Extending the hospital to the patient’s home

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Abstract

Hospital beds are often occupied by patients that could be at home or in less equipped hospital wards when provided with suitable telemedicine equipment. Such telemedicine health system to prevail and become a reference must be modular to cover patients’ different needs, portable to be used at any place, easy to use so that there is no need for medical staff, affordable and compatible with the existing HIS.

This paper presents a patient centric healthcare platform based on a distributed system and on modular, multifunctional, low-cost acquisition units, called bedside units.

I Introduction

The cost of providing healthcare services to an ageing population and changing patterns of use of hospital resources (a rise in admissions but a fall in the average length of stay) is increasing [1]. A shifting in the focus of care from the hospital to the patients’ home is needed in order to reduce these costs and improve patient care freeing hospital resources [2].

To perform this shift the patient must be provided with portable equipment which can follow him everywhere with at an affordable price. This equipment must be integrated with the hospital network so that the medical staff can upload signal acquisitions into the HIS.

II System overview

Specification – Use cases

A functional tele healthcare platform must provide interaction between the patient and the medical staff. In order to achieve this there must be means to collect, process, store, made available to the medical staff the patients’ data. There is also the need to provide remote operability to provide to the medical staff the possibility of performing remote signal acquisition.

The UML model in Figure 1 shows the system use cases [3].

Figure 1 – System use cases

The start, stop signal acquisition and signal viewing to the Patient is provided with the bedside unit and its peripheral sensors, responsible for patients’ signal acquisition.

Medical staff has more needs than patients. Needs to search and view former patients’ signal acquisitions, needs to upload patients’ signal to a server in the Hospital network.

The system has to have storing functionalities and has to have a distributed architecture, to avoid network overload.

System architecture

Figure 2 – System architecture
The system architecture has two possible systems deployments (figure 2), one to support patients at home, the dark gray box, and another one to support patients at the hospital wards, the light gray box.

The bedside unit communicates with the Proxy PC through sockets over TCP/IP (Figure 3). At home the patient can establish the communication with the Proxy PC via modem and in the hospital wards via Ethernet. The Proxy PC and central server use IIOP protocol to communicate. The Hospital client unit or terminal accesses patients’ data with a web application or applet using either http requests or sockets.

All the communication protocol are TCP/IP based allowing the telecommunications technologies that work with it, such as Ethernet, Modem, ISDN, ADSL, Cable, GSM, GPRS, UMTS, etc.

**Signal acquisition**

For signal acquisition a box was built which incorporates a main processing module and the different peripheral sensors. This box called bedside unit (Figure 4) has outlets where the patient can plug-in the sensor cables to perform the different possible exams or to allow remote operation and monitoring to the medical staff.

The main processing module is based on one of the most popular handsets, the handheld computer. The choice fell on the Personal Digital Assistant (PDA) technology and on the Palm OS® operating system [4].

This beside unit was built based on the Handspring Visor deluxe with 8 MB of Ram, which is very compact, low cost and user friendly allowing a 190 minutes of exam recording.

Hardware development for this PDA it’s easier than others kinds of handsets because the interface with the PDA bus is open and all documentation is available on the Handspring web site [5].

The PDA acts as controller for the different sensors to it attached. This control is achieved using the I2C bus and its Master-Slave architecture. This bus allows the use of 10 sensors working at full rate.

This paper covers the current implementation which includes the vital signs acquisition module which includes sensors shown in Figure 5, ECG, SpO2, Temperature and Blood Pressure using the RS232 interface.

The bedside unit has different interfaces such as the modem or RS232 that support the connection to a remote computer for patients’ data transfer.

**Processing and storing**

To optimize the platform resources several levels of processing and storing were created. The first level is the bedside units which are responsible for acquiring and storing signal intervals relative to one patient. These units can operate on and off line allowing signal acquisition and transferring at different times or in real time for monitoring purposes. Since the bedside can only store a finite number of signal acquisitions (equivalent to 8 MB) it is necessary to create an intermediate level between this unit and the central system, the proxy PC.

The proxy PC is a PC within the Hospital network, responsible for collecting the patient’s data for 1 to n bedside units, as shown in Figure 2.
When the connection is established with the proxy PC it is possible to upload all the patients’ data already stored in the unit manually. The central server is responsible for collecting the patient’s data stored in the Proxy PCs. This data will be stored in the in the database.

**Accessing and operating**

The signal visualization and operation is provided at the bedside unit and at the web application which the medical staff can access from any computer with a browser installed.

1. **Bedside unit**
   The bedside unit viewing screen allows the patient or the medical personnel to view the signal information in real time that is being acquired from the patient and store in the bedside unit memory.

   Current implementation supports the simultaneous viewing of three signals (Figure 6) on the bedside unit screen.

   The bedside unit has three available operations, start signal acquisition, stop signal acquisition and signal upload to the Proxy PC.

2. **Web application**
   The web application has two components, one to access patients’ data and the other one to operate with the bedside unit.

   The bedside unit operation is provided through an applet that invokes the available CORBA [6] services at the Proxy PC, which perform operations on the bedside unit using sockets TCP/IP communication.

   Some of the available services at the Proxy PC are:

   - Signal acquisition listing, gives a list of all available data on a patient
   - Signal information, gives a complete information on the currently stored signals at the palm
   - Signal interval information, returns the desired signal for a certain period.
   - Signal remove, removes from the Palm memory the desired signals
   - Signal saving, uploads signal intervals to the Proxy PC.
   - Start acquisition, Starts signal acquisition for the specified sensors.
   - Stop Acquisition, Stops signal acquisition in the specified sensors.
   - Signal Information, Retrieves signal information concerning one specific patient.
   - List patients, List the patients stored in the Proxy PC disk.
   - Read signal, Retrieves the signal for a specific time interval from a specified start position and length.
   - Read signal interval, Retrieves the signal for a specific time interval.

   Some of these CORBA services don’t operate on the bedside unit but one the Proxy PC itself, providing access to patients’ data store on the disk. It is important to notice that it is transparent for the medical staff where patients’ data resides. When they request a list of the available signal intervals relative to a patient they don’t have to know if those signals are coming from the bedside unit or from the Proxy PC.

   The CORBA services provide the access to patients’ data to any client application and to other HIS through CORBA services.

**III Results**

The vital signs acquisition module was tested at the S. João Hospital at Oporto, more specific the ECG, SpO2 and temperature sensors [7].

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<tr>
<td>Temperature</td>
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Table 1 - Tests carried out

Although signals acquired had the quality expected by the medical staff the temperature sensor was measuring the temperature with two degrees below the real value due to the fact of not using a skin sensor.
IV Discussion

The bedside monitoring unit is a promising technique to enable more reliable and accurate diagnostics in some pathologies at the Hospital and more important at the patients’ home. At this stage we are only registering vital signs but our goal is to register other types of patient signs and to do pattern recognition, which will enable us to detect some know pathologies, such as cardiac arrhythmia, helping medical staff in their diagnostics.

The bedside unit is already very flexible and portable, but it is necessary to go further and include wireless devices and/or to make this box wearable, like an inlaid sensors T-shirt.

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VI References