WEB-BASED INTERFACE SYSTEM FOR BEDSIDE MONITOR

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JUDUL: **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.

Hospital management systems are made up of various departments in the various areas of specialization. Hospital Selayang in Malaysia is the first hospital in the country to claim itself a paperless and filmless hospital. Thus, it is looked upon as a reference in this project. The Total Hospital Information System drawn up by Team Vantage, the Information System sub-contractor and Systems Integrator, is as shown in Figure 1.1. The highlighted regions are the areas that this project is based on. Although not all of the characteristics of each area are integrated in this project, it has features of each of the areas highlighted [10].

Integration concept for monitoring in Critical Care System (CCS) according to Team Vantage is as shown in Figure 1.2. There are three divisions from where the information in the electronic medical record (EMR) is updated [10]. However, this project focuses on the Critical Care Charting and the information from the ICU/CCU. The detailed summary of the scope of project is as shown in Figure 1.3.

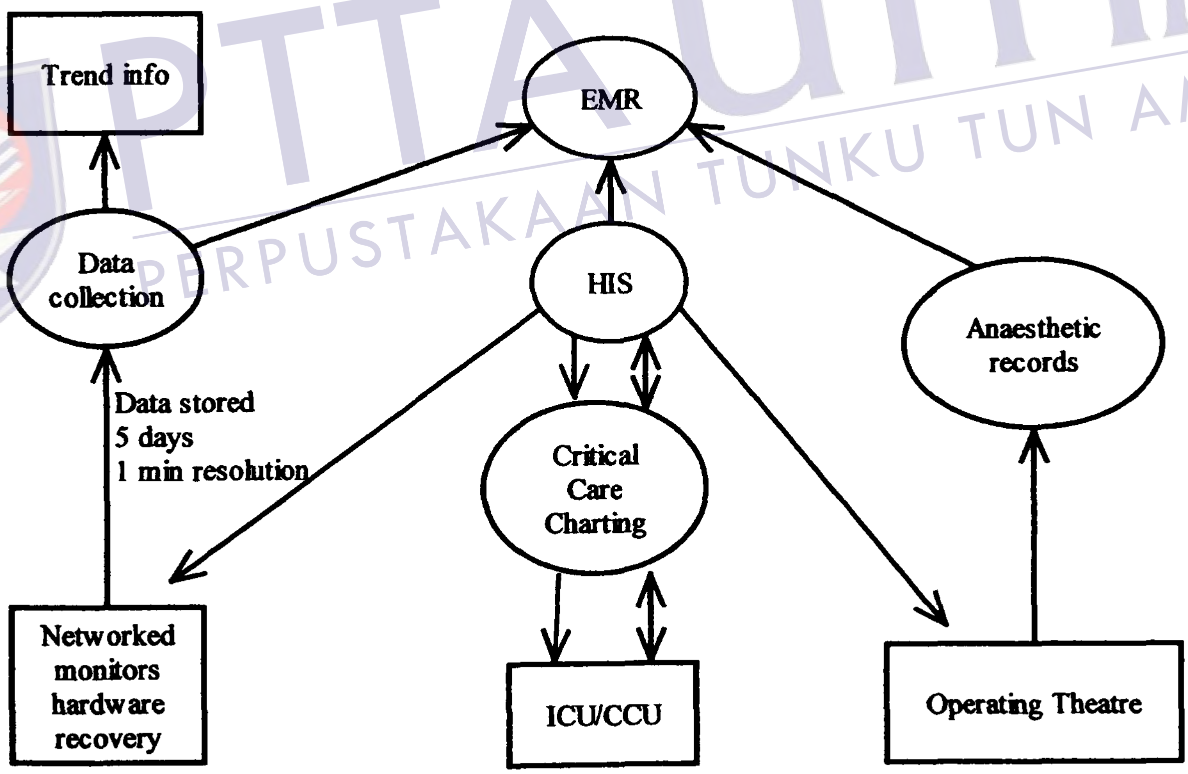


Figure 1.2: Integration Concept for Monitoring

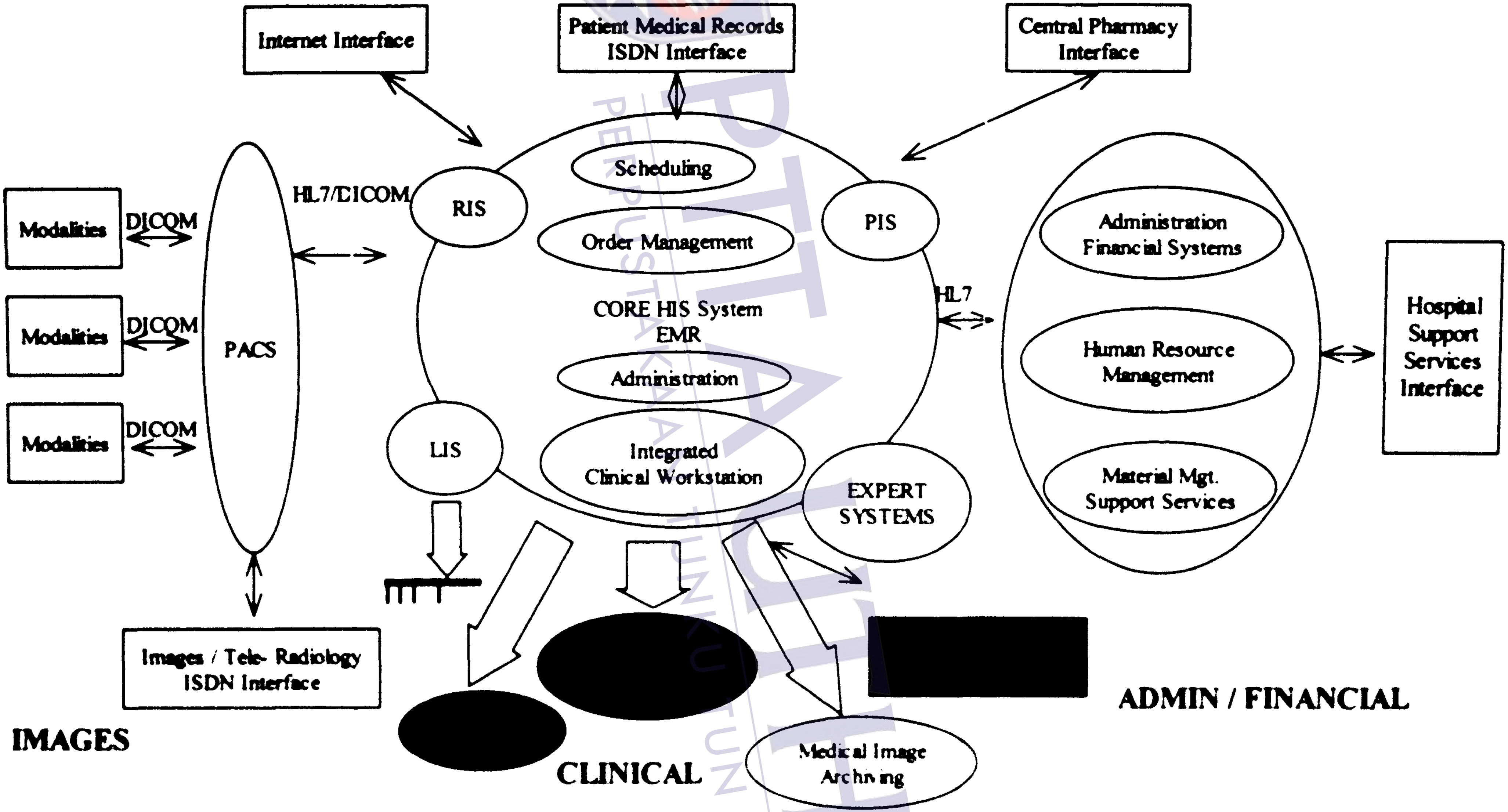


Figure 1.1: Total Hospital Information System Concept

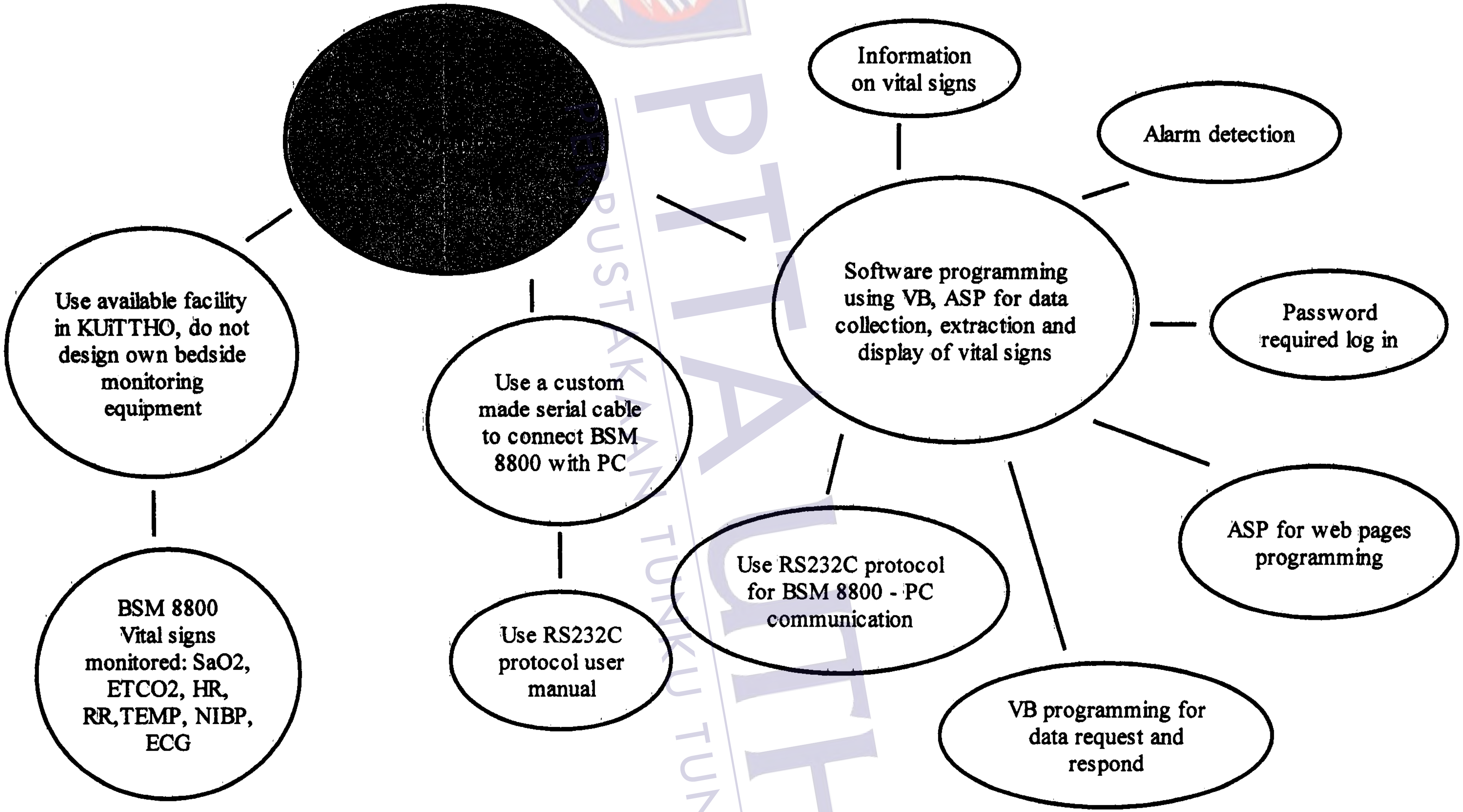


Figure 1.3: Scope of Project

After the hardware configurations and connection problems has been solved, comes the programming section. In this project, VB6 with SoftWIRE Technology has been used. Visual Basic is a popular programming language among programmers globally. SoftWIRE is an add-in programming tool with drag and drop icons. Programming with SoftWIRE is also easy as it is a graphical programming language within Visual Basic. User interface, including the data communication and extraction from the medical equipments are developed using these programming tools. There is also alarm detection for the monitoring system. A patient database has been developed in Microsoft Access 97 to store patient data and vital signs.

The web interface and programming are done using Active Server Pages (ASP). ASP is commonly used for the programming of web pages for Microsoft platforms. Most of the scripts are in Visual Basic Script (VBScript) but it can be combined with other scripting language such as Java Script (JScript). Modules have to be created for the extraction of data from the saved text format. Due to security reasons, this monitoring system has a login system, so as to prevent unauthorized access to the patient's signals and data. There is also some basic information uploaded with the system to provide information regarding the vital signs in human beings. Network settings and publishing using Internet Information Services (IIS5) has to be configured for the data transfer through the LAN and Internet.

Several limitations are taken into consideration when developing the project. First is the delay of the data transferred to another location. The signals may lag a few seconds, as time is needed to get the data, extract it and then display it. Type of network is also another factor in determining the delay of the data transfer. Broadband network provides faster data retrieval and transfer. Security is yet another factor to be considered. Although it has password protection, hackers can still find ways to hack into the system or while the data is being transferred. However, in this research, the focus is on the vital signs collection and the accuracy of the ECG waveform reconstructed of the interface system. As the data is taken from medical equipment, the accuracy of the vital signs being monitored is considered to be according to the preset customized standard.

1.6 Proposed Method

After determining the objectives and the scope of work in this research, the overall architecture of the proposed interfacing system is drawn out. Figure 1.4 shows the proposed system architecture of the interface system for patient monitoring.

In this proposed system, the patient is being monitored using BSM 8800 bedside monitoring unit. The unit is connected to the PC or laptop using a serial cable. A Visual Basic Communication Tool is developed for the data acquisition process from the bedside monitor. After the data are extracted and displayed in the web pages, IIS5 publishes the web pages in the Internet or Intranet. In this way, the medical practitioners are able to view the monitored patient's vital signs using a computer at a remote location using Internet or LAN facilities.

1.7 Thesis Organization

This thesis is divided into six chapters. Chapter I provides an overview of this project and the objectives, scopes and importance of the research. Chapter II gives an overview on the vital signs that are usually monitored in the ICU or CCU. Chapter III discusses the current trends of telemedicine applications and some details of the previous research done in this area. Chapter IV outlines the development methods of this project including the background information on the software used for the system and communication protocols of the RS232C. Chapter V presents the results and discussion of the project. Finally, conclusions and the recommendations for future works are given in Chapter VI.

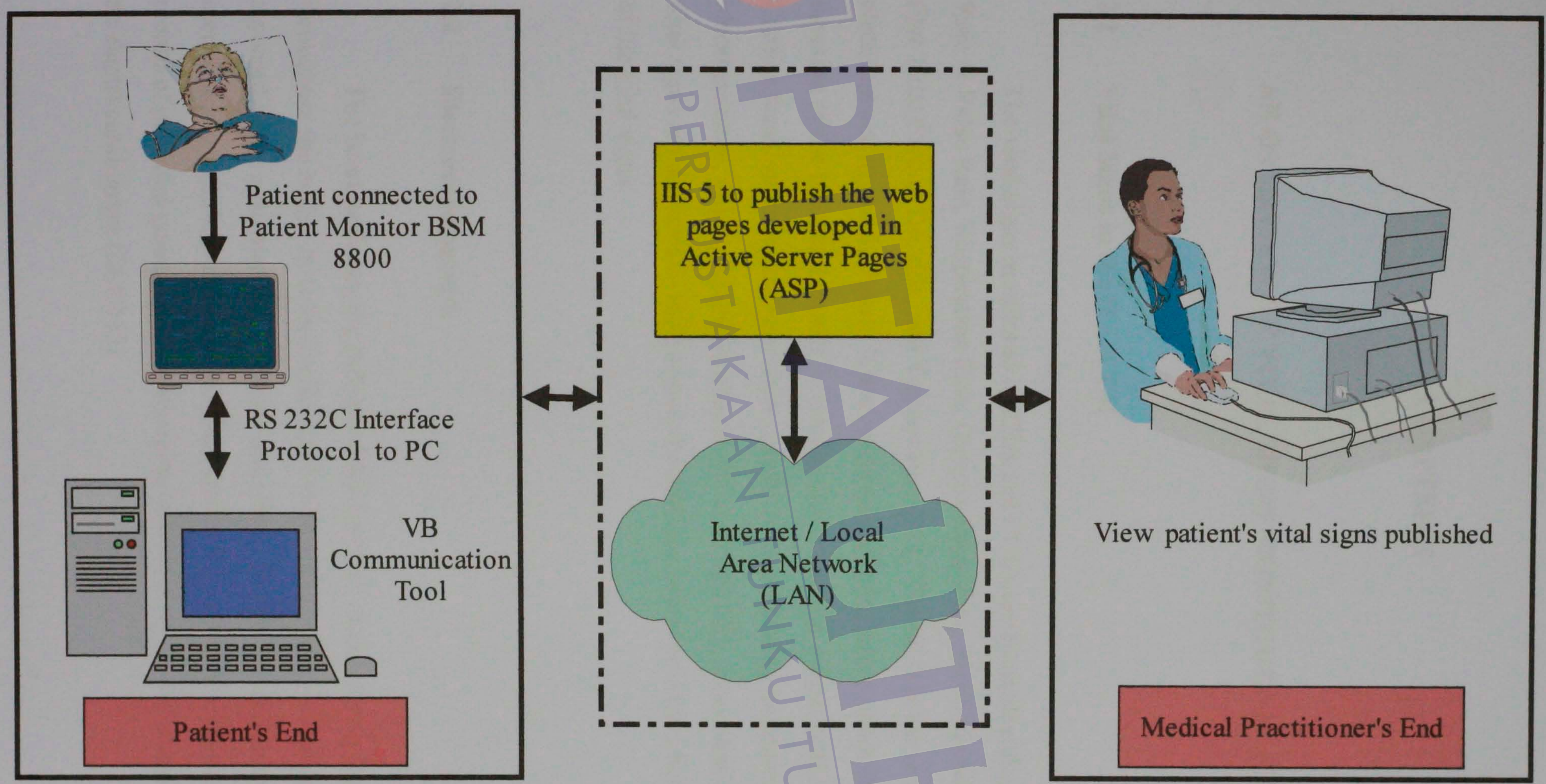


Figure 1.4: Overall System Architecture of Proposed Interface System for Patient Monitoring

CHAPTER II

AN OVERVIEW ON VITAL SIGNS MONITORED IN ICU/CCU

2.1 Vital Signs in the ICU/CCU

The vital signs monitored in ICUs and CCUs are Electrocardiograph, Heart Rate or Pulse Rate, Respiration Rate, Oxygen Saturation, Blood Pressure, Partial End Tidal Carbon Dioxide, and Temperature [11]. The ECG is the recording of the electrical activity of the heart. It does not provide information about the mechanical function of the heart and cannot be used to access cardiac output or blood pressure. Cardiac function under anaesthesia is usually estimated using measurements of blood pressure, pulse, oxygen saturation and end tidal CO_2 concentrations. As these vital signs are acquired in this project, the sections below provide a brief explanation of the vital signs.

2.2 Electrocardiograph

The heart performs the indispensable function of circulating blood throughout the body. In order for the heart to beat as a pump, it is necessary for the myocardium to systematically contract and relax. In order to initiate the contractions, electric excitations are generated at a specific location of the heart. The record of potential generated accompanying excitation of cardiac muscles is called an electrocardiogram (ECG) [3].

This is one of the vital signs acquired in the interfacing system. ECG is an important sign that is monitored at all times in ICUs and CCUs. From an ECG, the cardiologist is able to diagnose whether the heart is enlarged, where the enlargement occurs, whether the heart action is irregular and where the irregularity originates. It also provides information whether a coronary vessel is occluded and where the occlusion is located, and whether a slow rate is purely due to physiological factor or caused by heart block. An electrocardiogram may also disclose the presence of high blood pressure, thyroid disease, and certain types of malnutrition [12].

A typical ECG waveform is shown in Figure 2.1. The first upward deflection, P, is due to atrial contraction and is known as the atrial complex. The other deflections, Q, R, S, and T, are all due to the action of the ventricles and are known as the ventricular complexes [3]. Any variation from the norm in a particular ECG is an indication of a possible heart disorder. The irregular ECG waveform is called an arrhythmia.

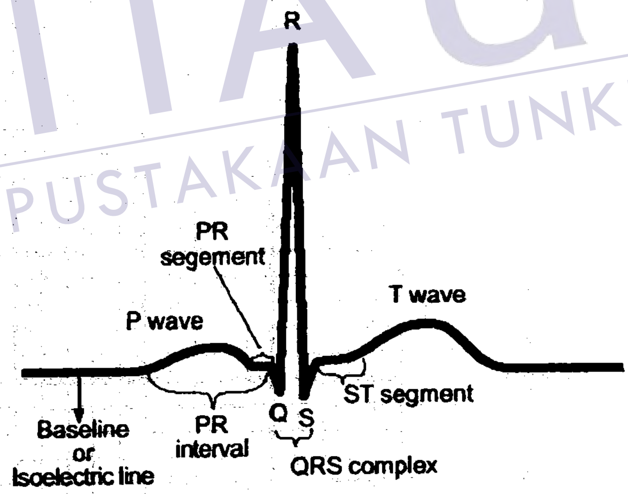


Figure 2.1: A Typical ECG waveform

Table 2.1 shows the electrode positions and connections for standard ECG leads. Different ECG leads measures the different potential points. Figure 2.2 gives a more detailed overview of the potential measurement of the different bipolar leads. The potentials are measured in triangles and are called the Einthoven's triangle [3].

Table 2.1: Electrode Positions and Connections for Standard ECG Leads

	Lead Symbol	Lead Name	Electrode Location & Polarity	
			(+)	(-)
Bipolar Lead	I II III	Lead I Lead II Lead III	Left arm (L) Left foot (F) Left foot (F)	Right arm (R) Right arm (R) Left arm (L)
Unipolar Limb Lead	aV_R aV_L aV_F	Augmented Goldberger Leads	Right arm (R) Left arm (L) Left foot (F)	Central terminal of: Left arm & left foot Right arm & left foot Right arm & left arm
Unipolar Chest Lead	V1 V2 V3 V4 V5 V6	Wilson's Leads	Chest Electrodes V1 V2 V3 V4 V5 V6	Wilson's central terminal

When monitoring using the electrocardiogram, Lead II is usually used. This is the most useful lead for detecting cardiac arrhythmias as it lies close to the cardiac axis (the overall direction of electrical movement) and allows the best view of P and R waves. This condition is similar to what is implemented in this project. However, the ECG leads monitor changes according to the settings of the bedside monitor. The bipolar lead detects variations of potentials at two points of a single apex of the triangle (one apex represents the left arm, one right arm and one the left foot). Unipolar Lead represents the difference between the potential of the one apex and zero potential of the central terminal by combining the other two apexes.

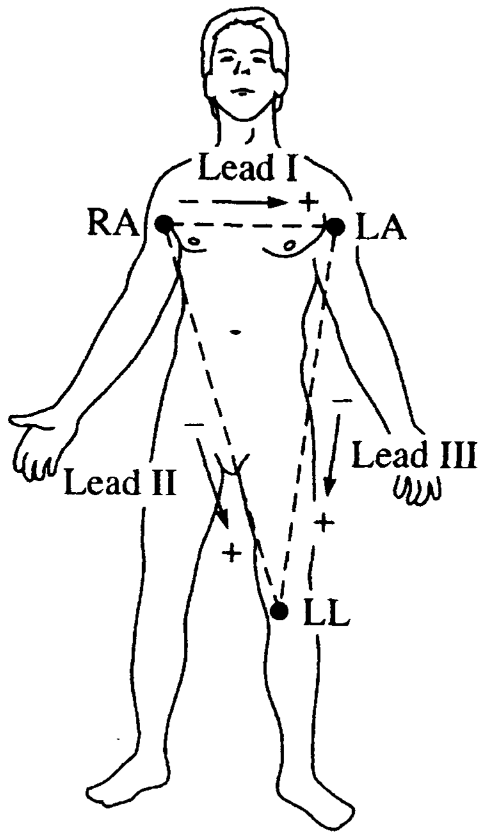


Figure 2.2: Einthoven's Triangle

Generally, ECG is of great value in the following clinical conditions [12]:

(a) Atrial and ventricular hyperthrophy

(b) Myocardial infarction

(c) Unipolar extremity leads, multiple chest leads, and esophageal leads have greatly increased the incidence of correct diagnoses

(d) Arrhythmias

(e) Unipolar electrocardiography is important to make more exact diagnoses

(f) Pericarditis

(g) Systemic diseases that affect the heart

(h) Effect of cardiac drugs such as the digitalis and quinidine

(i) Disturbances in electrolyte, especially potassium abnormalities

2.3 Pulse / Heart Rate

The second data obtained from the bedside monitor is the pulse rate or heart rate. With each contraction of the heart, the blood in the ventricle flows out of the arteries [12]. The flowing blood causes the walls of the arteries to throb and conduct undulations via the entire arteries branch, extending in peripheral directions. These undulations are called the pulse. The pulse of average adults is within 60-90 beats per minute.

The pulse provides clues concerning the problems of the cardiovascular function, the condition of the peripheral blood flow, the characteristics of the walls of the blood vessels, the control of the vascular system by the autonomic nervous system, etc. Other than that, it can also be used as the standard method to indirectly measure the blood pressure. Therefore, the pulse has become one of the essential pieces of information in the monitoring of patients during and after an operation, and in the monitoring of critically ill patients.

2.4 Oxygen Saturation

Oxygen saturation (SaO_2 or SpO_2) is an indicator of the percentage of hemoglobin saturated with oxygen at the time of the measurement. This data is also one of the vital signs acquired in the system. The reading, obtained through pulse oximetry, uses a light sensor containing two sources of light (red and infrared) that are absorbed by hemoglobin and transmitted through tissues to a photo detector [13]. The amount of light transmitted through the tissue is then converted to a digital value representing the percentage of hemoglobin saturated with oxygen. Normal SaO_2 values are 97% to 99% in the healthy individual. An oxygen saturation value of 95% is clinically accepted in a patient with a normal hemoglobin level. These values may vary with the amount of oxygen utilization by the tissues. For example, in some patients, there is a difference in SaO_2 values at rest compared with those during activity, such as ambulation or positioning. However, it has to be noted that SaO_2

does not reflect the patient's ability to ventilate and pulse oximetry cannot distinguish between different forms of hemoglobin [14].

Oxygen saturation test is a non-invasive method of measuring the amount of oxygen. To do the test, a small sensor is placed on the patient's finger, toe or ear lobe. The sensor is connected to a machine or equipment that displays the oxygen saturation and the pulse rate.

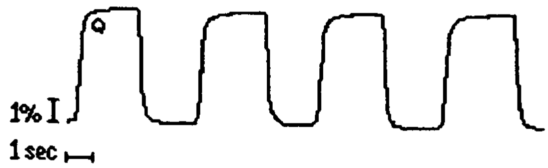
2.5 Respiration Rate

During respiration, oxygen is taken into the lungs and carbon dioxide is expelled. The respiration rate (RR), depth and rhythm correspond to the physiological needs of the body, and their abnormal changes are symptoms of diseased conditions. The respiration rate for adults is about 14-18 per minute [12]. It is often necessary to measure respiration for one minute in order to minimize error because the respiration rate can be somewhat irregular (intervals between respirations are not always constant). Respiration rate has always been an important life sign that is monitored in ICUs or CCUs.

2.6 End Tidal Carbon Dioxide

The end tidal CO_2 ($ETCO_2$ or $PETCO_2$), is a non-invasive method of monitoring the partial pressure of carbon dioxide ($PaCO_2$) [15]. This is displayed by a waveform called a capnogram or capnograph as is shown in Figure 2.3. Capnography comprises the continuous analysis and recording of carbon dioxide concentrations in respiratory gases. Although this waveform is not acquired in this project, the value of $PETCO_2$ is being displayed. The difference between a normal capnogram with an abnormal one can be seen in Table 2.2.

Table 2.2: Difference between Normal and Abnormal Capnogram

Normal waveform	
Significant bronchospasm - loss of vertical E2, -opening and blunting of angle Q, -tilting of E3.	

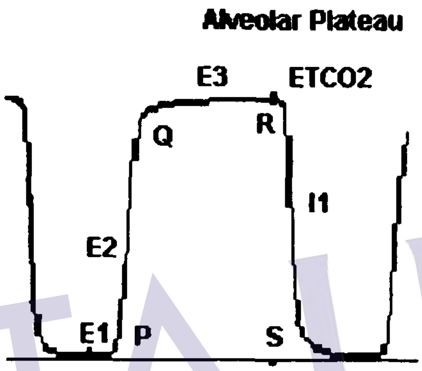


Figure 2.3: Normal Capnogram

The normal capnogram as illustrated in Figure 2.3 has a rectangular wave pattern exhibiting five main phases (after a brief unapparent stage "E1", corresponding to expiration of the anatomic dead space). Table 2.3 shows the description of the different phases aforementioned.

Table 2.3: Description of Different Phases of a Capnogram

Phase	Description
E_2	ascending slope, almost vertical (mixed air)
Angle Q	almost 90°, usually very distinct
E_3	alveolar plateau (alveolar gas)
R	end-tidal peak (ETCO2) close to $PaCO_2$ (5%)
I_1	vertical descending slope (start of next inspiration)

Changes in $PETCO_2$ could not be taken lightly. Medical practitioners may interpret a sudden decrease as ventilator disconnection, a leakage in the system, an obstructed endotracheal tube, sudden hypotension, sudden hyperventilation or a massive pulmonary embolus. A gradual decline could be a sign of hyperventilation, reduced pulmonary perfusion or decreased CO_2 production whereas a sudden increase in the $PETCO_2$ might result from an injection of sodium bicarbonate, a sudden release of a tourniquet or a sudden increase in cardiac output. A gradual increase could indicate a greater production of CO_2 or hypoventilation. Esophageal intubations would result in the total absence of a waveform. Therefore, although the analysis of respired gases is continuous, it is greatly influenced by the differences in the ventilation-perfusion ratios in various regions of the lung, the total CO_2 production and the total alveolar ventilation. Unfortunately, in the critically ill patients, these variables may not be stable; hence, monitoring the $PETCO_2$ may not provide a good warning of changes in the $PaCO_2$ [15].

2.7 Non-Invasive Blood Pressure

Blood pressure (BP) is the pressure of blood against the artery walls resulted by the force generated by the contraction of the left ventricle and conducted through arteries of the entire body. It is measured in two numbers: for example, '140/90'. The first number (140) is the systolic pressure, the pressure when the heart contracts and pumps the blood through the body. The lower number (90) is the diastolic pressure, which is the pressure at the atrial when blood is filling up the heart [3]. In this project, non-invasive values are acquired, as there is no module to measure the invasive blood pressure.

Diastolic pressure is the lowest pressure the blood places on the walls of the blood vessels when the heart is relaxed between beats. A reading of 120/80 is considered normal. A person has high blood pressure (hypertension) if his/her blood-pressure reading is equal to or greater than 140/90 for extended periods. Both of these measurements are important. A high systolic pressure indicates strain on the blood vessels when the heart is attempting to pump blood into one's bloodstream. If the diastolic pressure is high, it means that the blood vessels have little chance to relax between heartbeats. Elevated blood pressure means the heart is working harder than normal, putting both the heart and arteries under a greater strain.

The blood pressure usually is measured with a small, portable instrument called a blood pressure cuff (sphygmomanometer) in units called millimeters of mercury (mmHg) [3]. The blood pressure cuff consists of an air pump, a pressure gauge, and a rubber cuff. The cuff is placed around the upper arm and inflated to a pressure that blocks the flow of blood in the main artery (brachial artery) that travels through the arm. Next, the pressure of the cuff on the arm and artery is gradually released. As the pressure decreases, the health care practitioner listens with a stethoscope over the artery at the front of the elbow. The pressure at which the practitioner first hears a pulsation over the artery is the systolic pressure. As the cuff pressure decreases further, the pressure at which the pulsation finally stops is the diastolic pressure. Blood pressure catches the activities of the heart indirectly, and its variation indicates the condition of the pumping function of the heart as an important vital sign.

2.8 Temperature

The normal core body temperature of a healthy, resting adult human being is stated to be at 98.6°F or 37°C. Though the body temperature measured on an individual can vary, a healthy human body can maintain a consistent body temperature that is around the mark of 37°C [12].

The normal range of human body temperature varies due to an individual's metabolism rate. The higher (faster) the metabolic rate, the higher the normal body temperature and vice versa. Other factors that might affect the body temperature of an individual may be the time of day or the part of the body at which the temperature is measured. Body temperature is usually lower in the morning due to the rest the body received but higher at night after a day of muscular activity and after food intake.

Body temperature also varies at different parts of the body. Oral temperature, which is the most convenient type of temperature measurement, is at 37°C. This is the accepted standard temperature for the normal core body temperature. Auxiliary temperature is external measurements taken in the armpit or between two folds of skin on the body. This is the longest and most inaccurate way of measuring body temperature, the normal temperature falls at 97.6°F or 36.4°C. Rectal temperatures are internal measurements taken in the rectum, which fall at 99.6°F or 37.6°C. It is the least time consuming and most accurate type of body temperature measurement, being an internal measurement. Nevertheless, it is definitely not the most comfortable method to measure the body temperature of an individual.

2.9 ST Level and Ventricular Premature Contraction

The ST level is measured relative to the PR interval (Figure 2.1). When there is a short PR interval, it can be difficult for computer algorithms to find the isoelectric reference level. The direction of the ST vector and the relative position of the electrode measuring the vector determine whether the ST amplitude is positive (elevation) or negative (depression). It is important to determine if the ST elevation is documented on previous ECGs and if the ST level is currently changing or is stable [16].

According to Webster's New World Medical Dictionary, ventricular premature contractions (VPCs) are when the lower heart chambers, called ventricles, beat prematurely before the normal electrical activation sequence of the heart has occurred [17]. Normally, the upper chambers of the heart, called atria, beat first and then the ventricles contract. When the lower chambers beat early (prematurely), the entire electrical system of the heart must reset itself. This causes symptoms of skipped beats (palpitations).

2.10 Brief Overview of the Conditions in ICU/CCU

This section will provide some background information regarding the conditions in the ICU or CCU.

In a hospital setting, the main characters are mainly the administration and clerical staff, nurses and of course the health care practitioners. These three main characters play vital roles in keeping the hospital running and saving the lives of the patients.

In general, once a person is admitted to the ICU or CCU, it means that this person is in critical condition and needs immediate attention. Normally, in a hospital setting, the nurse-to-patient ratio is one-to-one, whereby the recording of the important signals (vital signs) are done in real time [3]. This is done in order to monitor the patient's condition closely so that if the patient enters into critical condition, the practitioners on duty will be informed to treat the patient immediately. Observations and results including history, signs and symptoms are converted by clinical staff into decisions and appropriate actions [18].

Nurses in the ICU and CCU work in shifts. Thus, the number of nurses needed for monitoring the patients will double from the normal conditions. Health care practitioners will have to go on rounds. Hence, they will not be at the patient's side every minute to monitor their condition continuously. However, it is the responsibility of the practitioners to ensure the health and living of their patients.

ICUs use sophisticated electronic instruments for observation, signaling, recording and measuring physiological functions besides monitoring temperature,

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