascading Style Sheet) and JS (JavaScript) web framework for designing responsive web application. According to Twitter developer Mark Otto: "A super small group of developers and I got together to design and build a new internal tool and saw an opportunity to do something more. Through that process, we saw ourselves build something much more substantial than another internal tool. Months later, we ended up with an early version of Bootstrap as a way to document and share common design patterns and assets within the company" [42]. Bootstrap is compatible with the latest versions of the Google Chrome, Firefox, Internet Explorer, Opera and Safari browsers. It contains nothing but CSS. That means there is no superfluous images, Flash or JavaScript.

- MySQL

MySQL is an open-source RDBMS (Relational Database Management System). MySQL is a popular choice of database for use in web applications. Between two editions – the open-source MySQL Community Server and the Proprietary Enterprise Server, we have used Community Server in our system.

APPENDIX B

The installation of the mHealth support system in a local server is described below.

- Install HTTP Server, PHP, and MySQL database:

  User needs to download and install http server, PHP and MySQL database in the target computer. There is a package named XAMPP which includes Apache HTTP server, PHP and MySQL database. This package or any other available package can be installed. XAMPP link: https://www.apachefriends.org/index.html

  Once XAMPP is installed our tool is ready to deploy. Execute XAMPP control panel and start server and database to start working.

- Install Yii framework:

  We have used Yii framework to develop the system. The framework needs to be downloaded and installed from the following link:

  http://www.yiiframework.com/download/#yii1

  You have to copy the downloaded "yii" folder and paste it to the public folder ("htdocs" in case of XAMPP).

- Setup database:

  We have used MySQL to store the data. User needs to create a database and import our database structure to incorporate it with the tool. In the configuration file (/protected/config/main.php) user needs to declare the

path of the database. The credentials of database must be mentioned in the configuration file.

- Install the system:

  User has to copy our whole source code folder and paste it to the server's public folder ("htdocs" in case of XAMPP). Then the tool installation is completed.