

## REMOTE ELECTROCARDIOGRAM MONITORING BASED ON THE INTERNET

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### ABSTRACT

Telemedicine is producing a great impact in the monitoring of patients located in remote nonclinical environments such as homes, military bases, ships, and the like. A number of applications, ranging from data collection, to chronic patient surveillance, and even to the control of therapeutic procedures, are being implemented in many parts of the world. As part of this growing trend, in this paper, we present a real-time remote patient monitoring service through World Wide Web (WWW), which allows physicians to monitor their patient in remote sites using popular Web browser. A prototype system is composed of data acquisition and preprocessing module connected to the computer as the remote site via its RS-232 port, two personal computers equipped with network and analog to digital cards, and software modules to handle communication protocols between data acquisition module and personal computer. The purpose of the system is the provision of extended monitoring for patients under drug therapy after infarction, data collection in some particular cases, remote consultation, and low-cost ECG monitoring for the elderly.

**KEYWORDS:** – ECG monitoring, home monitoring, Internet, telemedicine.

### 1. INTRODUCTION

Although telemedicine systems have been implemented for many years, Ethernet has just begun to be implemented in the last decade [1-2]. A much more cost-effective solution would be to use the already existing Internet. A differential amplifier-filter unit, two computers equipped with network and analog to digital (A/D) cards, and client server software would be all that is required to perform reliable, remote monitoring of electrocardiogram (ECG). Differential amplification of the weak heart signal, normally achieved by a 3 op-amp discrete component circuit, is better performed with an integrated circuit (IC) instrumentation amplifier. These chips offer a higher common mode rejection ratio (CMRR), greater balance between inputs, and less thermal noise. Low Pass, High Pass, and notch filtering are employed after amplification to cut out high frequency noise, dc offset, and 60 Hz noise induced into the circuit. Data integrity is paramount in biomedical signal transmission, as missing data would fail to alert the specialist to a serious condition. TCP is employed in this project as it offers permanent connection channels [3]. The software is constructed around a client-server model. TCP operations used to send and receive data, messages, and program run information are performed. ECG data analysis to detect possible cardiac abnormalities may also be incorporated. On closing either the client or server, data is written to a file for later analysis. Graphical User Interfaces (GUI) rather than text-based interfaces are employed for user-

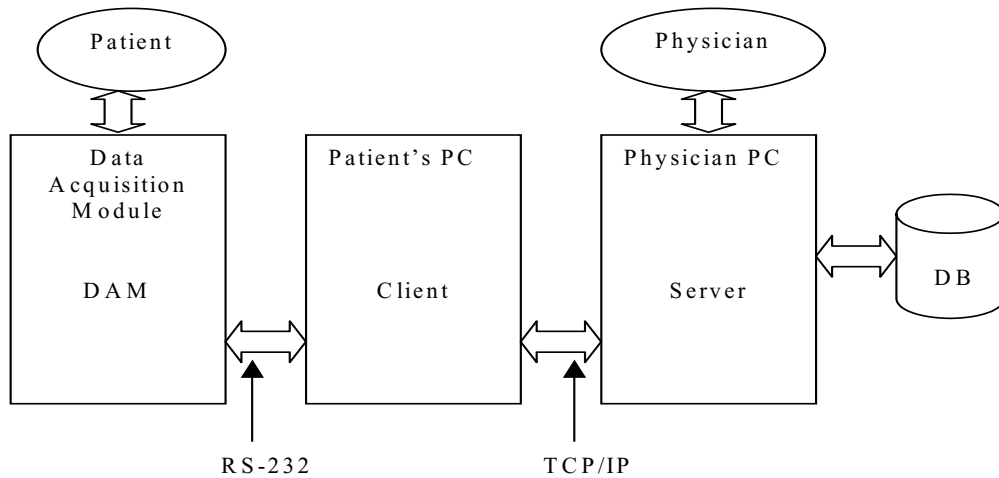
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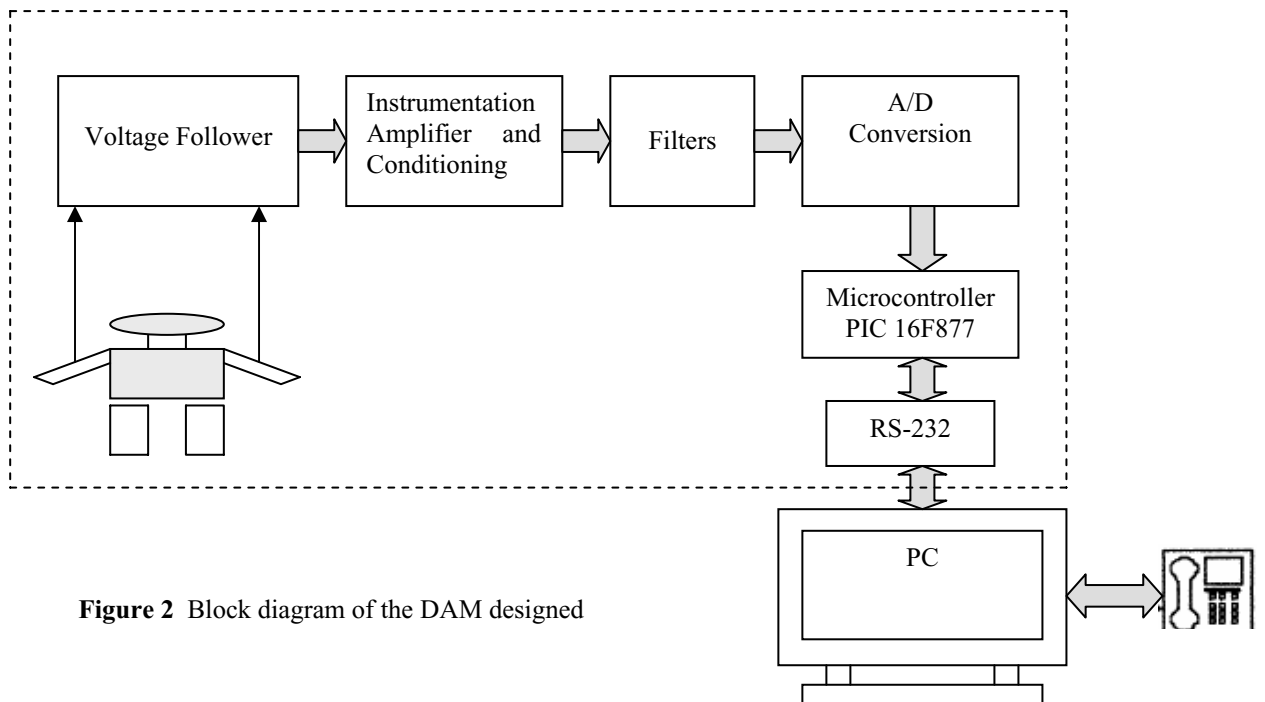
friendly software use. The remote observer can monitor the subject's ECG, by typing in the subject's IP address.

## 2. MATERIALS AND METHODS

This paper presents an internet-based ECG telemonitoring system, which has been developed as an instance of the general client-server architecture presented in Figure 1. The data acquisition module (DAM) is a device that allows acquisition and training aside from knowledge of widespread and standard Internet tools. The function of each one of the components of the proposed telemonitoring system and the detail regarding their implementation will be described in the following sections.



**Figure 1** General diagram of an Internet-based telemedical system



**Figure 2** Block diagram of the DAM designed

### **2.1 Data Acquisition Module (DAM)**

The data acquisition subsystem was designed taking into consideration the requirements of a nonclinical situation. The device should be easily connected to the remote computer and should not require any adjustments to be made by the patient. A block diagram of the DAM is shown in Figure 2. The DAM was implemented as a battery operated device. A LM 324 Instrumentation amplifier IC was used for amplification due to its improved characteristics. The signal should be amplified as close to the source as possible to alleviate loss of representation. However, the gain of the signal should not be too high to prevent DC offset and noise saturating the amplifier. The removes of unwanted frequencies in this case requires three filters. A low-pass filter is implemented cascaded the signals from the gain amplifier with frequency higher than 100Hz A notch filter or band reject filter is used to reduce 60 Hz noise. A 60 Hz notch filter circuit was implemented using TL082 IC [4]. Finally, a high-pass filter is used to allow the signal that has frequency above 10Hz. It should be noted that a band-pass filter was not used because the pass-band was large, and it is recommended cascaded high-pass, low-pass filters be used in this case. The digital section comprises the data conversion section and the control unit. A/D converter was employed.

The control unit governs the sampling frequency, and it can be switched between (200-400) samples per second. The control unit also implements the bi-directional communication protocol to the PC, through a proper RS-232 interface provided in the DAM. The control unit is built around the Microchip PIC 16F877 with a 10-MHz clock Microcontroller. It does allow a sampling frequency of 200 samples per seconds although, in the current version, the patient has to stay close to the PC during the monitoring period.

### **2.2 Client and Server Applications**

The client server architecture (see Figure 1) is defined as follows: the client application provided visualization, archiving, transmission, and contact facilities to the remote user (i.e., the patient). And provides control of the acquisition module. The server, which is located at the physician's end takes care of the incoming data, and organizes patient sessions. The client application has been designed and developed using VB Script in Asp page, and the server application designed and developed using HTML and Macromedia Dreamweaver MX 2004. Execution of the client's application generates the GUI shown in Figure 3. The client's application is mainly to measure the patient's heart rate, temperature and based on the waveform generated by (DAM) capture ECG waves in real time. The interface can be divided to three main sections. At the top are shown the patient details; The user is able to perform the add new patient, save, edit patient details, delete patient record, search in engine based on patient identity card, patient age and password number. In the middle, are shown hardware device setting such as hardware ID, sample rate, analog channel, COM port, trigger channel and the current heart rate and current body temperature. The bottom section contains the ECG with button to control the input wave of the device.

While the server is running, the client (patient) can start a session from anywhere in the Internet by accessing the server's connection port and providing a proper log in and pass - word. Before any interconnection has been accomplished, the DAM is totally under the control of the client. The entire system web site is written in HTML. Screen visualization can be modified from 25mm to 50mm in one of the submenus shown in the interface.

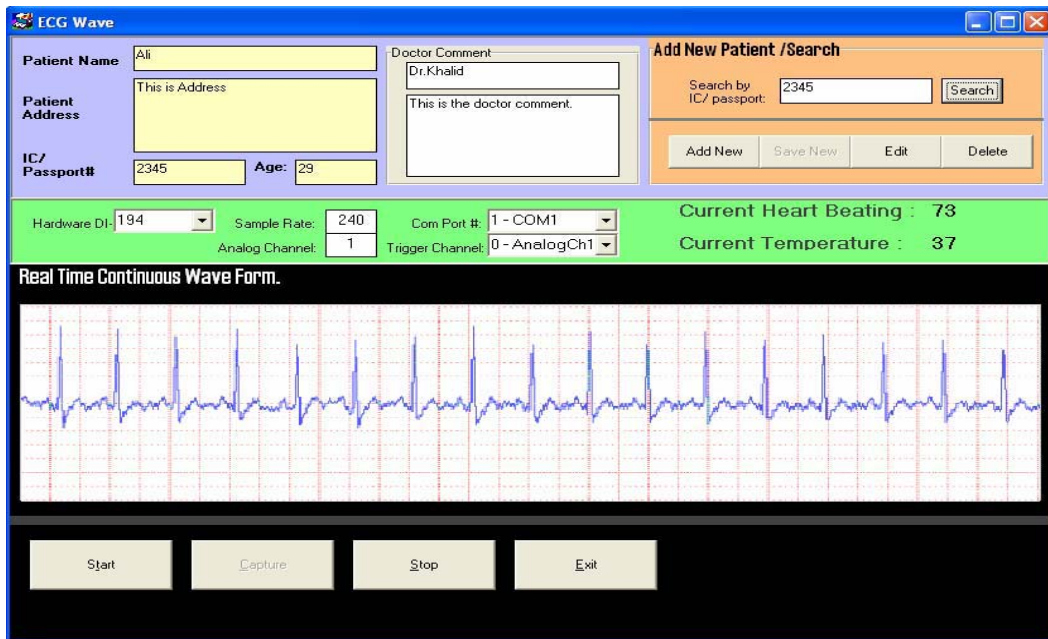


Figure 3 Client's interface

### 3. RESULTS

Figures from 4 to 9 show the sequence of the web pages according to the measurements process. Figure 4 requires the user name and password to access the system web site. Then after these pieces of information are typed in, the page for view the patient's ECG history and current online patients are given (Figure 5). Zero indicates that the patient is offline status whereas one indicates the active mode or in i.e. the patient is undertaking his ECG test somewhere. After the symptoms are given, then the physician can click on the patient who appears on line to view the patient's measurements as shown in Figure 6. Figure 6 shows the patient details such as name, age, address and IC, the current heart rate and temperature. Figure 7 shows the real time ECG waveform, which was recorded at the remote side. Figure 8 illustrates the report and diagnosis page; this page can be used to save the diagnosis and any information about the patient on the hospital database. In the section Q and A the physician can send his advice or diagnosis to the patient as in Figure 9.

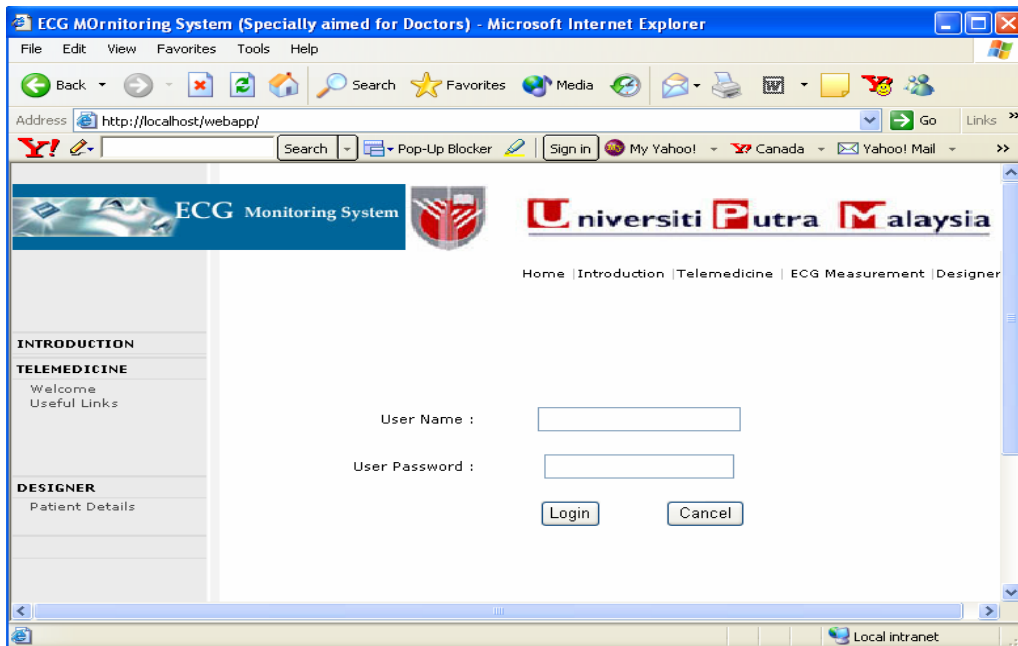


Figure 4 User name and password

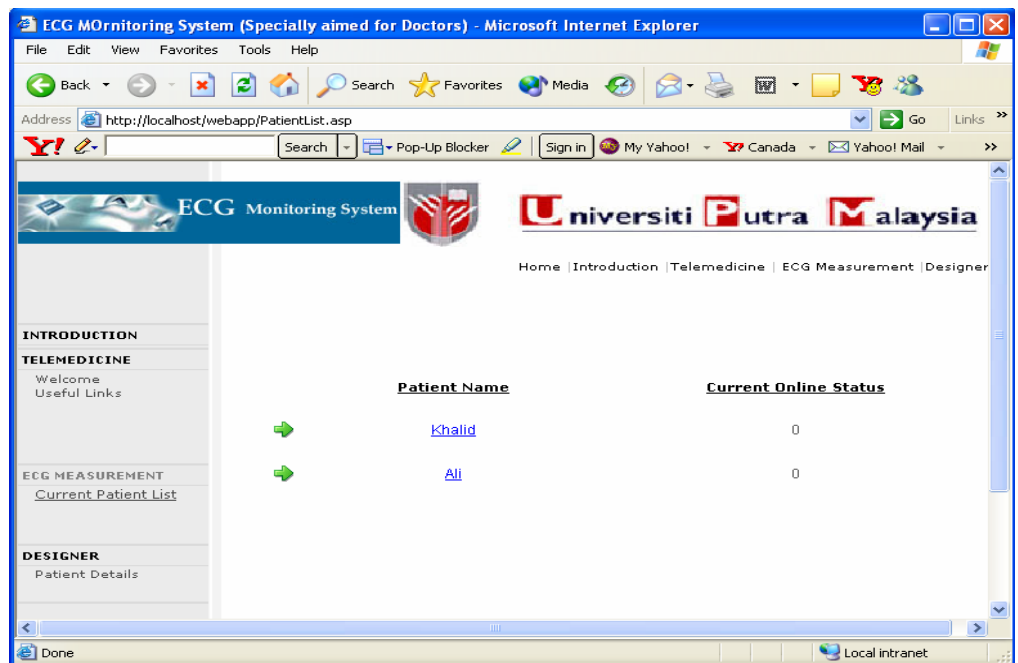


Figure 5 Patient's current online status

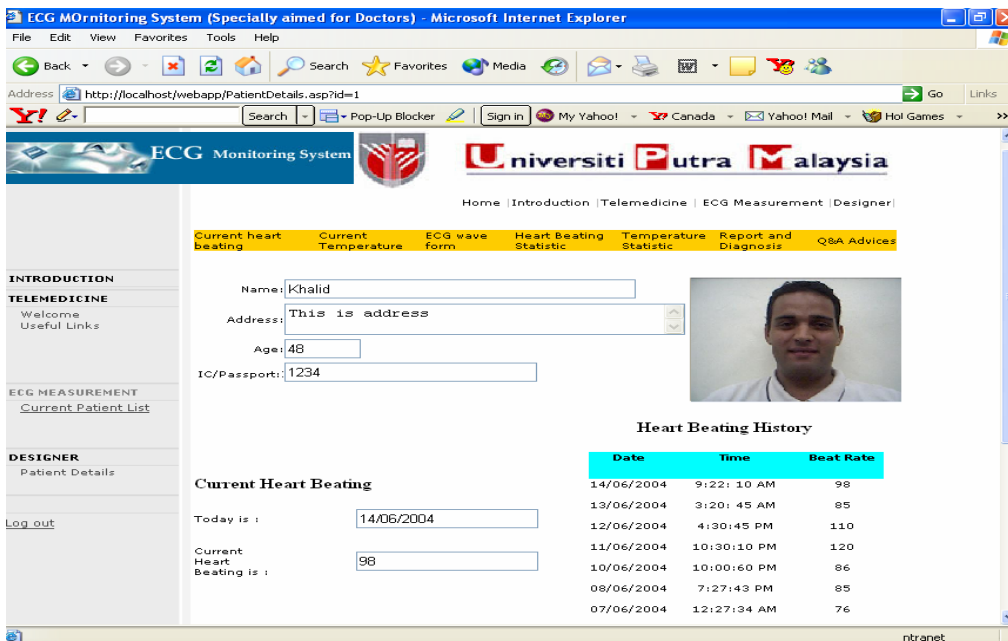


Figure 6 Measurements page

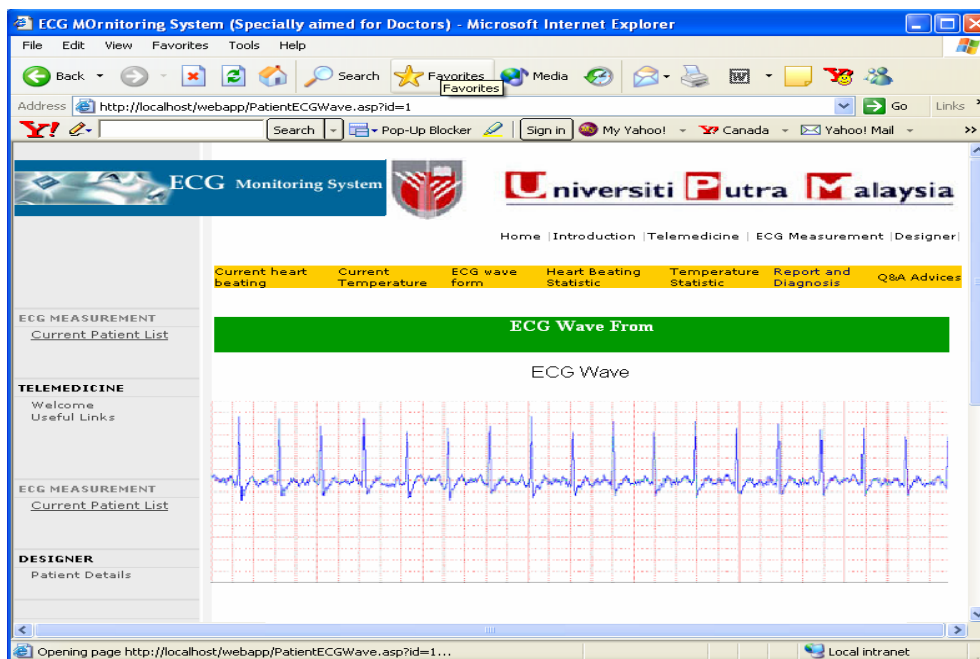


Figure 7 Real-time ECG waveform

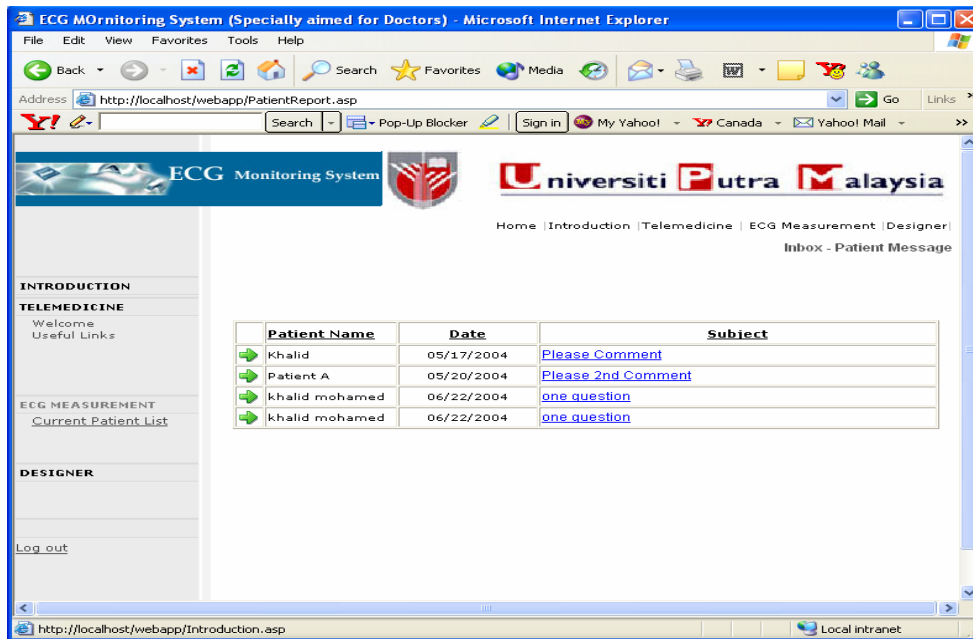


Figure 8 Report and diagnosis page

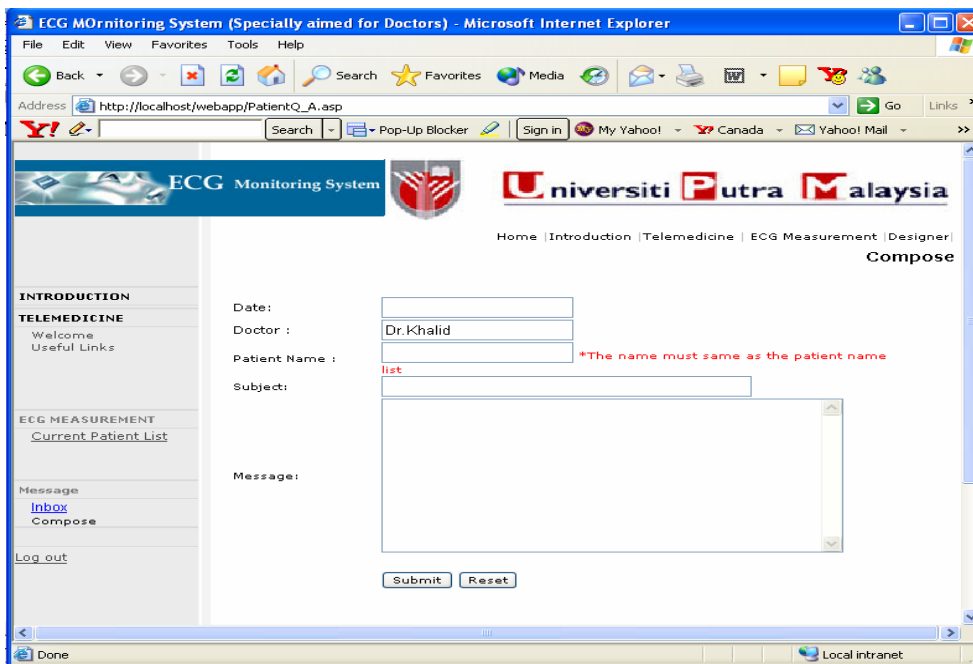
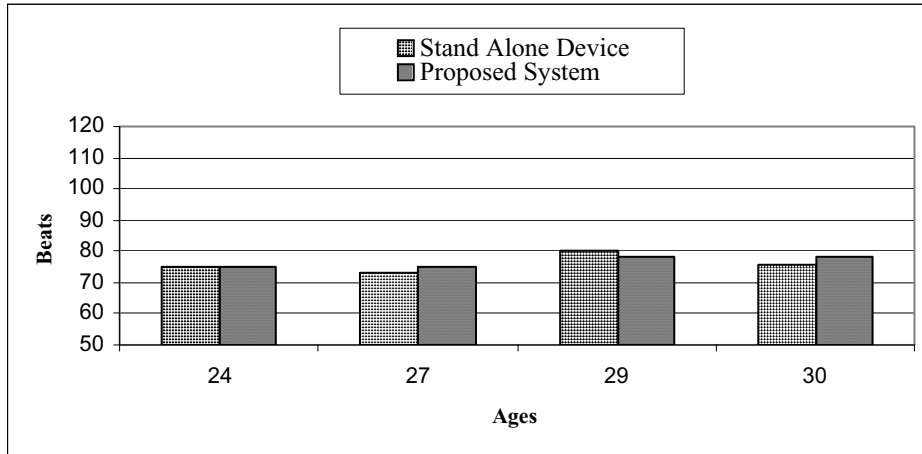


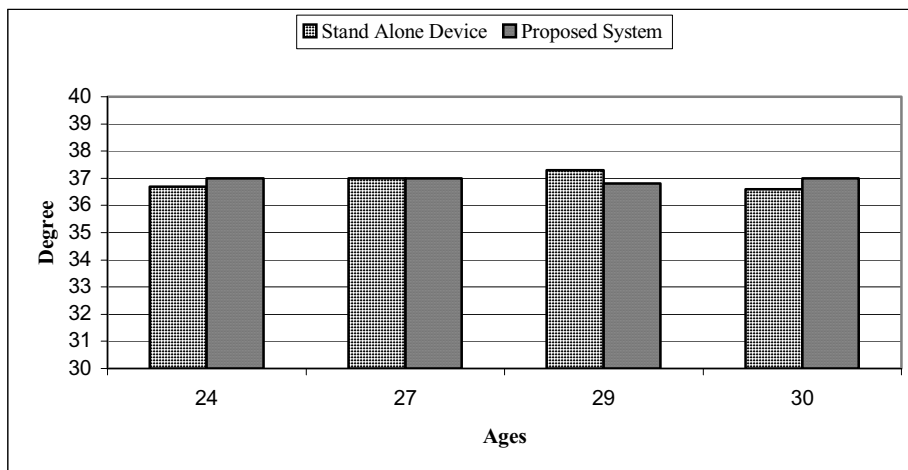
Figure 9 Contact window

Figure 10 shows a comparison between stand alone device and the proposed system for four persons; the system appeared to be stable and variable as digital ECG monitoring. The differences between both are a bout  $\pm 5\%$  for heart rate. Figure 11 shows the differences between the measurements using thermometer and the proposed system the differences is about  $\pm 2\%$ . The source of the error may be due to the following reasons: (1) the instability of

the battery used and (2) the wires used are 1.50 m, these wires will effect the capacitance that will cause effect to the measured signal.



**Figure 10** Comparison between heart rates measured by stand-alone device and the proposed system



**Figure 11** Comparison between temperatures measured by stands alone device and the proposed system

The design of a complete real-time ECG acquisition, transmission, storage, and visualization system, which is easy to use and dedicated for clinical applications, has been presented in this paper. A Microcontroller-based small-sized ECG DAM remotely controlled and adjusted has also been presented. This device does not require any involvement or maintenance by the patient. The client server interconnections are easily accomplished, and the contact window allows excellent version. The system used to monitor one patient. In the future, the system can be extended to monitor more than one patient at the same time and the server application could include more sophisticated signal processing analysis. Also, we plan to add video conferencing capability for the users under the networking environment where video data can be handled.



## 5. ACKNOWLEDGEMENT

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