ABSTRACT

Mission critical or high-pressure environments are environments that are vital to a business functions. Issues like downtime, errors, equipment failure, interruptions, etc. cannot be tolerated in these types of environments because they can lead to total business failure, social turmoil, or loss of life. Examples of mission critical or high-pressure environments include; the cockpit of an aircraft, train communication system, the intensive care unit of a hospital, nuclear reactor safety system, etc. Research shows that developed countries use various software applications in mission critical or high-pressure environment. Most developed countries have employed various human-computer interaction(HCI) and interaction design principles to develop user friendly interfaces for the software applications used in mission critical environments. This study is aimed at understanding the effect of these HCI and interaction design principles on designing user friendly interfaces for software applications, also suggesting and designing a more appropriate system for the intensive care unit of Del international hospital using these HCI and interaction design principles to limit stress and challenges faced by staff, patients and provide quality care services to patients in the ICU.

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

To understand what a mission critical environment means, one has to first understand what the term "mission-critical" means. According to an article *The new scope of mission-critical computing*, written by Nicholas (2013), mission-critical refers to any factor of a system (equipment, process, procedure, software, etc.) that is essential to the business operation or the organization. Failure or disruption of mission critical will result in the serious impact on business operations or organization, and even can cause social turmoil and catastrophes. Therefore, it is extremely critical to the organization's mission. As a matter of fact, an organization can decide what is and what is not critical to its business. For example, an online business will choose the communication system as its mission critical system. While for a steel mill, water and power supply would have the same importance. Mission critical environments are vital to a business functions. Issues like human errors, equipment failure, downtime, interruptions or shutdown cannot be tolerated in a mission critical environment.

In other cases, a mission critical environment is an environment where any slight mistake or error can lead to loss of a life or lives. For example, the radar system in an aircraft is very critical to the pilots' successful operation of the aircraft. It gives the pilot an edge on situational awareness and informed decision making by providing strategic weather trending information. It makes the pilot know if weather is building or dissipating and the likely direction to travel. In the case where the radar system of the aircraft malfunctions, the consequences could be severe. Also, the navigation system of an aircraft is also mission

critical to the pilot. The aircraft is highly dependent on the navigation system. It helps the pilot calculate the time and distance of the checkpoints they set, the GPS is also used to provide precise location data which includes speed, position, and track. So therefore the malfunctioning of the navigation system in an aircraft would be mission critical and will cause serious consequences. Another example of a mission critical environment is the intensive care unit of a hospital. It is mission critical in the sense that it is the part of the hospital where people with severe cases are admitted and these people have to be under intensive care. Lack of intensive care could lead to the loss of the patients' life. Train communication system is also an example of a mission critical system. According to base2 train communication systems, a train control center fitted with base2's VCS touch screen communications consoles(CTWS) can distribute incoming calls to train controllers based on variety of criteria with priority queuing for emergency calls and automatic conferencing of locomotives based on location. Failure of this system can also lead to casualties. Other mission critical environments include Angle of Attack (AOA) aircraft solution, Nuclear reactor safety system, etc.

For this study, we will be focusing on the intensive care unit of a hospital (Del International hospital). We aim to propose a method of automating the processes involved in responding to emergency situations by Nurses and Doctors in a Hospital.

1.1.1. Del International Hospital

DEL International Hospital is an ultra-modern hospital providing varying in-patient and out-patient services to the Accra Metropolis in Greater Accra Region, Ghana and even beyond. Strategically located opposite the PH Hotel, East Legon this is about 30 minutes ride/drive from the Kotoka International Airport. DEL International Hospital prides itself with ultra-modern facilities providing comprehensive medical care to everybody in need of health. It is

manned by world class medical experts in several fields of medical practice. The hospital operates 24/7 with hygiene at a top class level. The hospital has dedicated resident doctors, in addition to a host of locums and other health specialists who come on scheduled / appointments times complimenting the dedicated and caring nurses. DEL has three categories of wards for inpatients. They are: private wards, semi private wards, general wards. There are two states-of- the- art theaters, an IVF unit, maternity or Labor Theater and ward, ICU, Consulting Rooms and many more.

DEL operates a 24/7 pharmacy and ambulance services. DEL can boast of an ultra-modern laboratory and an Ultra-Sound and ECG unit.

1.2. Problem Statement

Del International Hospital as at the time of conducting this research has just one method of collecting vitals of patients. Nurses go to various wards of patients with their necessary equipment's and their booklet to measure the vitals of patients and record them on their booklet. They do this at set intervals. When the vitals are below or above normal (emergency), they walk down to the doctor's office so that he would respond to the condition at hand.

This particular process becomes a problem in situations where the number of patients in the ICU keeps on increasing exponentially.

Workload on the nurse becomes too much, the nurse would not be able to perform her responsibilities accordingly as the vital signs of patients in the ICU are to be taken at set intervals.

Inability of nurses to instantly call the doctors attention in adverse or emergency situations.

1.3. Justification

The proposed automated system, that is the DigitalICU, will provide feedback of the vital signs of patients in the ICU to the nurse after they have been collected with the sensors at set intervals and at various wards of patients.

1.4. The Proposed System

The manual system is faced with a lot of challenges where nurses have to go to each of the patient's bed in their respective wards and read the values of the vital signs which is being taken by the instruments, the challenges in getting instant assistance of doctors in emergency situations. This issue makes nurses undergo a lot of stress and time in taking necessary information about patient’s health and getting assistance from doctors. Choosing the proposed system will reduce the workload of nurses, enable them to perform their responsibilities accordingly and easier and also enable them to interact and get instant feedback from doctors in emergency situations.

The proposed system will provide a means where sensors would collect vitals of patients (oxygen saturation, blood pressure, temperature, and heart rate) and store them on a database. Nurses in different wards will have an interface on their smart phones or tablets that would display the vitals of patients. The interface will also provide a means where nurses can make a phone call to doctors in cases where the condition of patients is below or above normal. This project research is centered on The Intensive Care Unit of Del International Hospital.

The nature of health communication is changing as people increasingly rely on the internet for health information. Technological advancement has brought highly interactive computer systems to help your medical care team respond to problems. To improve the overall hospital

experience and improve patient satisfaction and retention, hospitals should create content-rich, interactive mobile apps that will engage patients, visitors, and staff. In Del International Hospital, Nurses are required to go to the various wards of patients using instruments such as: Pulse Oximeter, Sphygmomanometer, Thermometer, and Electrocardiography to collect vitals of patients and record them manually in a book at time intervals. In a case where a patient's condition is below or above normal, the nurse has to walk down to the doctor's office so that the doctor will be able to deliver an appropriate treatment to the patient. This is a very big issue for a mission critical environment like Del International Hospital as it takes a lot of time to take vitals of patients by nurses, a lot of time in seeking for the doctors' attention in responding to emergencies of patients, it could also lead to loss of lives of patients since there is a delay in responding to adverse situations. The proposed system will automate the manual processes nurses and doctors undergo as well as optimizing the flow of operations in the Hospital.

1.4.1. Advantages of the Proposed System

- **Feedback:** This system provides feedback of patients' vitals to nurses after they have been collected by sensors and various instruments and also provides feedback information about any control or feature they select.
- **Accessibility:** This system will be accessible by nurses at their various wards.
- **Time saving:** This system will cut down the time taken to manually collect vitals of patients by nurses and also cut down the time taken by nurses to move from the wards of patients to get assistance from doctors.
- **Affordance:** This system uses clear controls and features that enables novice users(nurses) to make appropriate use of them in carrying out their work
- **Mobility:** The system will run on smart phones and tablets devices since Mobile computing by way of tablet computers are becoming more popular and easily accessible.

- **Visibility:** Relevant parts of the interface of the proposed system will be visible to the nurses by using appropriate labels on them to carry out their work effectively.
- **Accuracy: -** The use of wireless sensors for collecting the vital statuses of the patients would give a more accurate reading as compared to when collecting vital statuses is handled by the nurses.

1.5. Hospitals in Ghana

The healthcare industry is one of the largest and fastest-growing industries in the world, health care can form an enormous part of a country's economy. The overall aim of the health sector is to promote healthy lifestyles and reduce risk factors that arise from environmental, economic, social and behavioral causes. Some healthcare industries in Ghana are gradually moving their manual processes to the automated environment. Many healthcare industries in Ghana have adopted technological advancements to fasten their daily operations and it has provided a lot of benefit for them in automating their manual processes.

1.6. The Impact of Digital Technology and the Internet in Del International Hospital

The revolution of digital technology and the availability of internet facilities has improved communication in Ghana. Hospital staff with their mobile devices and computers can now have access to the internet, share files such as electronic mails, and solve each other's problems. Business are also moving to this new trend and have adopted the use of technological facilities to conduct their transactions over the internet (Electronic Business).

1.7. Motivation of Study

We were motivated to conduct a thorough research on this study due to the inconveniences and stress faced by nurses, time wastage in collecting vitals and calling for the doctor's attention, and the rate at which patients suffer when emergencies occur.

1.8. Aim of the Study

The study is aimed at evaluating the interface of an Automated System (DigitalICU) for patients for Del International Hospital.

1.9. Objectives of the Study

The objectives of this study are to:

- facilitate an appropriate collecting, storing, retrieving and feedback of information
- propose an automated system (DigitalICU) for Del International Hospital and evaluate the interface of the automated system using interactive design principles.
- suggest a system that provides a better platform to enable staff (nurses and doctors) speed up their manual way of carrying out their work.

1.10. Significance of the Study

The implementation of this DigitalICU will provide certain benefits that would significantly affect the quality of service hospitals provide to patients. Such benefits include:

a) high interactivity

b) time saving

c) appropriate feedback for nurses

d) consistent controls which makes it user friendly

e) authentic storage of information through the use of a database

f) reduction of stress and challenges faced by staff and patients

1.11. Scope of the Study

This research work is focused on the intensive care unit of Del International Hospital. The approach that is used in collecting vitals and dealing with patients is complicated and stressful thus, this system will be available to the Nurses, Doctors and the IT department of Del International Hospital.

1.12. Limitations of the study

Limited Finance: We have a great limitation in finance for purchasing the necessary equipment's (such as sensors, tablets and other equipment's) that will be used in implementing this system.

1.13. Research Questions

The following are questions that this research aims to address

I. How will nurses and doctors interact with the interface to carry out their operation in the ICU?
II. What will be the benefit of the designed user interface to nurses, doctors and their patients?

1.14. Project Outline and Chapter Organization

The project is aimed at developing and evaluating an automated system (DigitalICU) for staff and patients for Del International Hospital and it is in six chapters.

The first chapter concerned with the overview of the project taking into consideration, the problem given rise to the system establishment and justification. It also emphasizes on the

general objectives, individual objective, automated system (DigitalICU), summing up with organization of document.

The second chapter provides the literature review, which encompasses the reviews of related works, the interface, database design, design review, evaluating the design review, and development tools.

The third chapter is made up of the research methodology, which explains in detail the method which the researchers used to address the problem and how the researchers gathered data for the design of the DigitalICU

The fourth chapter talks about the analysis, design and the proposed system architecture of the application. Here, the researchers analyzed the existing system, reviewed the data gathering technique they used, and came up with the requirements of the new system.

The fifth chapter talks about usability testing, system testing and implementation. The tools for implementing the DigitalICU would be reviewed here, the different views of the DigitalICU, and the type of testing the researcher carried out.

The sixth chapter is made up of the summary, conclusion, and recommendation. This chapter consist of the summary of the entire research, conclusions deduced from the research, and possible recommendations.

CHAPTER 2

LITERATURE REVIEW

2.0. Introduction

This section reviews literature on human-computer interaction (HCI) and the user interfaces of automated systems used in mission critical environments like aircraft, railway, military, and hospitals. It also includes the software review, and a review of numerous development tools.

Shelly and Rosenblatt (2009), in their book *System analysis and Design, (9th ed.)*, described user interface (UI) as how users interact with a computer system, and consists of all the hardware, software, screens, menus, functions, output, and features that affect two-way communications between the user and the computer. As information management evolved from centralized data processing to dynamic, enterprise-wide systems, the primary focus also shifted from the IT department to the users themselves. The IT group became a supplier of information technology, rather than a supplier of information. Today, the main focus is on users within and outside the company, how they communicate with the information system, and how the system supports the firm's business operations. In a user-centered system, the distinction blurs between input, output, and the interface itself. Most users work with a varied mix of input, screen output, and data queries as they perform their day-to-day job functions. Because all those tasks require interaction with the computer system, the user interface is a vital element in the systems design phase. User interface design requires an understanding of human-computer interaction, and user-centered design principles which would all be discussed subsequently.

2.0.1. Human-computer interaction (HCI)

Shelly and Rosenblatt (2009), in their book *System analysis and Design, (9th ed.)*, described human-computer interaction (HCI) as the relationship between computers and people who use them to perform their jobs. HCI concepts apply to everything from PC desktops to global networks. In its broadest sense, a user interface includes all the communications and instructions necessary to enter input to the system and to obtain output in the form of screen displays or printed reports.

The human-computer interface started in the 1980s with users typing complex commands in green text on a black screen. Then came the graphical user interface (GUI), which was a huge improvement, because it used icons, graphical objects, and pointing devices. Today, designers strive to translate user behavior, needs, and desires into an interface that users don't really notice.

The goals of human-computer interaction (HCI) are to produce usable and safe systems, as well as functional systems. In order to produce systems with good usability, developers must attempt to:

- understand the factors that determine how people use technology
- develop tools and techniques to enable building suitable systems
- achieve efficient, effective, and safe interaction
- put people first

Underlying the whole theme of HCI is the belief that people using a computer system should come first. Their needs, capabilities and preferences for conducting various tasks should direct developers in the way that they design systems. People should not have to change the

way that they use a system in order to fit in with it. Instead, the system should be designed to match their requirements.

2.0.2. User-centered design principles

Shelly and Rosenblatt (2009) also stated in their previously referenced book that although different people have their perception on interface design, most would agree that good interface design depends on seven (7) basic user-centered design principles. The seven principles are briefly described below:

- Understanding the business: - The interface designer must understand the underlying business functions and how the system supports individual, departmental, and enterprise goals. The overall objective is to design an interface that helps users to perform their jobs.
- Maximize graphical effectiveness: - Studies show that people learn better visually. A well-designed interface can help users learn a new system rapidly, and be more productive
- Think like a user: - An interface designer should understand user experience, knowledge, and skill levels. If a wide range of capability exists, the interface should be flexible enough to accommodate novices as well as experienced users. To develop a user-centered interface, the designer must learn to think like a user and see the system through a user's eyes. The interface should use terms and metaphors that are familiar to users. Users are likely to have real-world experience with many other machines and devices that provide feedback, such as automobiles, ATM machines, and microwave ovens. Based on that experience, users will expect useful, understandable feedback from a computer system.

- Use models and prototypes: - From a user's viewpoint, the interface is the most critical part of the system design because it is where he or she interacts with the system. It is essential to construct models and prototypes for user approval. An interface designer should obtain as much feedback as possible, as early as possible.
- Focus on usability: - The user interface should include all tasks, commands, and communications between users and the system. The objective is to offer a reasonable number of choices that a user easily can comprehend. Too many options on one screen can confuse a user, but too few options increase the number of submenu levels and complicate the navigation process.
- Invite feedback: - Even after the system is operational, it is important to monitor system usage and solicit user suggestions. You can determine if system features are being used as intended by observing and surveying users. Sometimes, full-scale operations highlight problems that were not apparent when the prototype was tested.
- Document everything: - You should document all screen designs for later use by programmers.

2.0.3. Interaction design

Sharp, Rogers and Preece (2002), in their book *Beyond Interaction Design* defined interaction design as designing interactive products to support the way people communicate and interact in their everyday and working lives. They also stated that the goals of interaction design are to

- develop usable products (usability)
- involve users in the development/design process

Usability here means a particular product is easy to learn, effective to use, efficient to use, safe to use, have good utility, easy to learn, easy to remember, and provide an enjoyable

experience. Interactive design is also concerned with how to create quality user experiences. Sharp, Rogers and Preece (2002) also described user experience as the way people feel about a product and the pleasure and satisfaction they derive from using it, looking at it, holding it, and opening or closing it. In effect, every product that is used by someone has a user experience. Sharp, Rogers and Preece, came to a conclusion that interaction design principles can help to create decent usability and quality user experience. Some of these design principles are discussed below

2.0.3.1. Design principles

Several design principles have been propounded by different individuals and organization. These principles are the do's and don'ts of interaction design, they state what to and what not to provide at the interface, and they are derived from a mix of theory-based knowledge, experience and common-sense. These design principles include Neilson and colleague design principles, Veen's design principles, Shneiderman's eight golden rules of interface design, Donald Norman's design principles, etc. This study, focuses on the design principles propounded by Donald Norman.

Donald Norman is one of the greats of computer human interaction and user-centered design and his principles are a good place to start with any design project. Norman’s main idea is that devices, things, computers, and interfaces should be functional, easy to use, and intuitive. His idea is that there are two gulfs to avoid: the gulf of execution and the gulf of evaluation. The gulf of execution is the degree to which the interaction possibilities of an artifact, a computer system or likewise correspond to the intentions of the person and what that person perceives is possible to do with the artifact/application/etc. In other words, the gulf of execution is the difference between the intentions of the users and what the system allows them to do or how well the system supports those actions (Norman, 1988). Say for example,

you want to make a call on your phone. Your goal is to make a call, and the end result is the call connection. What happens in between is the gulf of execution. On the other hand, the gulf of evaluation is the degree to which the system/artifact provide representations that can be directly perceived and interpreted in terms of the expectations and intentions of the user (Norman, 1988). Or put differently, the gulf of evaluation is the difficulty of assessing the state of the system and how well the artifact supports the discovery and interpretation of that state (Norman, 1991). Say for example, you fill a form online and submit it and then there is no feedback like say "form successfully filled" or "fill-in the important fields", you do not know what to do because the feedback you expected did not come. This confusion is the gulf of evaluation.

To avoid these two "gulfs", Norman (1988) propounded six (6) design principles. They are:

- Visibility: - users need to know what all the options are, and know straight away how to access them
- Feedback: - every action needs a reaction. There needs to be some indication, like a sound, a moving dial, a spinning rainbow wheel, that the user's action caused something.
- Affordance: - refers to an attribute of an object that allows people to know how to use it
- Mapping: - Mapping is the relationship between control and effect. The idea is that with good design, the controls to something will closely resemble what they affect.
- Constraints: - Constraints are the limits to an interaction or an interface
- Consistency: - The same action has to cause the same reaction, every time.

These six (6) guidelines provide the basic outline for a great user experience and design.

When designing applications interface for mission-critical or high-pressured environments, these six (6) guidelines are also employed because of how important they are in enabling workers in mission-critical or high-pressured environment to carry out their work smoothly and efficiently.

The next section contains some mission-critical environment interfaces, and these interfaces have been evaluated using Donald Norman's six (6) principles of design

2.1. Animated ADS-B radar solutions

Figure 2.1. Animated ADS-B radar solutions

The In-flight animated ADS-B radar gives pilots another edge on situational awareness and informed decision making by providing strategic weather trending information. It makes pilots know if weather is building or dissipating, and the likely direction of travel.

2.1.1. Evaluating figure 2.1. using interactive design principles by Donald Norman's (1988):

1. Visibility: Controls such as GPS altitude, Track, current lat/lon, geographical locations, and relevant information on the interface are very eligible and clear enough and they convey information to pilots at a glance.

2. Feedback: "Maps" is highlighted blue because it has been selected and this enables the pilot to know that he is viewing details about the Map Tab.

3. Constraints: Also, Tabs have Clear labels that identifies them and this constrains the pilot from selecting an incorrect Tab.

4. Consistency: Tabs are used for similar operations which makes the interface consistent.

5. Affordance: The interface provides good affordance for pilots. The search area notifies the pilot to search for weather conditions of different locations, the zoom-to-route button above the Map view zoom control makes the pilot know that when he clicks on it, it will re-center his route in the Map view. Also, the animation play button in the lower left corner of the screen enables the pilot know that when he clicks on it, it will play up to five frames of contiguous NEXRAD updates.

6. Mapping: The "+" and "-" buttons on the bottom left corner of the interface look like they are to "zoom in" and "zoom out" and that is just what they are used for.

2.2. Solutions designed by BIO-NEXUS

Figure 2.2. Solutions designed by BIO-NEXUS

System designed by BIO-NEXUS (a U.S. based company building the military-grade hardware and medical software) to save wounded soldiers on the battlefield by guiding a paramedic's actions in emergency conditions proving situational pictures for paramedical staff, reporting the status of the injured and more.

2.2.1. Evaluating figure 2.2 using interactive design principles by Donald Norman (1988):

1. Visibility: The system's interface is very clear. Vitals of soldiers are displayed with visible colors which makes the staff (operator) determine the conditions of the soldiers on the battle field. The system also provides a voice recognition for hands free capabilities. Other relevant controls in the system's interface are also visible.

2. Feedback: The system's interface provides feedback to staff (operator) as vitals of the soldiers changes in color from Green (normal) to Red (emergency or below normal). Also,

Label (Patient: S1) enables the staff to know that he/she is accessing information for Patient: S1.

3. Constraints: The system's interface provides constraints. The On and off buttons for smart port, ventilator, ccm and ivec labeled appropriately prevents staff from selecting incorrect options.

4. Consistency: The system's interface is consistent which makes it user friendly. It uses consistent control for displaying vitals of patients and also uses similar elements in conveying information for the injury, alarm Tab and other tabs.

5. Affordance: The Home button enables the operator to know that if he selects it, he would be directed to the home Tab. The Message button enables the operator to know that he or she could send and receive messages about patient’s condition to the doctor and various department. Other controls also enable the operator to know the possible actions that he can perform on the system's interface.

6. Mapping: The back and home buttons look like what exactly they are used for

2.3. Aspen's Angle of attack (AOA) Aircraft Solution

Figure 2.3 Aspen's Angle of attack (AOA) Aircraft Solution

Aspen's Evolution AOA indicator calculates angle of attack using flight envelope data received from an air data computer and attitude heading reference system (AHRS) integrated in the Evolution 1000 PFD or Evolution 1000 MFD, and a certified GPS. It does not require additional hardware, nor does it require any external aircraft modifications or sensors. It improves safety - provides real time flaps up and down stall margin awareness. It enables the pilot to see available lift before changing configuration. It is crucial when making a go-around. AOA is displayed on the Aspen PFD or MFD. Information is displayed in pilot's natural field of view.

2.3.1. Evaluating figure 2.3. using interactive design principles by Norman (1988):

1. Visibility: The system has an Intuitive display which provides an immediate, clear visual display of trend toward stall and stall margin. Pilot comprehends important information at a glance.

2. Feedback: The system's interface provides an appropriate feedback on the flaps down and flaps up by using appropriate colors/indicators that gives feedback to the pilot when he approaches a caution zone or low angle of attack zone or normal approach zone.

3. Constraints: The interface uses well labeled controls for GPS, Navigation Map, view and other areas which prevents pilots from selecting incorrect options.

4. Consistency: Screen display are of similar sizes which makes it easy for pilots to view information. Also similar controls are used in the interface which makes it consistent.

5. Affordance: This interface does not provide a good affordance and this becomes an issue for novice pilots who do not have enough knowledge on how to use the system.

6. Mapping: The buttons on this interface are somewhat confusing and do not really look like what they are supposed to be used for.

2.4. Train Communications System Australia Solutions

Figure 2.4. Train Communications System Australia Solutions

The aim of this system is to leverage commercial communications systems such as 3G in order to minimize infrastructure costs imposed by building a railway specific network throughout an entire continent. It provides a constant 3G data connection to the ICE allows consistent updates of locomotive position through the in-unit GPS receiver, call information, extensive logging capabilities as well as the integration of monitoring and fault detection to allow over the air configuration and updates of firmware and software. Train Control Centre fitted with base2's VCS touch screen communications consoles (CTWS) can distribute incoming calls to Train Controllers based on a variety of criteria with priority queuing for

Emergency calls and automatic conferencing of Locomotives based on location. In the event of 3G network coverage or module failure the ICE is designed to automatically fallback to Satellite communications for both data and voice giving the assurance of total coverage.

2.4.1. Evaluating figure 2.4. using interactive design principles by Norman (1988):

1. Visibility: The system uses clear controls which makes every part visible. An example is the button for emergency communication. It is labeled clearly.

2. Feedback: The system provides a good feedback to operators. The controller button has been selected and it is highlighted white which enables the operator to now that he/she is in the control zone.

3. Constraints: Also, the control button which is been selected and highlighted white which enables the operator to now that he/she is accessing the controller area **constrains** the operator from selecting incorrect options that he/she does not want to access.

4. Consistency: This interface has similar operations and also uses similar elements (F1, F2, F3, F4, and F5) as well as a consistent numeric key pads for similar task which makes it easier to learn and use.

5. Affordance: This interface provides a very good affordance. Arrow keys which enables the operator to navigate up, down, right, left. The "✕" button labeled red which makes the operator to know that when he/she presses the button, he would cancel/close a particular task.

6. Mapping: The button labeled "emergency" gives a clear description of what it is used for and it does exactly what it is meant to be used for. Also the navigation buttons are used for navigating through the interface. The "✕" and "✓" also perform the functions they look like they perform.

2.5. Front-end

BIO-NEXUS (a U.S. based company building the military-grade hardware and medical software) described that the front-end page is the page where the staff (operator) will interact with the system. This page will require the username and password for the operator or staff. This is to ensure users authenticity and to prevent unauthorized access or modification of information in the system. Every nurse/staff that will interact with the system is assigned a username and password and it is been stored in a database. The system will therefore check for authenticity of the username and password. After a successful Login, the user (nurse or staff) will then have access to patient wards and then to patient beds and then to the patients details and patient vitals page where nurses will collect vitals of patients and this makes their work easier and faster.

2.6. Back-end

BIO-NEXUS also described the back-end to be the design for the IT administrator to modify, update and make changes to the system when necessary. The administrator is required to login with a username and a password which would be authenticated by the database. If the username and password meets requirements, Login successful else an error message will be displayed to the administrator. When Login is successful, the administrator can now be granted access to the system to perform his/her administrative task.

2.7. Software Review

Chitkara (2007) in his design of a hospital management software listed the software to be used are:

- Windows XP professional service pack 2
- Microsoft access database server 2003

- Microsoft visual basic version 6.0
- Microsoft office 2006
- Graphical User interface
- Reporting Tool (Data Report)

Also, Chitkara (2007) stated that the hardware requirements for their hospital management system are:

- Windows server 2003 enterprise edition
- RAM of 64 Mb or Higher
- Pentium iii processor
- Minimum of 130 Megabytes of RAM

2.8. My Software Review

The list of various software and tools that would be used in the design of DigitalICU for Del International Hospital are:

- Microsoft Visual Studio 2010
- Microsoft Office 2007
- Microsoft Access Database 2007
- Microsoft windows 7 operating system
- Microsoft Visual Studio 2010 Testing Software

The hardware requirements that is required for the design of DigitalICU for Del International Hospital are:

- Intel core i3 for windows operating system
- A minimum of 32 GB hard disk space
- A minimum of 512 MB of RAM

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

Research methodology can be described as the means which a researcher uses to get a solution for the problem in the research he/she is looking into. In the field of IT, there are basically three research methodologies: software review, investigation, and software design. For this study, software design has been chosen as our main method of getting the solution to the earlier stated problem.

Software design is the process of implementing software solutions to one or more set of problems. Software design is both a process and a model. The design process is a sequence of steps that enable the designer to describe all aspects of the software to be built. The design model is the equivalent of an architect's plans for a house. It begins by representing the totality of the thing to be built (e.g., a three-dimensional rendering of the house) and slowly refines the thing to provide guidance for constructing each detail (e.g., the plumbing layout). For this research, we aim to design a user-centered system. User-centered systems are designed in such a way that they try to optimize the product around how users can, want, or need to use the product, rather than forcing the users to change their behavior to accommodate the product. User-centered systems may involve user-experience design because user-experience design aims to enhance user satisfaction by improving the usability, accessibility, and pleasure provided in the interaction between the user and the product. User experience design encompasses traditional human–computer interaction (HCI) design, and extends it by addressing all aspects of a product or service as perceived by users.

Shelly and Rosenblatt (2009), in their book *System analysis and Design (9th ed.)* stated that one of the most important parts of software design is requirement gathering. They cited that requirement gathering is the process of collecting the requirements of a system from the users, customers, and other stakeholders. Shelly and Rosenblatt (2009) also established that there are lots of requirement gathering techniques, but for the purpose of this study, we are going to employ interviews as our main requirement gathering technique. Shelly and Rosenblatt (2009) said "interviews are generally individual in nature and focused on the perceived needs of the stakeholders and the way each stakeholder sees things". Due to the unique perspective of each stakeholder, we have the advantage of getting a richer understanding of the stakeholder's unique business processes, decision-relevant business rules, and perceived needs.

Shelly and Rosenblatt (2009), in their book *System analysis and Design, (9th ed.)*" also lay down some steps to follow when planning or conducting interviews and we will be applying the steps in our interview. The steps lay down by Shelly and Rosenblatt (2009) are stated below: -

Step 1: Identify stakeholders

We identified our stakeholders to be the nurses, doctors, IT staff, patients, and the CEO (all of Del International Hospital)

Step 2: Establish interview objectives

After we identified our stakeholders, we will need to establish objectives of each interview session. We will determine the general areas to be discussed such as the intensive care unit, how things work in the intensive care unit, how the hospital responds to emergencies, etc. We will also try and solicit ideas, suggestions, and opinions during the interview.

Step 3: Develop interview questions

Developing interview questions would help to keep us on track and avoid unnecessary tangents during the interview. Questions we are going to be asking in the interview are provided in the appendix

Step 4: Prepare for interview

Careful preparation is essential because an interview is an important meeting and not just a casual chat. We have to notify our stakeholders of the interview, tell them how long the interview would take, and let them suggest a specific date that would be convenient for them.

Step 5: Conduct the interview

After the above steps have been completed, we will then proceed to conduct the interview on the specified date.

As stated in Step 3, a copy of the interview questions is available in 'Appendix A'. In the next chapter, we are going to be performing an analysis on the feedback of the interview. It also includes the design of the DigitalICU.

CHAPTER 4

SYSTEM ANALYSIS AND DESIGN

4.0. Introduction

The chapter focuses on the analysis and design of the proposed system (i.e. the DigitalICU).

4.1. System Analysis

Analysis can be described as the detailed study of the various operations performed by a system and their relationship within and outside of the system. In the process of analysis, data are collected on the available files, decision points, and transactions handled by the present system.

Requirements of the DigitalICU were categorized into user requirements, system and hardware requirements.

4.1.1. Analysis of the Existing System

From the interview, we confirmed that the existing system in the intensive care unit of Del International hospital is currently manual. Nurses are required to come to the bed of the patients admitted in the ICU at set intervals and take their vitals. In the case where the vitals of the patients are not normal, the nurse has to walk down to the doctor's office and alert him/her of the emergency at hand. The taken vitals of patients are written on different papers, human errors where vulnerable since it was paper based. Also retrieval of the history of a patients vital was time consuming. With the information obtained, nurses have complained of how time consuming it is to take vitals and alert the doctors of emergencies in the ICU. In the case where the number of patients in the ICU increases, the workload on the nurse’s increases

and this is not a good case being that the ICU is a mission critical environment, any little mistake can lead to the loss of the patient's life.

To curtail this problem, we proposed to the nurses and the entire hospital administration the DigitalICU. The DigitalICU is a user friendly, highly interactive system that uses wireless sensors to take live readings of patient vitals and displays them on tablets which are in the nurse’s possession.

4.1.2. Review of the Interview Questions

The questions asked during the interview were designed by the researcher and a copy of it can be found in ‘Appendix A’. All questions were deigned based on what we intended to do with the feedback. From the feedback we got after the interview, all the questions that were designed and asked were very useful in coming up with suitable requirements for the DigitalICU. The preceding sections looks at those requirements.

4.1.3. User Requirement

We investigated and found out how the current system operates and also identified problems and how best they can be fixed. Some of the basic requirements stated by the nurses includes; take and view patient details and vitals, update vitals at set intervals, contact doctors in time of emergencies, notify nurses in the time of emergency, access different wards and beds at the same time.

4.1.4. Functional and Non Functional Requirements

The desired functionality of the new system is to collect and display live readings of a patient's vitals, notify nurses on emergencies, provide a means for nurses to contact doctors during emergencies.

To meet the desired functionalities of the new system, the system interface is going to have different views. These views are;

- Notification area: - this is where the users will be alerted on critical conditions or emergencies
- Authentication area: - this view will authenticate the user, using his/her fingerprints, before they can gain access to the wards and beds
- Select ward view: - shows the general ward view where the nurse can select any of the available wards
- Select bed view: - shows the available beds, in a selected ward, from which the user can select to view a patients' record
- Patients bed view: - shows the details and values of the vitals of the patient in a selected bed

Non-functional requirements of the DigitalICU include;

- The system interface should be able to provide feedback regarding actions that have been taken
- Controls on the system interface should be easy to see
- System interface should give a clue on how it is to be used
- System interface should be time saving
- It should be easy to navigate through the system interface during emergency and otherwise
- System interface should provide constraints that restrict users from selecting incorrect options
- System interface should provide an enjoyable user experience
- Should be easy to remember how to use system interface

- System interface controls should closely resemble what they affect
- A system interface control should do the same thing every time
- Patients vitals should be color coded on the system interface

We are going to meet each requirement using Interactive design principles.

4.1.4.1. The system interface should be able to provide feedback regarding actions that have been taken

Feedback, according to the principle described in section 2.0.3.1, states that every action needs a reaction. There needs to be some indication, like a sound, a moving dial, a spinning rainbow wheel, that the user's action caused something. For the interface we will be implementing, feedback is going to be given based on every action a user takes on the system interface. For example, touching a button would provide a visual feedback, paging the doctor would provide a visual and an audio feedback to the user.

4.1.4.2. Controls on the system interface should be easy to see

Interactive design principles on visibility is going to help meet this requirement. Visibility, according to the principle described in section 2.0.3.1, states that users need to know what all the options are, and know straight away how to access them. For this system interface, the notification area for example would clearly inform the user that he/she is in the notification area, and controls that would be used to convey notifications would be very clear. Also the authentication area control would be labeled appropriately such that users would know the actions that are required of them. Other controls on the interface would also be visible so that users can know what possible actions they can perform.

4.1.4.3. System interface should give a clue on how it is to be used

For the system to be able to give a clue on how it is to be used means the interface must have a reasonable level of affordance. Affordance was described in section 2.0.3.1. For this interface, the controls we choose should be able to give a clue on how to use them. Buttons for instance would invite clicking, scroll bars afford moving up and down, icons invite clicking on, touch screens invite swiping, etc.

4.1.4.4. System interface should be time saving

The use of proper system interface controls would help reduce the time it takes to navigate through the system interface. For example, the use of buttons instead of checkboxes would save time because checkboxes would require the user to check and uncheck, as compared to buttons which only require clicking. Also the use of a biometric identification like fingerprint instead of username and passwords would also save time. 'Fingerprint' would only require the user to place his/her finger on the biometric reader as compared to using username and passwords which would require some sort of selecting and typing, which would not be favorable in a high-pressured environment like the ICU.

4.1.4.5. It should be easy to navigate through the system interface during emergency and otherwise

Good visibility and affordance would help meet this requirement. If controls are visible enough and if the controls also give a clue, it would enable users navigate easily through the interface. For example, if a user sees on the notification area that a patient is in a critical condition, being able to see how to address that situation would make the user's job easier.

4.1.4.6. System interface should provide constraints that restrict users from selecting incorrect options

Constraints, as explained in section 2.0.3.1, are limits to interface. Using proper constraints would help users not to select the incorrect options. We are going to be using labeled controls to help achieve this.

4.1.4.7. System interface should provide an enjoyable user experience

To achieve enjoyable user experience, all the interactive design principles have to be in place. If controls on the interface are visible, provide affordance, are consistent, provide feedback, easy to learn, easy to use, etc., the user experience of the system would be enjoyable, pleasurable, and satisfactory.

4.1.4.8. It should be easy to remember how to use system interface

One of the HCI usability goals is that the product should be easy to remember how to use. To achieve this, consistency, which was also described in section 2.0.3.1. would be taken into consideration. So therefore, for this interface we are going to employ controls to do the same action and use similar elements for similar task.

4.1.4.9. System interface controls should closely resemble what they affect

In section 2.0.3.1, we described mapping as the relationship between control and effect. The idea is that with good design, the controls to something will closely resemble what they affect. So therefore for our design, we are going to make controls look like what they affect.

4.1.4.10. The system interface control should do the same thing every time

Consistency again would come to play here. Controls of the interface we would be implementing would do the same action and use similar elements for similar task.

4.1.4.11. Patient's vitals should be color coded on the system interface

Visibility would be the key principle to consider here. We would be employing colors to differentiate between a normal patient vital reading and an abnormal patient vital reading. Colors to choose should be very visible and distinct.

4.1.5. System Requirements

This section describes the hardware components and software components needed for effective and efficient running of the system. The table below shows the hardware requirements for the proposed system

Hardware	**Minimum Requirement**
Processor	1GHZ processor speed
RAM	2GB
Hard Disk Space	10GB
Display resolution	800 x 600 high color 16-bit
Wireless sensors	

Table 4.1 Hardware requirements

The table below depicts the minimum software requirements for the DigitalICU

Software
Access Database
Windows, Mac OS X , or Linux
Microsoft Visual Studio 2010

Table 4.2 Software Requirements

4.2. Context Diagram

A context diagram is a diagram that depicts the system and all the external entities that one way or another interact with the system. External entities are those things that are identified as needing to interact with the system.

In the case of the DigitalICU, the identified external entities are: the ICU nurses, doctors, and patients. The DigitalICU uses wireless sensors to collect live details of the vital signs of patients, and then those vital signs are reported concurrently to the nurses' tablet. The DigitalICU also alerts nurses on patients whose conditions are critical. When the nurse gets to the patients bed and the condition at hand cannot be managed by him/her, the DigitalICU provides a button that he/she can use to page the doctor. When the doctor receives the page, he/she goes to the patient's bed, view the patient's vitals on the nurses' tablet, and then takes the appropriate measures to deal with the patient's condition. Figure 3.1 shows the context diagram for the DigitalICU.

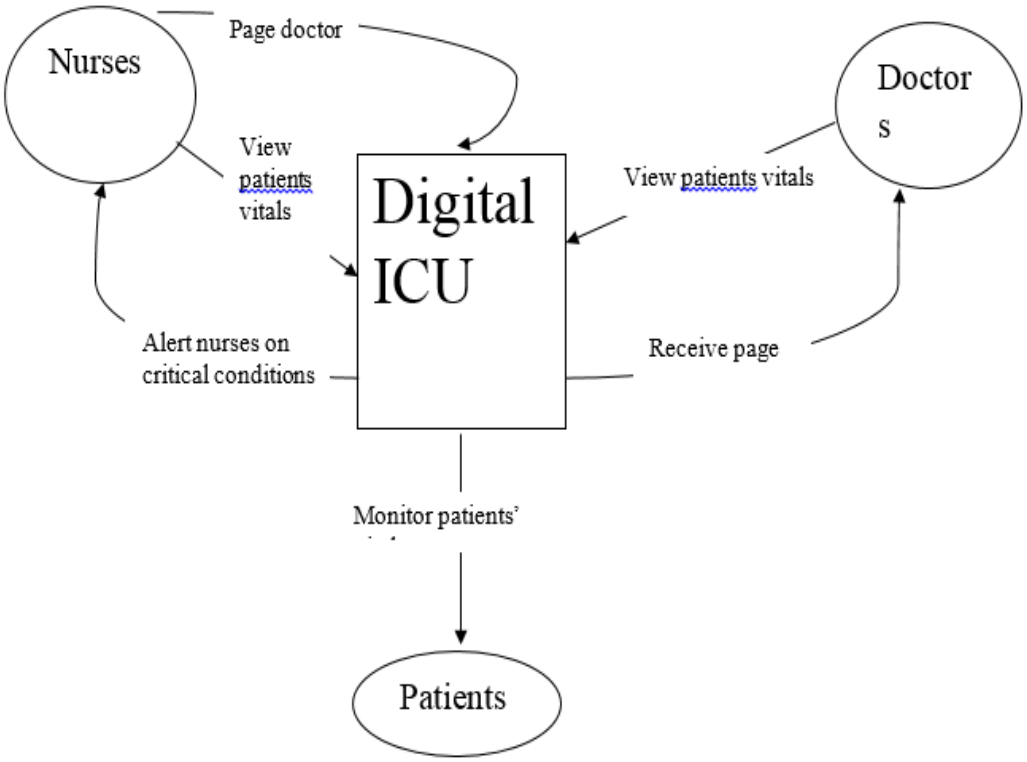

Figure 3.1 Context Diagram for the DigitalICU

In conclusion, we have performed analysis on the existing system, reviewed the interview question that enabled us to define the requirements (user, functional, non-functional, system, and hardware), stated how we are going to meet the functional and non-functional requirements in the future using interaction design principles. The next chapter would talk about the experience we encountered during the implementation and testing phase.

CHAPTER 5

IMPLEMENTATION AND TESTING

5.0. Introduction

In the previous chapter, we looked at various requirements of the DigitalICU and also pinpointed ways we were going to meet those requirements. This chapter describes the implementation, testing, and feedback gotten.

5.1. Implementation

According to Awesu (2015), in his thesis *Design and Implementation of an Electronic Patient Management System*, implementation is the realization of an application or execution of a plan, idea, model, design, specification, standard, algorithm or policy. For this study, we are going to describe implementation as the execution of our design.

5.1.1. Tools for Implementation

Various tools are available for implementation. For the DigitalICU, the main implementation tool we used is Microsoft visual studio 2010.Net Framework.

5.1.1.1. Microsoft visual studio 2010.Net Framework

Microsoft visual studio 2010.net framework is most suitable for building type-safe and object-oriented applications. The studio consists of different templates installed on it such as: visual c++, visual C#, visual F#, Databases, Modeling Projects, Testing projects and other types of projects. It provides the opportunity for cross platform application development. This means that you can build android, windows and IOS applications with Microsoft visual studio.net framework. We have decided to design our interface using Microsoft visual studio and the most preferred programming language we are using is visual basics programming language. Visual basics is a third generation programming language and an integrated development environment developed by Microsoft. You can create forms in visual basics using the drag and drop approach. Visual basics consist of different form controls which

includes: check boxes, list boxes, buttons, pointers, labels, link-label, notification icon, list view, picture box, etc. that enables programmers to create various kinds of interfaces for applications. Visual basics controls are made up of event handlers and attributes. Every control selected has its default values although programmers can change those default values to meet their design requirements. This makes visual basics a very scalable programming language.

We will be using visual basics forms as well as several controls such as buttons, textboxes and labels for our interface design.

5.2. Views

The interface of the DigitalICU which would run on a tablet PC, comes with nine (9) tab pages. The views includes :

- Notification view
- Authentication view
- Select ward view
- Select bed view
- Patient bed view

5.2.1. Notification View

A screenshot of the notification view is shown below

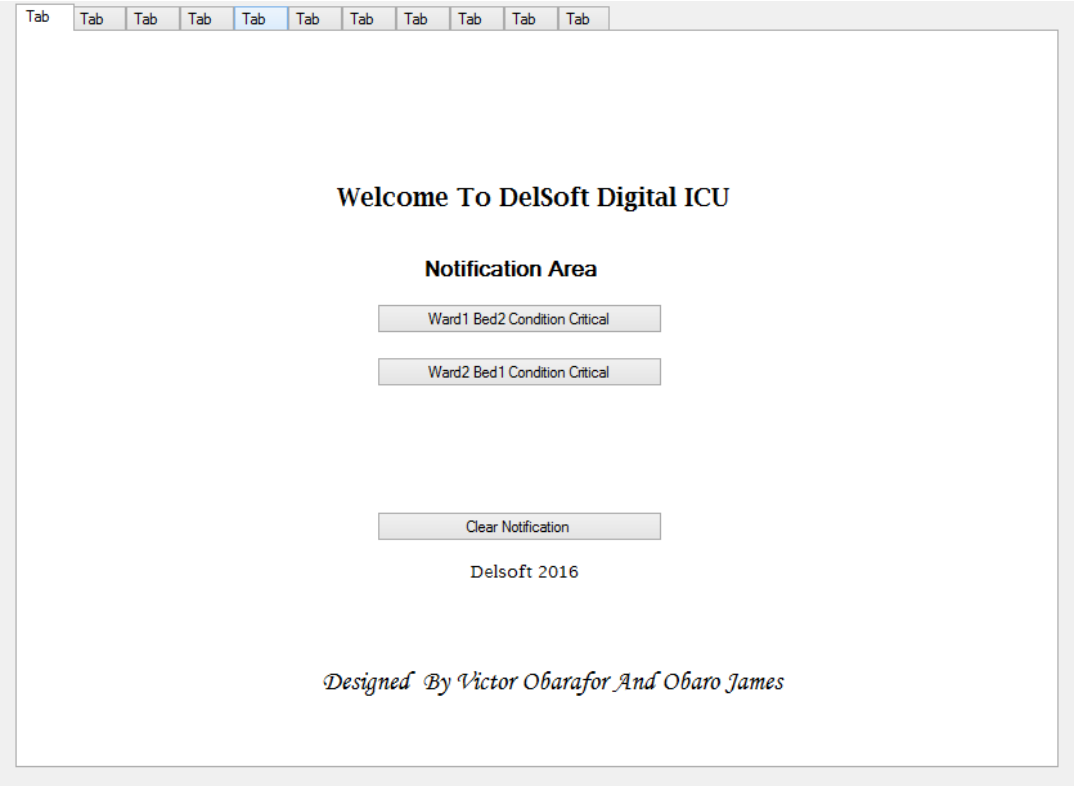

Figure 5.1 Notification view.

The above view notifies users on critical conditions or emergencies in the ICU. The buttons which are labeled "Ward 1 Bed 2 Condition Critical" and "Ward 2 Bed 1 Condition Critical" notify the users on critical patient conditions. Users can select any of the notifications by touching on the button. For example, if the user wants to attend to the first notification, all she has to do is touch the button labeled "Ward1 Bed2 Condition Critical". Nurses can also choose to clear all the notifications in the notification area by touching the button labeled "clear notifications". If a user touches any button, the button is highlighted blue to show that the user has selected that button while other buttons remain un-highlighted

5.2.2. Authentication view

A screenshot of the authentication view is given below.

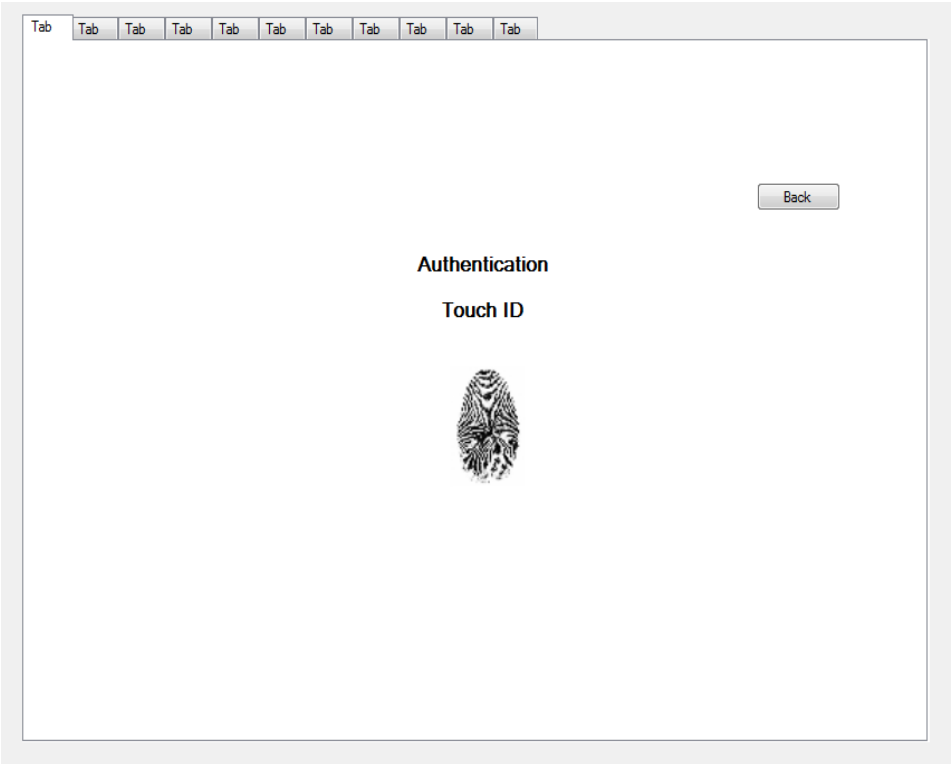

Figure 5.2 Authentication view

After the nurse has either selected a notification or cleared the notifications from the previous view, they are authenticated using their fingerprint before they can gain access to the wards or beds. Initially, usernames and passwords were our main form of authentication for this interface. Due to the fact that an ICU is a high-pressured environment, the number of clicks and touches has to be significantly reduced and that is the reason why we chose to use fingerprints instead. When the user touches the "back" button, they are taken back to the notification view.

5.2.3. Select Ward view

A screenshot for the select ward view is given below

Figure 5.3 Select Ward View

This interface allows the user to select either of the wards available. The user selects Ward 1 to view that ward or Ward 2 to view the other ward. We limited the number of wards to just two (2). But ideally, all the available wards are supposed to appear here. If a user touches any of the ward buttons, the selected ward button is highlighted blue to show that the user has selected that button while other buttons remain un-highlighted.

5.2.4. Select Bed View

A screenshot of the select bed view is given below

Figure 5.4 Select Bed View

The select bed view is peculiar to the ward selected by the user. This select bed view for example is for Ward 1. It gives the nurse the chance to select a specific bed in this particular ward. It also gives the nurses the chance to go back to the previous view i.e. the select ward view. If the user selects the button labeled "Bed 1" for example, the user would be directed to the view that displays the patient's vitals and details of the patient in that bed. If the button labeled "previous tab" is selected, the user is directed to the previous view (i.e. the select ward view).

5.2.5. Patient bed view

The patient bed view is of two types. We have the view where the patient's vital readings are normal, and the view where the patient has abnormal vital readings

A screenshot of the view where the patient's vital readings are normal is given below

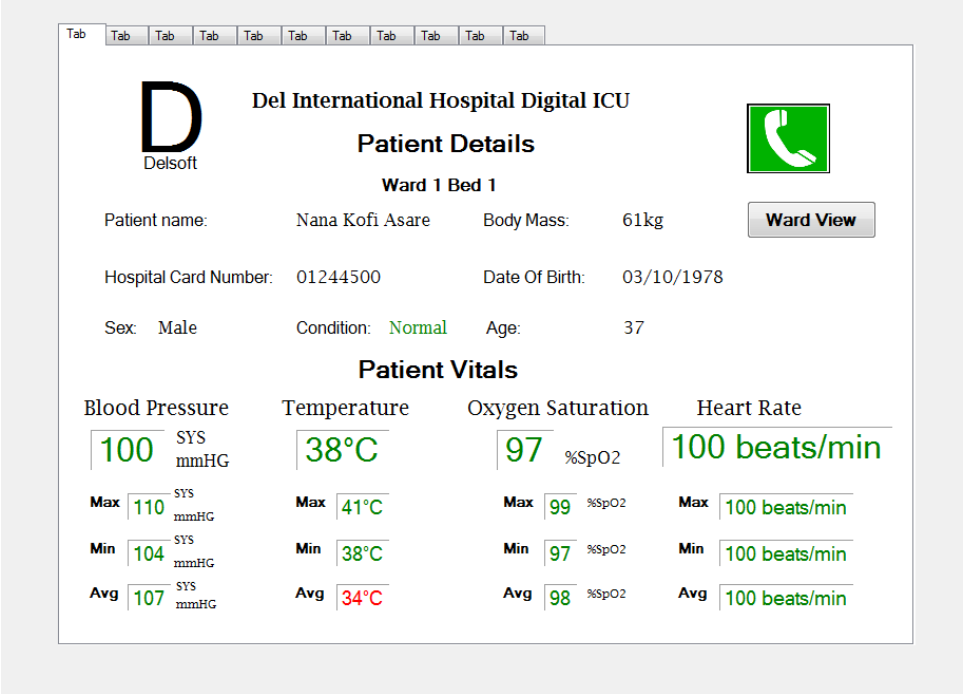

Figure 5.5a Patient Bed View (where patient's vitals readings are normal)

The patient bed view is peculiar to the bed selected by the user. This patient bed view for example is for the patient in ward 1 bed 1. This view provides the user with the patients details like name, sex, age, date of birth, body mass, condition, etc. The view gives users the opportunity to go back to the 'select ward view' by selecting the button labeled 'ward view'. The view also shows the details of the patient's vitals. The maximum, minimum, and average readings of the patient's vitals in the last hour are given in the boxes labeled max, min, and avg respectively. The readings of the patient's vitals are color coded. For this patient, the condition is normal and that is why the vital readings are green.

A screenshot of the view where the patient's vital readings are abnormal is given below

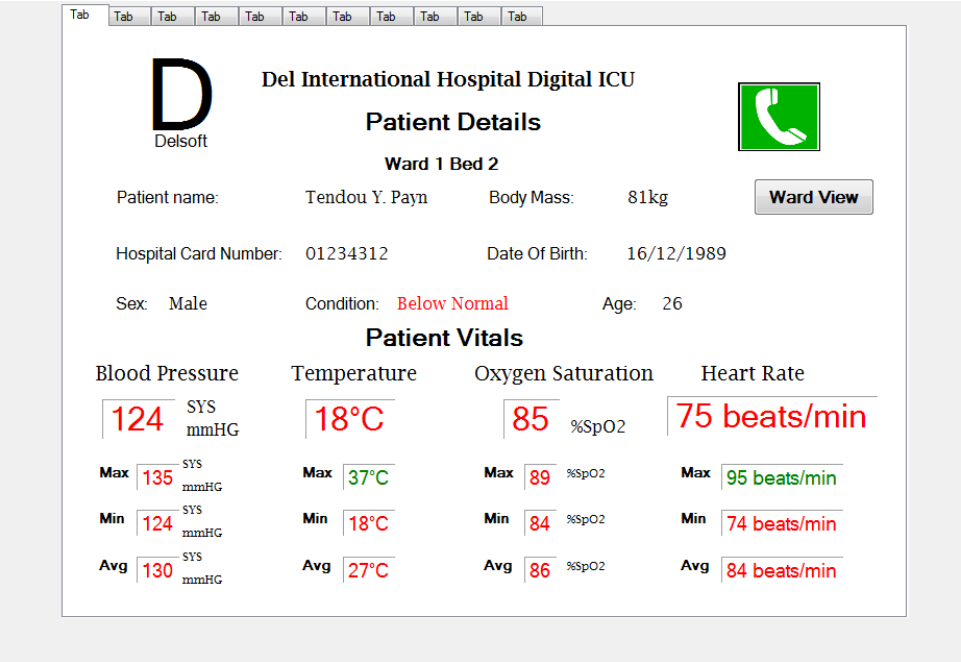

Figure 5.5b Patient Bed View (where patient's vitals readings are abnormal)

This view is the same as the previously discussed view. The only difference is that it is for the patient in ward 1 bed 2 and the condition of this patient is abnormal according to the vital readings and that is why the readings and the condition label are red in color. When the nurse notices this, she has to page the doctor. This process of paging the doctor can be handled by touching the telephone like button which is provided by the interface. The interface, as shown below notifies the nurse that the doctor is being paged.

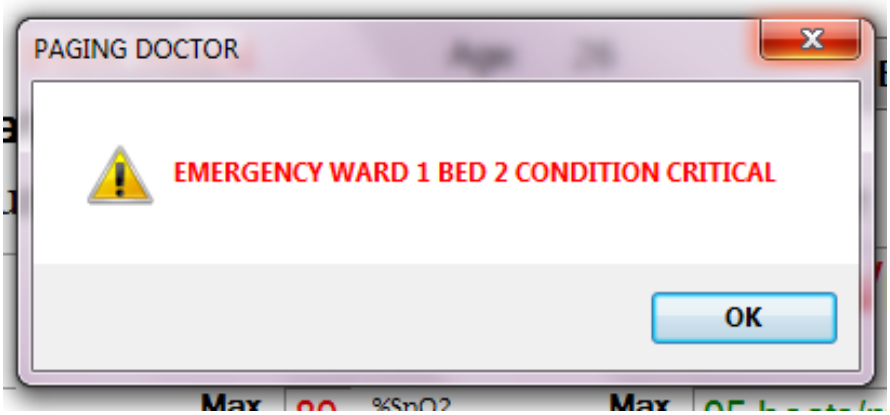

Figure 5.6. The "Paging-doctor" window

5.3. System Testing

Testing was done after the development of this system. The entire system was first of all tested by us (the developers) to ensure its full functionality, correct errors, and further improve on the entire system design. User acceptance testing was another form of testing which we carried out in order to get feedback from users.

5.3.1. User Acceptance Testing

User acceptance test is usually the last phase of the software testing process. During user acceptance testing (UAT), the actual software users test the software to make sure it can handle the required task in the real world scenarios according to the requirement or specification. After the development of the DigitalICU, we took the system to Del International Hospital, picked some ICU nurses and doctors at random, and gave them the system to 'play' around with. The reason for this is to get their opinion on the system, and find out if there were things that from their perspective need to be added, subtracted, or done differently.

Mostly, we received positive feedback. Some nurses and doctors of the ICU were thrilled with the way the system would help improve the time it took to collect patient's vitals, contact doctors during critical conditions, etc. We also got some unwanted feedback. Some nurses and doctors complained of how difficult it took them to switch between beds and wards. So we had to refine the "Select bed view" and the "Patient bed view as given below

For the patient bed view, we added two buttons, which would allow us to switch between wards and beds easily. The buttons are: the "ward 2" and "bed 1" buttons. A screenshot of the improved patient bed view is given below

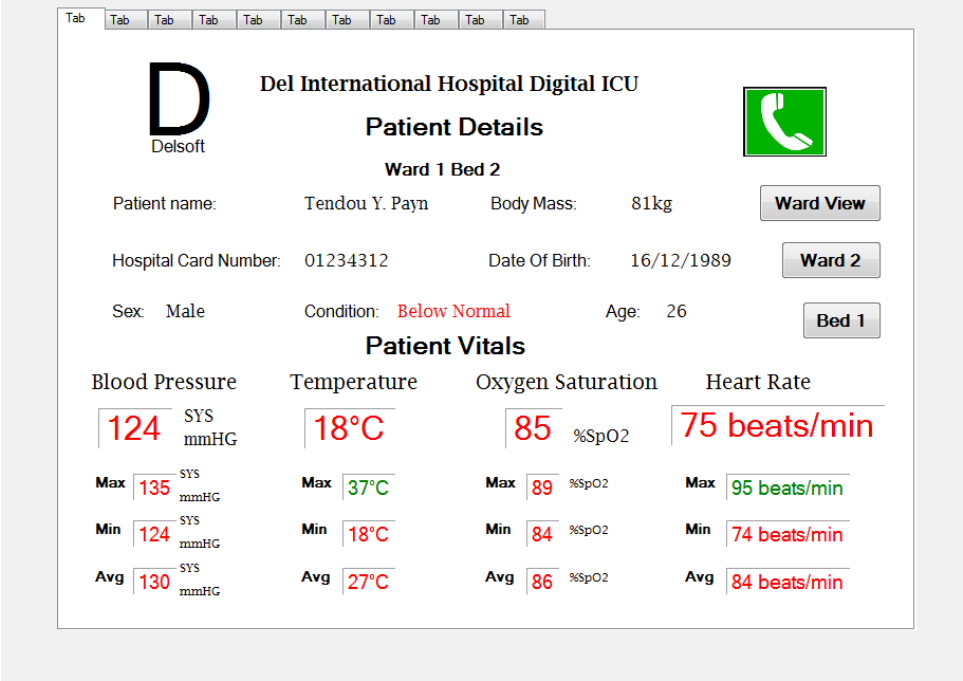

Figure 5.7 Improved patient bed view

For the select ward view, we added the "ward 2" button to enable users switch between wards easily. A screenshot of the improved select ward view is given in the next page.

Figure 5.8 Improved Select bed view

Now, we have implemented the system based on the requirements we stated in Chapter 4, we also performed a user acceptance testing for the DigitalICU which led to improvements in its implementation. The next chapter is the conclusion of all we have done, includes recommendations, and also summarizes the entire project.

CHAPTER 6

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

6.0. Introduction

This chapter describes the objectives of the system discussed in earlier chapter, summary, conclusion, and recommendation of the system.

6.1. Summary

The purpose of this study was to design a user friendly interface for the intensive care unit of Del International Hospital, using interactive design principles, and to evaluate this interface using the same interactive design principles.

Literature on human and computer interaction, interaction design principles, and other mission critical interfaces were reviewed. The mission critical interfaces we reviewed include; Animated ADS-B radar solution, Solutions designed by BIO-NEXUS, Aspen's Angle of attack (AOA) Aircraft Solution, and Train Communications System Australia Solutions.

Software design was the main methodology used in this project. Requirement gathering is one of the important parts of software design, and our requirement gathering technique was interviews. Doctors, nurses, staff, and other potential users of the DigitalICU were interviewed and the results of the interview were analyzed in Chapter 4.

The objectives of the project are:

- To facilitate an appropriate method of collecting, storing, retrieving and feedback of information

- To propose an automated system (DigitalICU) for Del International Hospital and evaluate the interface of the automated system using interactive design principles.
- To suggest a system that provides a better platform to enable staff (nurses and doctors) speed up their manual way of carrying out their work.

We were able to meet the second and third objectives. But the first objective was partially met. This was due to the limitation of funds, we were not able to get the appropriate wireless sensors, server, etc. that would have been used in the implementation of the DigitalICU. Also, the timeline for this project was not sufficient enough, though much of the blame goes to us for not starting early.

6.2. Conclusion

In conclusion, we clarified the objectives of this project in the summary and in the previous chapters. This project tried to pin-point the challenges staff undergo in the ICU of Del International Hospital in dealing with emergencies, collecting and retrieving patient's vitals. We conducted a thorough research concerning this project and we were able to propose a system to the hospital. We designed a user interface for the proposed system and evaluated that interface using the interactive design principles propounded by Donald Norman.

6.3. Recommendations

We recommend that appropriate time should be given to any researcher who will be working on a similar project like this to gather as much information relevant to the research. Also, if the hospital wants to implements the DigitalICU, they should purchase the necessary equipment required to implement this application. This application should be implemented on mobile phones, tablets, and other handheld devices to make the application a portable and easily accessible platform.

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APPENDIX A

Interview questions

- Does the hospital have an intensive care unit(ICU)?
- How many beds are in the ICU?
- What are the activities that occur in the ICU?
- How are the patient's vitals collected in the ICU?
- Who collects these vitals?
- Are the vitals stored? If yes, where?
- At what intervals are the patient's vitals collected?
- How does the hospital respond to emergency in the ICU?
- Are there stand-by nurses and doctors in the ICU?
- In the case where nurses and doctors are not there, how are they contacted?
- Is the means of contacting them easy and quick?
- What are some of the difficulties you face with the current way activities occur?
- Is there any way you feel the activities in the ICU can be improved/changed? How?
- How do you feel about the proposed system?
- Do you see the proposed system as a system that can be implemented?
- Do you see any advantages with the proposed system?
- Disadvantages?
- Any ideas or suggestions on the best way to implement the proposed system?