WEB-BASED INTERFACE SYSTEM FOR BEDSIDE MONITOR

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for my beloved parents, brothers and Chee Kiong, may God shower uncountable blessings upon all of you

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ABSTRACT

From face-to-face consultation to medicine at a distance, technology is changing the way medical services are delivered to the people. We are going into an era where the information is being digitized to be stored in a database. This is done in order to reduce information overlap and redundancy that are the main problems the health care sector are facing right now. More hospitals in other more advanced countries are going paperless. In order to provide better services to the critically ill patients in the ICU or CCU, a data acquisition program is developed for the acquisition of vital signs monitored in the critical care units. This work discusses the work done in extracting the data and signal from patient monitor BSM 8800 to the computer. The data are acquired using RS232C Interface Protocol. The vital signs acquired include oxygen saturation (SaO_2), heart rate (HR), electrocardiograph (ECG) signal, non-invasive blood pressure (NIBP), respiration rate (RR), temperature (TEMP) and end tidal carbon dioxide ($PETCO_2$ or $ETCO_2$). Ventricular Premature Contraction (VPC), ST level and arrhythmia information are also acquired and displayed to provide a more thorough information on the condition of the patients. Alarm detection is also programmed so that in critical conditions the vital signs will be displayed in red for extra caution. An ECG user control is designed and embedded in the web page in order to convert and plot the ECG waveform from hexadecimal values sent from the bedside monitor. The user control has been tested its accuracy and proved its validity to reconstruct the original ECG waveform. Basic patient information can also be seen from the graphical user interface (GUI) that has been developed. Physicians and medical practitioners have to register with the system before gaining access to the system and only the physician-in-charge of the patient can see the more intricate details of the patient.

ABSTRAK

Teknologi sedang mengubah cara perjumpaan pesakit dengan doktor secara konvensional kepada cara rawatan dari lokasi lain sedikit demi sedikit. Kita sedang menuju ke era di mana maklumat ditukar kepada bentuk digital untuk disimpan dalam pangkalan data. Ini adalah bertujuan mengurangkan informasi dan maklumat yang sama difailkan dua kali. Sektor perubatan kini sedang menghadapi masalah perlapisan data serta data lapuk yang tidak dikemaskinikan. Hospital di negara-negara maju telahpun lama mengaplikasikan cara penyimpanan rekod secara digital untuk mengelakkan pembaziran kertas. Bagi memberikan rawatan yang lebih baik kepada pesakit-pesakit di unit-unit kecemasan, satu program untuk mendapatkan data pesakit untuk pemeriksaan doktor dan jururawat dibangunkan. Tesis ini membincangkan kerja yang dibuat untuk mendapatkan data tersebut daripada BSM 8800 kepada komputer. Data didapatkan melalui protokol RS232C yang membolehkan komunikasi antara alatan dengan komputer. Data yang didapatkan termasuk kepekatan oksigen (SaO_2 atau SpO_2), kadar denyutan (HR), elektrocardiograf (ECG), tekanan darah (NIBP), kadar respirasi (RR), suhu badan (TEMP) dan kepekatan karbon dioksida dalam darah ($ETCO_2$ atau $PETCO_2$). Kontraksi ventrikel awalan (VPC), tahap ST dan maklumat mengenai ECG yang tidak normal turut didapatkan bagi mengetahui keadaan pesakit yang lebih menyeluruh. Di kala terjadinya kecemasan, data akan terpapar dalam warna merah. Satu program bagi menukarkan maklumat dalam bentuk heksa kepada voltan ECG yang sepatutnya dibangunkan. Ia diuji dalam ketepatannya dan terbukti bahawa ianya boleh dipercayai untuk menghasilkan gelombang ECG yang sama seperti yang sebenar. Maklumat mengenai pesakit serta doktor yang merawat terdapat dalam laman web yang dihasilkan. Doktor haruslah mendaftarkan diri sebelum boleh mengakses laman web tersebut. Hanya doktor yang bertanggungjawab terhadap seseorang pesakit boleh membaca maklumat pesakit yang lebih terperinci.

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LIST OF ABBREVIATIONS

ADO	-	ActiveX Data Object
ASCII	-	American Standard Code for Information Interchange
ASP	-	Active Server Pages
AV	-	Atrioventricular
CCS	-	Critical Care System
CCU	-	Coronary Care Unit
CIS	-	Clinical Information System
COM	-	Component Object Model
CPR	-	Computer Patient Record
CTI	-	Computer Telephone Integrated
DCOM	-	Distributed COM
DICOM	-	Digital Imaging and Communications in Medicine
DSL	-	Digital Subscriber Line
ECG	-	Electrocardiograph
EEG	-	Electroencephalograph
EHR	-	Electronic Health Record
EMG	-	Electromyograph
EMR	-	Electronic Medical Record
$ETCO_2$ or $PETCO_2$	-	End Tidal Carbon Dioxide
GUI	-	Graphical User Interface
HIS	-	Hospital Information System
HL7	-	Health Level 7
HR	-	Heart Rate
IBP	-	Invasive Blood Pressure
ICT	-	Information and Communications Technology
ICU	-	Intensive Care Unit
IIS	-	Internet Information Services

IOM	-	Institute of Medicine
ISDN	-	Integrated Services Digital Network
IT	-	Information Technology
JScript	-	Java Script
LabVIEW	-	Laboratory Virtual Instrumentation Engineering
LAN	-	Local Area Network
LIS	-	Laboratory Information System
NIBP	-	Non-Invasive Blood Pressure
$PaCO_2$	-	Partial Pressure of Carbon Dioxide
PACS	-	Picture Archiving and Communication System
PC	-	Personal Computer
PDA	-	Personal Digital Assistant
PICIS	-	Patient Integrated Clinical Information System
PIS	-	Pharmacy Information System
PM	-	Patient Monitor
PVC	-	Premature Ventricular Contraction
PWS	-	Personal Web Server
RIS	-	Radiology Information System
RR	-	Respiration Rate
RW	-	Reconstructed Waveform
SA	-	Sino-atrial
SaO_2 or SpO_2	-	Oxygen Saturation
SC	-	Strip Chart
TEMP	-	Temperature
USB	-	Universal Serial Bus
VB	-	Visual Basic
VI	-	Virtual Instruments
VPC	-	Ventricular Premature Contraction
1NF	-	First Normal Form
2NF	-	Second Normal Form
3NF	-	Third Normal Form

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CHAPTER I

INTRODUCTION

1.1 Background

In the Intensive Care Unit (ICU) or Coronary Care Unit (CCU) and other critical care settings, patients' physiological state needs to be monitored at all times but medical staff do not have the human resources and technical capabilities to perform this task continuously. Ever since the technology of monitoring astronauts' vital signs in space was transferred to the bedside in the 1960s, patient monitoring systems have become an essential part of critical care [1]. Today, these systems can gather multiple physiological signals simultaneously and derive clinically important parameters. Many monitoring systems are geared towards remote monitoring of patients' physiological signals.

Although the amount of information patient monitoring systems provide to medical practitioners is more than ever before and still improving, the usability and usefulness of the information is less than desirable. The raw data contains measurement errors and noise from biosensors. Corrections for these errors and elimination of noise have to be done for better accuracy of the signals and data acquired. Data integration and multi-parameter data analysis might be able to extract useful information from the imperfect raw data, but the state-of-the-art monitoring systems carried out limited data integration and analysis for effective decision support. Therefore, many manufacturers are improving their products constantly, hoping to give more satisfaction and functionality to the practitioners.

One symptom of this lack of data integration and analysis is the lack of electrocardiograph (ECG) signal analysis. Patient monitors located at the patients' bedside are able to monitor their ECG signals. However, physicians are unable to determine the voltage levels of the P, Q, R, S, and T points of the ECG without the waveform printouts. The same problem also arises for the R-R intervals.

In order to solve these, researchers have been creating web-enabled software to allow the analysis of the ECG waveform and the peak detection features. The ability to monitor the patient remotely is an added value for the physicians so that they do not have to be always on site whenever they want to know their patients' conditions.

Other than wired applications using landlines, researchers from other parts of the world are also looking into wireless and mobile applications for remote monitoring systems. There is little doubt that mobile computing can be a powerful tool to reengineer business processes. The benefits of such reengineering include reduced paper handling, reduced travel, improved data accuracy and timeliness, and reduced need for large central office facilities. Nevertheless, one particularly difficult issue for wireless communications is security. For instance, some wireless technologies are not suitable for applications in which sensitive client information is exchanged between a central database and a remote device because the data signal can be intercepted [2]. Wireless communication is often ruled out due to cost or simply not feasible. In some cases, mobile computing must rely on replication and synchronization of data over landlines. Therefore, it is important to balance the initial and ongoing costs of implementing these technologies, including training and support, against the potential benefits of time and monetary savings.

Before proceeding further into the discussion of the research, section 1.2 will first define the terms of web-based interface system for better understanding the rest of the discussion in this thesis.

1.2 Definition of Title

Web-based applications have been widespread with the advent of Internet and communications technology. Various gadgets and utilities available in the market made the dreams of pioneers in the medical field a reality. This research has been conducted and developed to enable monitoring of a patient in the ICU/CCU using Internet or Intranet connection.

Web means computer network consisting of a collection of Internet sites that offer text, graphics, sound and animation resources through the hypertext protocol. Interface means a program that controls the display for the user, usually on a computer monitor, that allows the user to interact with the system. An interface can be a hardware connector used to link to other devices, or a convention used to allow communication between two software systems. In a nutshell, this project used RS232C Interface Protocol to link a computer and a bedside monitor so that information from the bedside monitor can be acquired and displayed in the computer. This application can be accessed using computer network. The information available include electrocardiograph (ECG), which measures the potential generated accompanying the excitation of cardiac muscles [3], pulse or heart rate, oxygen saturation (SaO_2 or SpO_2) as an indicator of the percentage of hemoglobin saturated with oxygen, respiration rate (RR), end tidal carbon dioxide ($ETCO_2$ or $PETCO_2$), non-invasive blood pressure (NIBP), temperature, ST level and ventricular premature contraction (VPC). The first seven parameters are the vital signs usually monitored in the Intensive Care Unit (ICU) or Coronary Care Unit (CCU). Further discussion regarding the vital signs is available in Chapter II.

A system or structure has to be set up to enable patient's vital signs to be web-enabled. A database has to be built for the storage of patient and physician information. The whole application that combines all the different parts of the monitoring and database modules is called a system. It should be noted that this application does not have remote control of the amount of fluids given to the patient, remotely starts the measurement of a vital sign of a patient or have any

communication tool between the physician and the nurse-on-duty in the ICU or CCU.

1.3 Problem Statement

Intensive care is required when the patient's vital functions are disturbed due to a disease or trauma and their monitoring requires continuous external support to allow time for restoration and normalization of these functions [4]. As critical care is critical, the demands for patient monitoring are high. However, the problem of insufficient intensivists in hospitals is unsolved until today. This problem is not only faced by hospitals in Malaysia but also in other developed countries. Countries such as Norway [1], Australia [5], United Kingdom [5], The United States of America [6] and Japan [7] have used telemedicine applications to provide better medical services to their patients.

Due to insufficient intensivists, the problem of not being able to provide point-of-care treatment at crucial time also arises. Health care practitioners are not able to be at two places at the same time, as they have to go on rounds to treat other patients. Therefore, the nurse-to-patient ratio in the ICU or CCU is usually 1:1 in order to observe and record vital signs data [8]. The patients' conditions are monitored at each bed and there is a central monitoring system located in front of the room that can see all the beds currently being monitored. Patients' vital signs and graphs are collected manually at intervals except for the ECG waveform that is printed out from the printer attached to the ECG monitor.

More advanced hospitals use software to collect the vital signs automatically, such as Clinical Information System (CIS) or Patient Integrated Clinical Information System (PICIS). CIS is used to collect patient vital signs and store the information in the patient database. It is intended to replace the Medical Records Department of a medical institution, supporting the acquisition, storage, manipulation and distribution of clinical information throughout the organization. However, CIS lacks

the data access capability at remote site. This problem is solved by PICIS. PICIS is an advanced version of CIS. It offers more features and enables remote viewing of the patient charts and reports.

Both these systems are tailor made according to the requirements and needs of the ICU or CCU. However, these softwares are very costly. It may not be affordable by all the hospitals in the country.

The practice of medicine is based on the making the right medical decisions. It is no surprise then, that the major efforts of medical informaticians have been directed at the problem of medical decision making in automating medical practice. This requires not just the use of advanced computer science and technologies but also an understanding of how human physicians use information and reason in order to make decisions. Modern physicians must have up-to-date access to medical knowledge, a function that information retrieval systems and the Internet are being used to provide.

Thus, a web-based interface system for bedside monitor has been developed in the study of this research. Its purpose is not to replace the role of full time staff but to provide a complement to it. It is a better way to leverage critical care expertise among smaller institutions that do not have the resources to hire people [6]. Although it may not be as advanced as the PICIS, it provides the basic need of the physicians for monitoring patients. By logging into the system, health care practitioners are able to see and monitor the condition of their patients in the ICU or CCU. ECG waveform and data of the vital signs collected are displayed and updated at 5 seconds interval to accommodate new data. Report generation is provided in the monitoring system for easy printout of patient records.

1.4 Objectives

The objectives of this project are as follows:

(a) To design and build a user-friendly patient monitoring system for medical practitioners.

(b) To propose a way for the data acquisition from bedside monitor, BSM 8800, to Personal Computer (PC).

(c) To develop a patient database to store basic patient information and physician details.

(d) To publish the patient monitoring system on the Internet or Intranet to enable the patients to be monitored remotely.

The overall goal of this research is to develop a personal computer (PC) web-based interface system for the patients in the ICU/CCU that are monitored using Nihon Kohden BSM 8800 and other compatible bedside monitor models so that the practitioners can monitor their vital signs even when they are away. Their vital signs are first saved into the database before the data is updated and accessed through the local area network (LAN) or Internet. The system used serial connection that provided low cost customization in linking the bedside monitor and the PC. This is especially useful for hospitals that have not so up-to-date equipments but wish to be able to enjoy the benefits of modern technology with lower budgets.

1.5 Scope of Work

Using the facility in Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO), bedside monitor BSM 8800 from Nihon Kohden is selected for the

vital signs data acquisition. According to Dr Poh Yih Jia (please refer Appendix A) and Dr. Yek Kiung Wei (please refer Appendix B), the vital signs usually monitored in ICU/CCU are the electrocardiograph (ECG), oxygen saturation (SaO_2 or SpO_2), heart rate (HR), non-invasive blood pressure (NIBP) or invasive blood pressure (IBP), respiration rate (RR), end tidal carbon dioxide ($ETCO_2$ or $PETCO_2$) and temperature (TEMP). This has been confirmed by Dr. Zulkifli bin Taat (please refer Appendix C) who is serving in KUiTTHO University Health Care Centre.

The vital signs collected from the bedside monitor are HR, SaO_2, RR, NIBP, $ETCO_2$ or $PETCO_2$, Temp, ECG waveform, VPC and ST level. These vital signs are collected using both simulated and real person's data. The vital signs collected are displayed in the web page. The ECG waveform is reconstructed from the ASCII files that are sent out from the bedside monitor. From the displayed waveform, practitioners are able to view the amplitude and determine the voltage of the ECG signal of a particular patient. The system has been tested in both non-noisy environment where only the patient monitor and PC are connected and in noisy environment where other medical equipments are connected and running at the same time when the acquisition took place. This is done in order to determine if the data from the bedside monitor gets attenuated or wrong when there is electrical interference.

Bedside monitor BSM 8800 uses serial output protocol, RS232C Interface Protocol, for the requesting and sending data out from the equipment. The protocol has to be obtained from Nihon Kohden itself, as it is not shipped together with the equipment's manual. A utility has to be programmed using Visual Basic 6 (VB6) so that it is able to send request strings and receive responses from the bedside monitor. The data output from the bedside monitor is in ASCII or text format. ASCII stands for American Standard Code for Information Interchange [9]. Computers can only understand numbers, so an ASCII code is the numerical representation of a character such as 'a' or '@' or an action of some sort. A serial cable had to be custom made or bought from retailers for the connection between the equipment and PC for data collection and display.

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