An acquisition and management system for clinical data from Intensive Care Units for remotely controlling drug infusion pumps

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Abstract: - The main objective of Intensive Care Units is to stabilize patients in a critical condition. In doing so, specialist doctors administer different types of drugs. Their decisions are mainly based on the vital signs provided by different monitoring devices. Most of the drugs administered are given via infusion pumps located at the foot of each patient’s bed. The doctor has to constantly take vital decisions based on this information. This procedure suffers from a series of flaws that could be corrected: the human factor leads to errors occurring when making decisions, by not always taking into account all of the parameters that may be known; often there is not enough time to analyze the situation, due to factors such as stress and the number of cases to be treated; and it is not possible to continuously analyze and memorize all of the data generated, particularly when working with large numbers of patients. This paper describes a system that automates the acquisition of the most significant data provide by Philips monitors with RS232 ports (with MECIF protocol) and then stores it in a database. The information is provided for clinicians in real time through an integrated interface, allowing it to be managed. A remote control system has been programmed for managing the pumps that supply drugs. The system was developed and is currently being tested at the Anesthesia Unit of Meixoeiro Hospital in Vigo, Spain. It improves the medical assistance offered, as it records the progress of each patient, so that the specialist does not have to memorize this information, reducing the stress they are subject to when making decisions in relation to how to treat the patient. It also optimizes the specialist’s time, as it means they do not have to move between the different boxes to access the information being monitored, and order that drugs be supplied.

Key-Words: - Medical Informatics, Medical Control systems, ICU, Intensive Care Unit, Monitoring Systems, Philips Monitors, MECIF, Infusion Pumps

1 Introduction
When a patient enters an intensive care unit, their vital signs vary continuously, meaning that the doctor has to take decisions quickly and make frequent alterations to the dosage of drugs being supplied.

The care required by these patients requires the intervention of highly specialised health personnel, and particularly the continuous monitoring of the parameters on the monitors showing the patient’s condition, due to the serious condition of the patient and the important repercussions these drugs cause. New monitoring systems appear on the market practically on a daily basis, which incorporate new data so that specialist doctors have more and increasingly detailed information to help them in making their clinical decisions. This development means that monitoring is becoming increasingly complex, complete and less aggressive, adding larger amounts of information [1].
At the same time, there are constant improvements in systems for administering drugs, with the generalised use of programmable drug infusion pumps that may be controlled by computer [2] [3]. By having large amounts of data on the patient and more precise infusion pumps, the clinician personalises the treatment required by each patient by on their knowledge and experience gained during their studies and throughout their professional life [4].

This method has a series of pitfalls that may be corrected: the human factor leads to errors occurring in the decision taking process; sometimes not all of the parameters that may be known are taken into account; stress and the number of cases mean that often there is not enough time to analyse the case in detail; and it is not possible to continuously analyse all of the data generated, particularly when dealing with a large number of patients [5][6].

Commercial solutions do exist that integrate all of the data provided by equipment from the same manufacturer. The absence of open standards or protocols in this sector means that in most cases it is necessary to design ad-hoc solutions for each hospital [7].

2 Problem Formulation
Due to the high number of patients and to the great amount of information available the clinical personnel can be involved in very stressful situations. These situations can cause diagnostic failures because of they avoid an extrict pursuit of each patient.

We are in the presence of a situation where computer science can contribute with solutions.

3 Problem Solution
In this study, a system was developed for the acquisition of data provided by monitors at the ICU in the Meixoeiro Hospital in Vigo [8], Spain, for processing, and if considered necessary for intervening in the operation of the drug infusion pumps. This situation is always carried out under the supervision of a specialist. To do so, it is necessary:

a) To implement the communications protocol used by Philips CMS monitors [9]. Data is acquired in real time via the RS232 series port. The data defined by the experts includes: temperature, invasive arterial pressure, central venous pressure and cardiac output.

b) Remote control of the infusion pumps currently used at the ICU in Meixoeiro Hospital: Alaris MedicalSystem IVAC TIVA [10], via their RS232 ports. The implementation process must make it possible to easily change the pump being monitored. This means it must be easy to install a new implementation of the protocol.

c) To create a record of the progress of all of the patients dealt with at the hospital’s ICUs, making it possible to define diagnostic algorithms based on data, and to use data for the retrospective study of situations, recording data in situations with complications, etcetera.

3.1 Architecture
The system is divided into four modules with independent functions, which exchange information.

- **Communication module** Responsible for handling communications via the communications hardware in each device.

- **Acquisition module** Responsible for acquiring the different medical parameters from the patient, connected with a monitor recording vital signs.

- **Control module** Responsible for permitting access to the infusion pumps in order to control the patient’s condition, increasing or decreasing the dosage of drugs injected per time unit into the patient (in this case always via the RS232)

- **Integration module** Provides joint access to other modules and records the information in a database. Responsible for the integration of the other modules for simple, transparent use.

![System Architecture](image-url)
system. These changes in treatment must always be supervised by a specialist, and never automatically.

3.2 Materials
The following tools were used for programming the system:
- PC equipment for development and testing. This included all of the tools necessary for implementing the modules.
- Virtual Java machine with support for Java 5.0 [11]
- PostGreSQL 8.1 Data Base Management System [12]
- Libraries necessary for controlling the serial ports (javax.comm) [13]
- Eclipse 3.1 development environment [14]
- Due to a lack of series ports on the laptop used, COM (Serial Port) to USB (Universal Standard Bus) adaptors were used, in order to have the necessary number of ports required for testing.

3.3 Implantation process
The system was installed at the ICU of the Meixoeiro Hospital in Vigo, Spain, where the operational tests were carried out.

3.3.1 Communication and Acquisition Modules
A graphic interface was created, making it possible to request any type of data available via the monitor and show its values. Figure 2 shows a screen capture from the interface. The trials carried out were successful as the data was acquired without problems, and the MECIF messages from the Philips CMS monitors were translated correctly. Each data message carries one or more recording with information. In this example, the PRES 1 parameter was captured, corresponding to arterial pressure. Three basic values are shown (the first three) corresponding to systolic, diastolic and average pressure. These are the values monitored on the screen. Other values are then shown, corresponding to alarm limits and safety ranges.

![Fig 2. Screen shot of tests carried out with the acquisition system](image1)

3.3.2 Control Module
Different remote control tests were carried out using an Alaris IVAC TIVA pump. The system offers full control over the pump (Fig 3): information on the status, activation, halting and change of infusion speed for the drugs administered. Also, the changes that occur in the pump that are made directly and not via the system are detected and stored: for example, if a nurse makes any change to a pump directly. All of these changes, both manual and using the system, are recorded in the database. These changes are assigned to two dates. This makes it possible to...
know for how long the change was active. This information was also included in the system for helping to take decisions, so that it is possible to know the real change made after a proposal for change. As a result, all of the information interrelated in terms of time is obtained.

3.3.3 Integration Module

The system stores the data in a database and informs the user of the patient’s condition on-line, making it possible to operate the pumps remotely. Figure 4 shows the system interface. At the top are the data monitored, in the middle is the interface for controlling the pumps, and at the bottom is a graph showing the progress of pump operations.

![Figure 4](image)

Fig. 4 Application interface with the integration of all modules.

4 Conclusion

An application has been designed and implemented that makes it possible to acquire data from Philips CMS monitors using the MECIF protocol; a data model has been created supporting the storage of this information, and a remote control system for drug infusion pumps.

A solution organised in independent modules working in an integrated manner has been defined. An acquisition module (Acquisition) has been designed, making it possible to request information on any parameter the monitor is capable of capturing. A generic definition has been made so that clients do not depend on the implementation made for a specific device, allowing synchronous and asynchronous interaction between this module and its clients. A communications module, Communication, was implemented to support transmissions via the R232 series port in a transparent manner to the acquisition module.

The module for controlling drug infusion, Control, allows full interaction with the infusion pump. Generic definitions have been constructed that isolate the client from the specific implementation, and therefore from the specific infusion device. It also makes it possible to know the status of the pump at any given time.

The integration module, DataProcess, makes it possible to use the two previous modules jointly in a simple, transparent manner. This subsystem, which provides the basic functions for controlling the infusion process and acquisition of data, is responsible for storing all of the data received from the acquisition module and all of the significant events that occur in the control module in a database. This means that not only is the patient’s progress constantly stored, but also the operations of the infusion pumps that bring about this progress. Naturally, the functions were defined generically, disconnecting the system’s clients from its implementation.

A platform has been designed for the development of a system to help in the decision-taking process in an environment as complicated as an ICU. This makes it possible to improve the health assistance provided, by offering the specialist a new tool that optimises the management of the information necessary for taking medical decisions.

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