A LOW COST MODEL FOR PATIENT MONITORING IN INTENSIVE CARE UNIT USING A MICRO WEB-SERVER

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ABSTRACT

This work presents a model for patient monitoring in Intensive Care Units (ICU), using a WWW application tool - Micro WEB-Server (MWS) – an embedded computer system, in order to monitor physiological data, obtained by standard monitors, captured, made available via WEB and temporarily stored (previous 24 hours data). Monitors are connected to, also standard sensors connected to the patient. For the present model, the following data were chosen: (a) body temperature, (b) systolic blood pressure, (c) diastolic blood pressure, (d) cardiac frequency and (e) oxymetry. MWS executes a pre-processing, comparing each signal's value, which sample frequency can be regulated by the professional responsible for the ICU, and it triggers an alarm when something is abnormal. It stores the previous 24 hours records in itself, besides storing them in a remote server for further studies. That means, MWS allows remote patient monitoring, via Internet, Intranet or mobile phone. This technology allows optimizing the monitoring cost in ICU.

KEYWORDS

Hospital Information Systems, Micro WEB-Server, Patient Monitoring, Remote Monitoring.

1. INTRODUCTION

Remote patient monitoring [1-4] has been considered, in specialized writings, as an irreversible trend. When it comes to intensive care units (ICU), difficulties increase due to the high cost of equipments necessary to proceed an efficient monitoring. As these equipments' functionalities get broader, their cost raise exponentially, making it hard for hospitals with fewer resources to use them. There is, therefore, a demand for lowering the monitoring cost, as the only way to guarantee most hospitals survival. Every hospital has presential monitoring equipments, which, in most cases, do not allow remote monitoring. This problem could be solved by adding this functionality to these equipments without having to acquire new ones. Another problem most ICU equipments present is to monitor the vital signals instantly only. Most of standardized monitors do not keep records of data; normally, the monitoring record is done with 1 hour intervals and manually. The doctor may lose information between these intervals. This functionality could be added to existing equipments. The proposed model provides these functionalities, concerning ICU patient remote monitoring and the amount of information available for the health professionals involved. And, most importantly, at an extremely low cost.

2. MICRO WEB-SERVER (MWS)

2.1 Why MWS?

Technology has allowed more and more innovative ideas in computing to come up, one of those ideas is the monitoring. Monitoring studies increase each day in different areas as air, land and water traffic; geology; climate; industry; laboratories and scientific research [7]. With Internet's popularity, the technology of Internet embedded systems has become a current trend for small Web Providers manufacturers, which will allow controlling and monitoring via Internet. Nowadays, equipments such as printers, routers, cameras, present this feature, which allows configuring status information and operations, as well as making them available [8]. There are several advantages in projecting and developing embedded Internet devices. One of them is to be able to remotely access the device and to have its use facilitated by Internet. A device using the Web has capabilities that wouldn't exist in an isolated device. Remote access allows failure detecting, firmware updating and device controlling that can result in maintenance cost reduction [6].

An area that uses technology to better perform monitoring is healthcare, specially in intensive care. Intensive Care Units (ICU) purpose is to keep patients alive. Back in the early 50's there was already the perception that it was necessary for physicians and nurses to observe patients closely, recording their physiological data manually from time to time [5]. Technology in general, as well as monitoring technology has come to give support and facilitate these professionals' work [9]. The monitoring of ICU has been improving, although many times with high cost solutions. In case of a centralized monitoring system, the investment is very high and it demands all the monitors should be manufactured by the same company. Concerned with the cost and flexibility, this work proposes a methodology that gathers together available tools and devices in order to optimize monitoring costs, and also making it easy to be implemented. Current ICU monitoring equipments usually display all the patients' data continually but those data are seldom recorded for further use because of expensive cost. So, monitored data are normally recorded manually each hour, and the data in between this records are lost together with, possibly, relevant information that could make the difference in diagnosis and follow up procedures. With Micro Web-Server, data are acquired in real time and stored in a more efficient and secure way, allowing both local and remote access.

2.2 What is MWS?

An important aspect in developing a device is the cost. With the use of solutions that offer free code and that can be taken to free operational systems it's possible to have a low cost device. To develop tools as Micro Web Server at a low cost and with high performance is the main objective of University of Santa Catarina Remote Experimentation Lab's (RExLab/UFSC). MWS presents the following characteristics: low cost, autonomous Web Server; low cost micro-controller with good AVR-RISC memory capacity of 8MHz; network Interface card (10baseT) interfaciable with available micro-controllers and drivers; TCP/IP pile and http Server (open code); additional code, data, HTML and image memory; CGI support, Java.

Figure 1. MWS

3. THE MODEL

Figure. 2 presents the system's general model. The proposed model provides the implementation of the access, via Internet, to the physiological data monitor information. This model characterizes a client/server application. In the server side - the ICU - each bed will have a MWS receiving the signals from the monitor that is connected to the patient through the sensors. The connection between the monitor and the MWS is made through a serial interface RS232C, common to both devices. MWS also presents a data communication interface, Ethernet 10BaseT standard, which allows an Internet connection. The client is simply any browser for Internet with Java support.

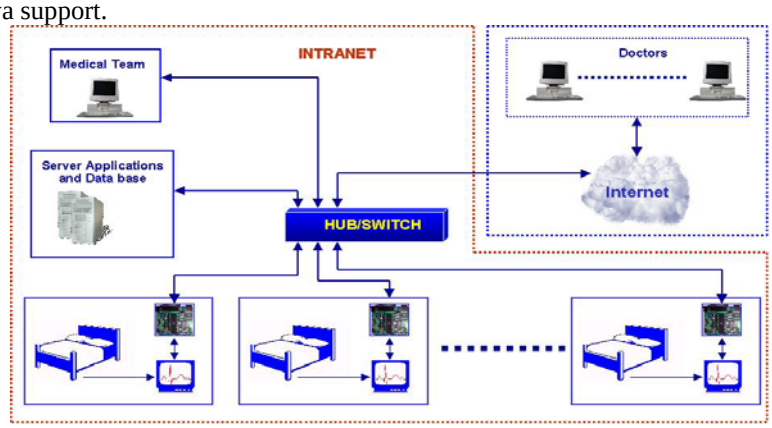

Figure 2. General view of the model

The client provides means to monitor and control the devices through an interface based on the WEB. The WEB and HTML pages provide the information and the basic browsing for this interface, although, it's the Java Applets embedded in these pages that allow the direct communication with the server, thus, the monitor controlling. This interaction with the server is implemented via CGI scripts executed in MWS. They contrast with ASP and PHP that are methods that provide dynamic WEB pages in large scale implementations. Body temperature, systolic and diastolic blood pressure, cardiac frequency and oxymetry are chosen to interpret and evaluate the patients condition: [11]-[14]. The received signals are compared to minimum and maximum value limits, when abnormal values are detected the alarm is triggered. Figure. 3 presents more details of the implemented model.

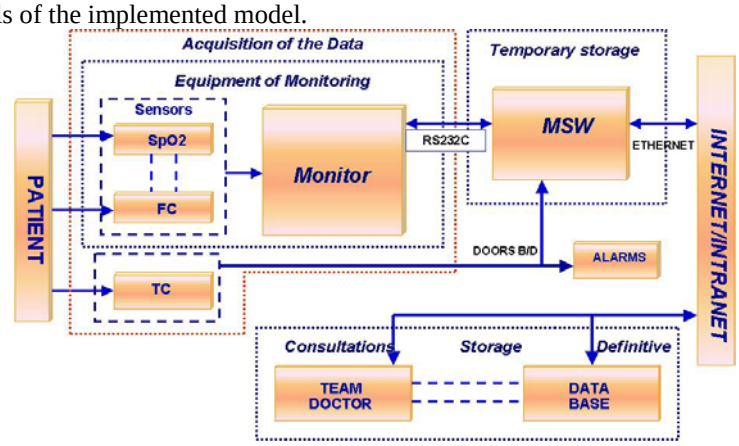

Figure 3. Some details of the model

The number of times the MWS alarm is triggered in a 24 hour period is recorded, besides the record of the monitor's own alarm. MWS alarm can inform the frequency of patient's vital signals abnormality, also, check on the monitor functioning, once unnecessary alarm sounding, when a patient is stable, is cause for a monitoring system verification. After the value comparison and alarm definition, MWS proceeds a data copy for each measurement moment. In order to do that, it's necessary to create an information record to store the patient's data. The system allows real time patient monitoring, implementing a 'virtual' monitor display

inside the browser. The patient's data storing will happen in a pre-determined time interval, making it possible to access and download the data stored in the monitor and allowing the construction of a trend graphic. Initially, a measurement in 15 minute intervals is enough, because, currently, as an ICU routine, the record is made manually in one hour intervals. The system will be flexible, it will also allow recording before the interval.

A copy of the patient's records is saved in MWS' memory and another one is sent to the local data Server. MWS keeps the last 24 hours information, the remaining information will be found in the local data Server, which can later be accessed. The Web remote access allows getting: 1) real time vital signal, 2) MWS's last 24 hours data and 3) local data Server. Remote access only allows data reading to authorized people who will sign up with a personal code and a login, preserving this way, the data integrity. MWS can be connected to monitors from different manufacturers with no compatibility restrictions.

4. PRESENT DEVELOPMENT

4.1. MWS Side

As mentioned before, the first WWW application of RExLab is to monitor the room temperature by a sensor, as it's already implemented so its use to monitor body temperature is easily adapted. For other physiological data which are taken from standard monitor, mainly those with serial interface RS232C, a communication protocol must be developed. For this purpose, an oxymetry monitor was chosen with objective of real time monitoring of blood hemoglobin saturation (SpO2) and pulse frequency, 2 of physiological data. SpO2 monitoring is necessary in a variety of clinical situations including respiratory therapy, anesthesia and its use in intensive care units including newborn and pediatrics ICU, all these can be remotely monitored with Micro WEB-Server, as it's shown in Figure. 4. Micro Web-Server proved to be versatile and easily adapted to different kinds of instruments; in this case, it was used to receive signals from a sensor and a monitor. A display to user, may be developed by any language, in our model, we used the Delphi to create the user interface.

Figure 4. Display of remote monitoring

4.2. Hospital Information System

The following stage of the development contemplated the implementation of the information system for data stockpile and treatment acquired by the oxymetry through the MWS originated from its files htm and routines cgi that stock the information in the MWS work memory and supply the information which fed the data-base, implemented with the Data Base (it was utilized the MySql). On the implemented model, the

client, through the browser, effects a call to a script CGI on the MWS through the HTTP protocol requesting patient's data, this call is implemented through an agent developed on the PHP language, which provides a dynamics interaction with the client initiating the acquisition process of the patient's vital signs with intervals of 5 minutes continually, stocking them in the data-base and afterwards making available these information to the users by visual and/or reports. The information system was implemented in PHP language (version 4.3.4) and the figure 5 presents the principal, denominated "index.php", which may be accessed from a URL, this page effects the users' authentication, with the objective of allowing access to the system only to the licensed users.

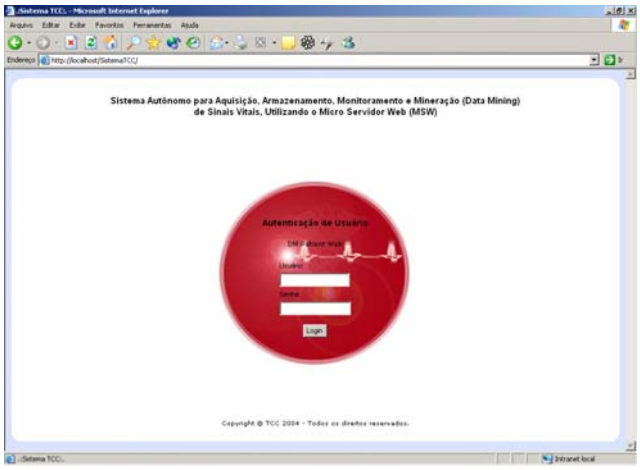

Figure 6. User's authentication System

After effecting the authentication with success, the user is connected in the main system denominated "Data Mining Patient Web" implemented in the file, denominated "php system", through a framesets structure containing heading.The system has diverse functions to obtaining not only information about the patient's clinic state as well to putting up useful information of the system maintenance, as the configuration modulus, where it is possible to gain entrance to patients, users, etc. On the configuration modulus it is possible to access new patients located on the hospital beds, declaring personal information by themselves. The patient will have to be accessed in the system for afterwards may be realized some evaluation about his clinic state. The system owns also configurations of menus, in which it is possible to insert a new menu informing data apt to itself, as well to alter it or exclude it from de data-base. And even, the system works with permission levels of users' access to the modulus, that consists basically on two definite levels as super user or administrator (level one) and the user (level two). The system administrator owns permissions to access every system modulus with no restriction, while the level two user suffers some limitations, being inhibited his access over all the system configuration modulus. The administrator owns even a tool denominated historic to control all the users' accesses realized up to that present moment. At the *user* modulus some information are presented about the user connected to the system bringing some statistics in regard to himself, like the last access date occurred and the total number of accesses. It puts up to the user the option of altering his password yet, if he desires. At the consultation modulus are sent out users and patients' reports accessed on the system for consultation or printing about them, and it will be able to export them to a kind of XLS archives. So, the user will be able to maintain the control of all patients' registers on the system.

The *graphic* modulus shows off diverse information in the sector graphic form (pizza) and bars to the user connected to the system. The graphics are up dated by each five minutes and on show to the user again. At the monitoring modulus, the system agent shows off the vital signs collected from the patients located on the beds. At this modulus, the user will be able to monitor his patient's vital signs collected through the last five minutes, that is to say, in real time. It shows off also information to the patient, like code, name, bed, date and probe status. The probe status will adopt 01 when the patient's vital signs were collected with success and 00 when it was not possible the acquisition. And the system informs to the user the agent's status which will assume always two positions: active or inactive, yet. The status presents itself active when the agent is realizing the collection of the vital signs, showing the " agent in execution" message, and inactive

when the agent did not get to realize the acquisition of the vital signs at the last five minutes, showing the "wait way agent" message to resume the collection. On the implemented system it was sought to conjugate the resources offered by the MWS supported by the Data Mining and that through the patients' data extracted from the data-base, disposed, to the health professionals, involved on the patient's treatment, a form of monitoring them constantly, even by long distance from their hospital beds.

5. CONCLUSION

The proposed system proved not only that its architecture, based on micro-controllers, is viable, but also that it's possible to produce flexible devices, of easy adaptation to the needs presented, with great quality and providing, as a consequence, the maximization of benefits at a low cost and with the advantage of providing support for multiple models or kinds of instruments.

Its application in ICU patients monitoring reduces functionalities implementation costs, as remote access to patients physiological data, alert system in case signals are out of limits considered normal for a certain kind of patient, besides data storing for further processing.

An advantage of the proposed model is that MWS can be connected to ordinary monitoring equipments using the signals they acquire, what means MWS only adds functionalities to the existing system, therefore, allowing cost reduction.

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