Physiological Data Stream from Monitoring System in Intensive Care Unit

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Abstract. In this paper, we propose a new system that takes profits of data stream technology. It aims to collect and store data arriving from monitoring system in intensive care unit (ICU). Then, it makes it available for the medical staff to analyze data and take the appropriate treatment for patients. In fact, monitoring system in ICU provides a large amount of data rapidly and continuously. Most of devices work with a very limited storage capacity which can make data available for only a limited time. To avoid loosing data, medical staff takes note from monitoring devices each time interval then, stores it using computer. However, the decisions taken by doctors can be influenced by the level of consistency of the collected data. In some cases, these decisions can be inaccurate especially if important information are not saved and ignored. Our proposed system improves the quality of monitoring by processing the monitor data at real time. It collects and stores all data reported from the monitoring devices avoiding the loss of important information. The new system will make data available for medical staff in order to provide a better care for patients.

Keywords: Monitoring system, intensive care units, data stream, labview

1 Introduction

Medical informatics is attracting many attentions due to the growth of technologies and the large amount and complexity of data [13]. In order to extract important and significant information from patients, various medical tools have been used. We can mention the sensors and networks of health information systems which produce speed and continuous flows of data. Unfortunately, these high flows of data are difficult to store, manipulate, and analyze. Besides, having real data extracted from patients is essential to develop intelligent monitoring algorithms. Such medical data translate real knowledge that can be used to evaluate monitoring models.

To improve medical service quality in intensive care unit (ICU), new technologies using computers were widely used. ICU is a data-intensive environment. It has a large amount of continuous data produced by monitoring devices. Medical data stream is the result of the measure of pathology values of a monitored patient such as blood pressure, heart rate, and pressure rate.
However, the majority of devices work without memory or used relational database [17]. We can mention the multi-parameter monitoring system which is not competent for managing the large amount of continuous monitoring data. Besides, doctors have to rewrite data using another system which delay the appropriate decisions at real time. In addition, to make ideal decisions, we need a high quality and precise data.

New solutions are needed to manage, process the continuous flow of information, and provide efficient and reliable decision support tools. The wide use of such monitoring devices in ICUs aims to allow physicians to be more alerted of the state of their patients. Thus, the medical staff needs a new system that guarantees a continuous monitoring of patient. In order to provide a better way for data stream management and to improve the data quality, we have integrated a data stream technology to collect and store data from monitoring system. Besides, the new monitoring system will help the medical staff in their works by providing better care to patients from any place and at any time [15].

The majority of collected data by the existing monitoring systems is dropped and lost forever after being stored locally for only some hours at the monitoring devices [16]. By applying real time analytics on physiological data collected and storied from monitoring devices, our proposal overcomes the limits of the current systems. Moreover, it offers to the medical staff electronic medical records and efficient patient management.

The rest of the paper is structured as follows: Section 2 gives an overview of the monitoring system and describes the structure of data in ICU. Section 3 explains the data stream technology. Section 4 presents with details our proposed system that manages the monitored data using data stream technology. Section 5 reports the experiments. Section 6 concludes the paper.

2 Monitoring System and Data in ICU

Patients' monitoring systems represent all various devices used to supervise patients. The first primitive of monitoring patients started with the work done by Santorio in 1625 that was measuring the body temperature and blood pressure [7]. Today, monitoring patients become an important point displaying data. Data generated by monitoring devices are characterized by being continuous, multiple, and arriving rapidly. However, the majority of these monitoring systems have not enough memory capacity to save continuously measured data and to collect stream data each time. This problem of memory capacity [14] makes

the storage and interpretation of data more difficult and complicate. There are many proposed works that have tried to improve the current monitoring system. We can mention the digital signal processing [5] where authors presented a clinical validation study for two recently developed on-line signal filters, the trend extraction methodology [2], [6] expressing the time evolution of a signal, the monitoring systems based on machine learning techniques [1], [3] that aim to detect the normal and critical states of patients.

Today, medical staff needs to collect important data to make the best decision and give the appropriate drug.
Based on a study made in [4], 13% of the total information used by doctors in the treatment of patients are taken from monitoring system. This latter helps doctors to take their decisions. This fact proves the need of these information and their importance when making decisions at real time.

The main problem of the current monitoring system is the risk of losing important information when not all data are stored. The main cause of this risk is the collection of data each time interval and not continuously [10]. Missing data reporting critical states of patients in ICU can cause serious problems and make the doctor's decision inaccurate. It can even threat the patient life when not taking the necessarily treatment.

In addition, the monitoring system has to allow the medical staff to be mobile [11]. Doctors should measure and collect data at any time without losing any important information relative to the patient states. Besides, they could have all the current charts and data ready.

In order to avoid these issues, the monitoring system has to be improved. To this end, we propose a new system based on data stream technology. This latter makes it possible to collect, store, and represent measured data as long as the doctors need them. The following section describes this technology.

3 Data Stream Technology

Since 1970, the innovations made on the management systems to improve the storage and manipulation of databases have not been stopped. Now, we have a new mode of data which is the dynamic (stream) data [9]. Compared to static data, the stream data is very large and continuously in time. Data stream technology is needed in many fields. As follows a brief description of data stream technology developed using the software labview (LABoratory Virtual Instrumentation Engineering Workbench).

To collect, store and analyze the produced data, we have used a powerful tool which consists of the software labview [12]. From the main advantages of this software, we can mention its ability to communicate with different brands

of bedside monitors and obtain physiological data.

labview is used as an integrating platform for the acquisition, processing and transmitting of the physiological data. Actually, this software presents an excellent graphical programming environment to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. The software also includes number of advanced mathematics blocks for functions such as integration, filter, and other specialized capabilities. labview professional development system allows creating stand-alone executables. The resultant executable can be distributed an unlimited number of times. The run-time engine and its libraries can be provided freely along with the executable.

Therefore, by using it in our system, labview software allows the collect of data from monitoring devices and considers all measured medical parameters.

4 Monitor Data Management in ICU Based on Data Stream Technology

Our main interest in this paper is to overcome the numerous issues of the current monitoring system. In fact, our new system stores all data that are directly collected from monitoring devices. We need physiological measurements or signals provided after the monitoring of patients. We need to know what is going on with the patient when these measurements become available. Thus, data sets containing all and high quality of patients data are the key of the development of intelligent patient monitoring systems.

In real-world, each monitoring system has its own platform, operating system, and network. We have focused on a specific type of monitoring system. It is IntelliVue MP60/MP70, it was manufactured by Philips brand.
In addition to design and develop our new system, we have collaborated with a public pediatric hospital Bechir Hamza in Tunisia.
l Our intelligent monitoring system based on data stream technology will facilitate the doctor tasks (i.e. the treatment of the collected data and making the right decisions). Our proposed system has enough computational power to receive data, store them into databases, and then simultaneously analyze them. Our system is divided into three main functions detailed in Fig. 1. They consist of the physiological data collection, the recording data, and the data presentation. We detail these functions in the following subsections.

4.1 Data Acquisition

Data acquisition is an essential step in the development and evaluation of patient monitoring system. This function takes as input analogical signal relative to patient generated by monitoring devices. Then, it converts them to numerical data. After this step, data become ready to be store in structured databases.

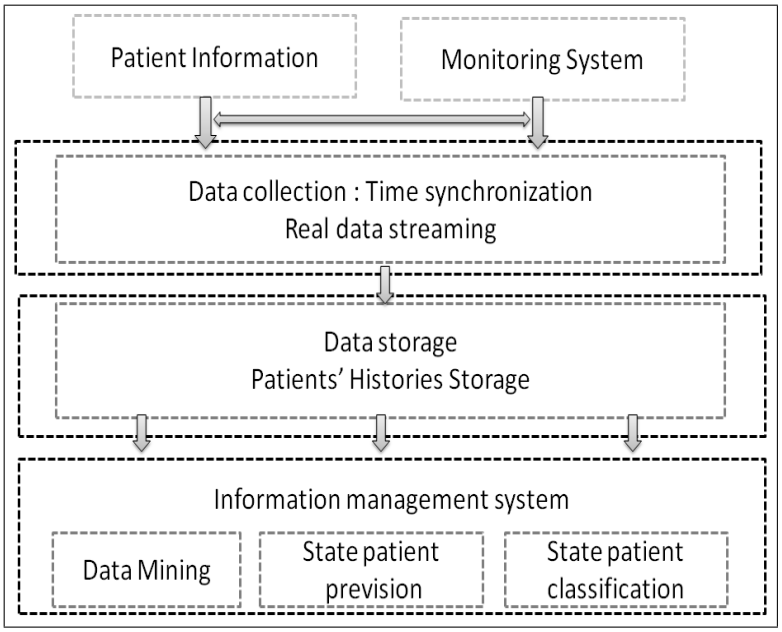

Fig. 1. The main structure of the proposed system

There are two possibilities to acquire data. The first one consists of the transfer of data from a file from Multi-parameter Intelligent Monitoring for Intensive Care (MIMICII) database [8]. This latter has been used for the test of our proposed system. The second possibility is to sample data and acquire them by a programmable hardware. We have developed a method that assures the sampling and the acquisition of data in order to evaluate our system and test it in hospitals.

The acquired signals are made available by the Data AcQuisition (DAQ) user interface in labview for further analysis that can be designed in the block diagram panel. Fig. 2 shows a block diagram of data acquisition module generated by labview.

4.2 Data Recording

The database is designed using Oracle Stream which is one from the most powerful databases management system (DBMS). By configuring specific capabilities of Oracle Streams, it can automatically propagate the information to other databases or applications. Fig. 3 shows the connection made between labview and Oracle Stream.

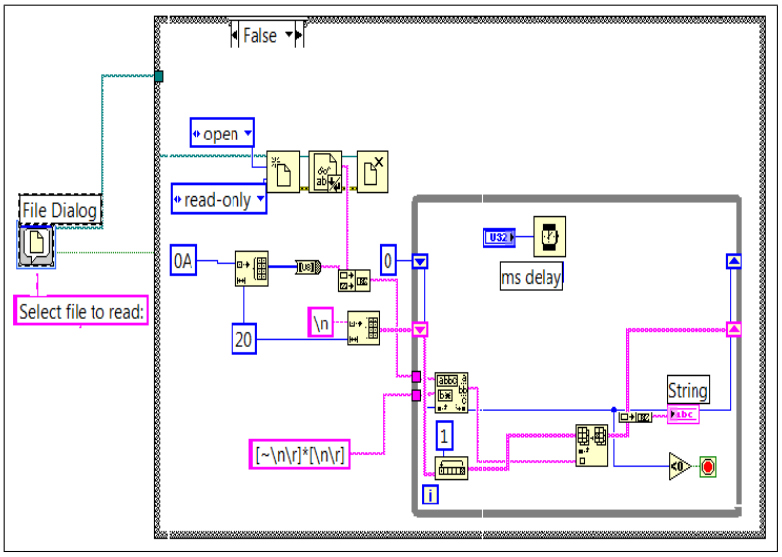

Fig. 2. Synchronization and collection of physiological data from monitoring system

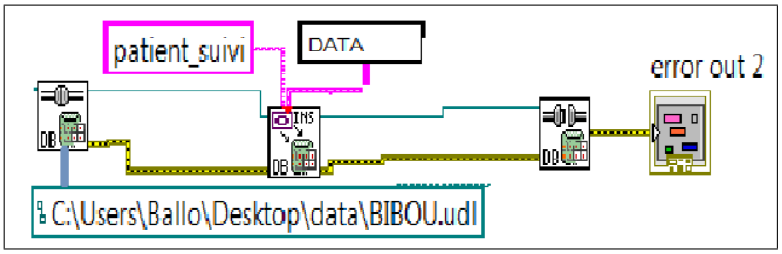

Fig. 3. Data storage

4.3 Data Presentation

We use the report generation toolkit available in labview. It is a real time patient record containing basic patient information such as name, age, gender and clinical information such as temperature, spo2, and heart rate.
Fig. 4 shows the report and the chart generated by our new system. We can consult and analyze this output from any computer and at any time.

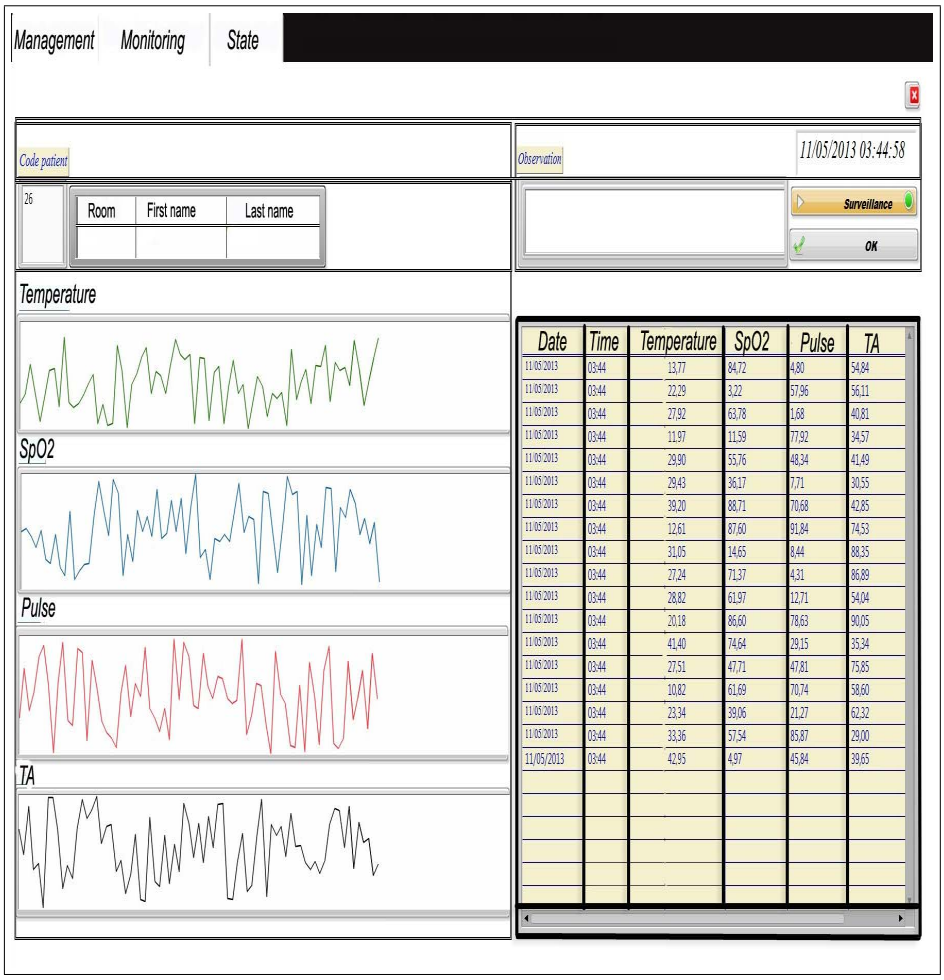

Fig. 4. Data presentation

5 Experiments

5.1 The Framework

The system is tested using real data from MIMICII database taken from Physiobank [8]. This database contains data from hemo-dynamically unstable patients hospitalized in 1996 in ICU of the cardiology division in the Teaching Hospital of Harvard Medical School.

Table 1 details the used real-world databases, where #Attributes and #Instances denote respectively the total number of measured parameters and the total number of instances for a specific database.

Table 1. Description of the used data sets

Databases	**#Attributes**	**#Instances**
Patient 01	6	4101
patient 02	8	42188
patient 03	8	42188
patient 04	7	42188
patient 05	9	42188
patient 06	9	5350
patient 07	7	11300
patient 08	7	10600
patient 09	12	5700
patient 10	5	42188
patient 11	7	42188
patient 12	7	42188
patient 13	9	42188
patient 14	7	42188

Different patients were monitored for different sets of physiological parameters. Some parameters, such as heart rate, were measured in every patient, while others were measured only in some patients. Table 2 lists the monitored parameters according to how frequently they were measured.

Table 2. The monitored parameters

Parameters	Acronyms
Heart Rate	HR
Oxygen Saturation	SpO2
Non-Invasive Blood Pressure	NBP
Respiratory Rate	RESP
Artery Blood Pressure	APB
Pulmonary Artery Pressure	PAP

To configure, acquire and store data from devices, we have used labview software [8] which is very powerful when it is used for the acquisition of data using DAQ (Data AcQuisition) applications. DAQ hardware acts as the interface between the computer and the monitor. Its principal function consists of converting analog signals to digital signal so that the computer can interpret them.

We have used labview to realize the following functions in our system.

- Acquiring signals from real-world (using monitoring system).
- Digitizing the signals.
- Analyzing, presenting, and saving data.

Fig. 5 describes these main functions proposed by the software labview.

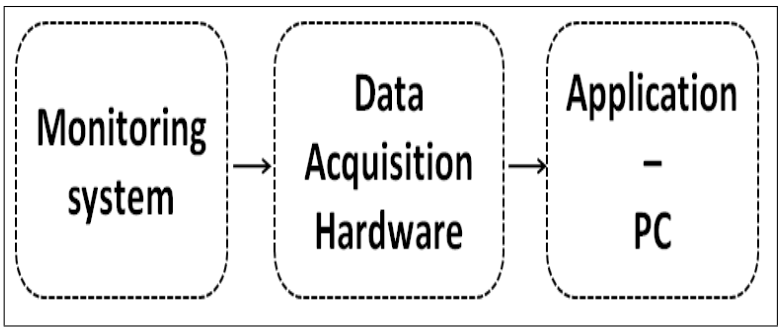

Fig. 5. Signal flow chart of DAQ system

5.2 Discussion

The proposed monitoring system provides many advantages and improvements in intensive care unit. On one hand, it allows the acquisition of large amount of data stream and hence, important knowledge relative to the patients' states. It also guarantees the storage of data coming continuously and rapidly from the medical devices to well describe the monitored parameters. On the other hand, the proposed system offers the possibility to better analyze the measured parameters and to specify the need of each patient. As a results, our proposal is considered as a very suitable system in nursing centers and hospitals and it can even replace the medical staff. In addition, the new system provides better health care to people at any time and anywhere.

Furthermore, by using the high technology in the software labview, our new system is able to easily connect to another monitor system. To test and prove the performance gain of our proposal, we have collaborated with pediatric hospital Bechir Hamza in Tunisia. Our system is connected to the current monitoring system and it is under evaluation. It collect data from the monitoring system, store them, and represent medical parameters using numerical and graphical models.

Using this system, we are able to collect a set of annotated physiological data with more certainty in data correlation than previous studies. Besides, it can be easily backed up or restored. The data storage format also allows an easy access during both prospective and retrospective data analysis. In addition, a printable patient report describing the patient state with details can be generated at any time when it is needed.

To conclude, our proposed monitoring system takes advantages of data stream technology and offers important services to medical staff. It is characterized by providing measured data (medical parameters) when it is needed by doctors which facilitates making right decision. In addition, medical staff can easily find medical records of patient. There are no loss or change of medical information. Furthermore, there is no waste of time, a life of patient can depend on the time of taking drugs. As a result, any needed information about a monitored patient should be available at real time. This is what the proposed system guarantees. Besides, it allows doctors to read and interpret medical data once they find them in the new system.

6 Conclusion

In this paper, we have proposed a new patient monitoring system able to acquire, store and present data to medical staff.
This system is able to independently operate and it can replace, in some cases, the medical staff in nursing centers. Besides, it provides a good environment

for the patients by offering an efficient monitoring and the adequate treatment. These improvements made in the monitoring system prove the ability of the data stream technology to handle real and large data. We can conclude that data stream technology can help medical staff to easily work in order to take the best decision at the best time.

As future work, our aim is to use a predefined query to plot chart and give information to medical staff in time. Besides, joining many devices in the same time, for example, the patient monitoring system and the ventilator, can be realized.

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