monitoring, pulse oxymetry, streams

Michał WIDERA*, Adam MATONIA*, Janusz WRÓBEL*,
Janusz JEŻEWSKI*, Krzysztof HOROBA*, Tomasz KUPKA*

NEONATAL SURVEILLANCE SYSTEM BASED ON DATA STREAM TECHNOLOGY

Pulse oximetry is a non-invasive measurement method of an arterial blood oxygen saturation. Pulse oximeter is one of the main bedside monitors used in neonatal units. The dispersed location of medical devices in such unit renders impossible to make a fast and valid decision in the case of simultaneous alarming situation. This paper present hardware and software structure of centralised neonatal monitoring system. Presented system can work as a single central station for monitoring of up to twenty four patients. Application of central monitoring system decreases the risk of undetected patients live and health threats. Thanks to this system the medical stuff is less burdened by routine procedures; therefore the medical unit is perceived as child- and mother-friendly.

1. INTRODUCTION

Central monitoring has become the standard approach to patient's monitoring in modern medicine. It is widely applied where longitudinal and simultaneous monitoring of many patients is required e.g. in operating room or in intensive care unit (ICU). Central monitoring system can be defined as a set of medical devices at the patient's bedside which provides data to the central monitoring computer.

Pulse oximetry is commonly used as a measure of arterial blood oxygen saturation (SaO_2). This is a non-invasive continuous method of measurement. When saturation falls below a certain threshold, an alarm is sounded. This alarm unambiguously means that the patient state has changed or that the instrument has become detached or dysfunctional. In any case, definite action can be taken at once. Pulse oximeter is the main bedside monitor used in neonatal intensive care unit (NICU) [1]. Continuous monitoring of each device parameters and reaction to accidental and disappearing information is extremely burdensome. The dispersed location of medical devices renders impossible to make a fast and valid decision in the case of simultaneous alarming situation on several monitors. The tasks of computer-aided neonatal monitoring system are: analysis of incoming data, dynamic presentation of traces along with analysis results as well as storing and printing the data. The centralized monitoring system provides much more information than conventional pulse oximeter. It allows easy and fast access to archive records and convenient observation of their longitudinal changes. The hardware structure of monitoring system is presented on Figure 1.

* Institute of Medical Technology and Equipment, 118 Roosevelt St, 41-800 Zabrze, POLAND,
tel./fax: (32) 2716013/2712312, e-mail: michal@widera.int.pl

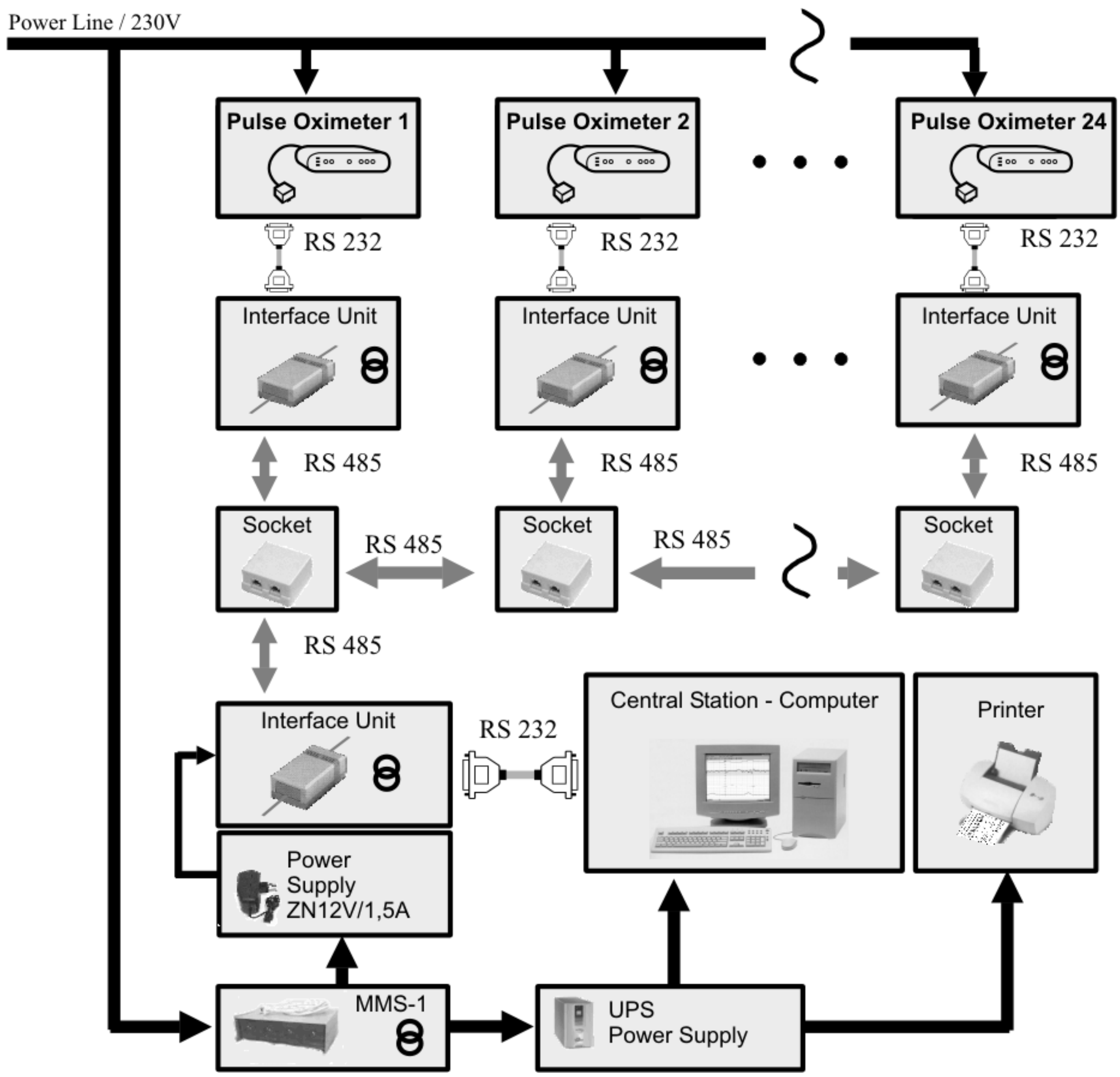

Fig. 1. Hardware structure of neonatal monitoring system

In the centralized neonatal monitoring system the Novametrix Oxypleth 520A pulse oximeter is an input device which enables oxygen saturation level and heart rate information to be accessed by a computer. However, connection of pulse oximeter monitors set to the system encounters a few serious software and hardware problems. In this paper, we would like to present our approach to development of monitoring system that provides high quality of patient's care in NICU environment.

2. SYSTEM HARDWARE STRUCTURE

The system can work as a single central station for monitoring of up to twenty four patients. Optional terminals can be used to access the archive data at any time independently from monitoring. Each pulse oximeter is connected to interface unit that accepts digital serial link. Interface unit assures the patient's safety complying with international standards for medical equipment. Access of several monitors to one RS232 connector of the computer is enabled by the data collection unit that multiplexes bedside monitors. Data collection unit is transparent for the data from monitors. Each interface unit with associated fetal monitor is identified by its unique number. This number is used by the data collection unit that periodically sends permission for transmission to consecutive monitors. The sockets for monitor connection are located within a neonatal department. Data transmission link between interface unit and data collection unit is going trough the RS485. The data collection unit and computer are connected via RS232 link. It ensures the reliable transmission on long distances and simplifies system wiring.

Incoming data are dynamically presented on the screen and analysed on-line. Received data are stored in a system database. The database includes patient's personal data, monitoring logs, results of analysis; parameters of alerting events and of course the traces.

2.1. INTERFACE UNIT

In practical application, every model of fetal monitor needs its own dedicated interface unit. We have developed unit that contains several modules. The interface unit is based on Atmel ATmega 128 microcontroller which supports interrupt controller and communications ports. Internal RAM of 128kB capacity is enough for implementation of communication procedures. The data block length is 43 bytes. Its structure is based on HP Series 50 data block and contains samples of all signals measured in 1 sec period. (i.e. Plethysmogram, values of Pulse Rate and Oxygen Saturation). Information of the pulse oximeter serial number is included in the data block. The interface unit (Fig. 2) collects data from pulse oximeters according to the data transmission protocol. The number of monitors connected and established data block length define the minimum value of transmission baud rate. We established transmission speed at 19200 baud which is enough to get data from up to 24 pulse oximeters connected to the computer simultaneously. The control program of ATmega 128 microcontroller was designed in C programming language.

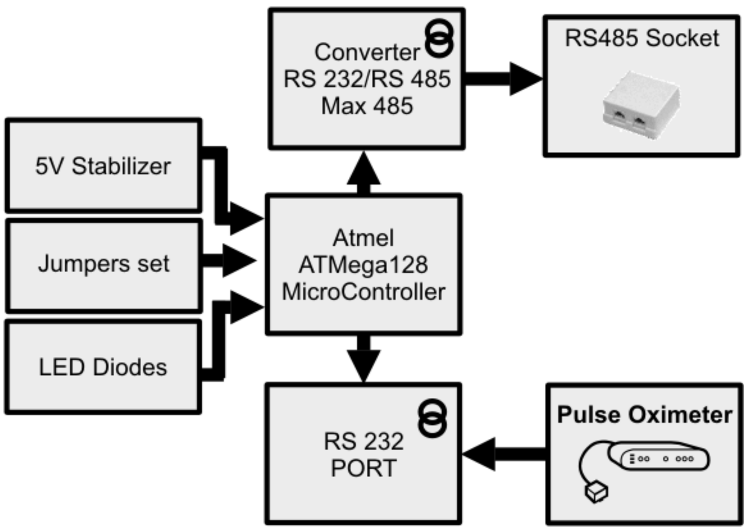

Fig. 2. Hardware structure of interface unit

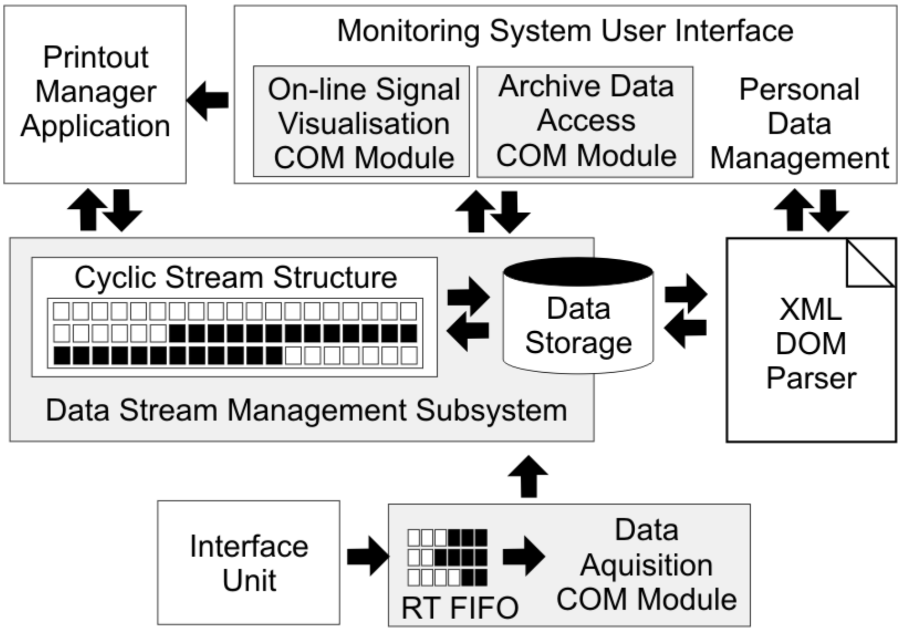

Fig. 3. Software architecture of centralized neonatal monitoring system

3. SYSTEM SOFTWARE ARCHITECTURE

The most important function of medical monitoring systems is the real-time processing and recording of the biomedical signals. A system that provides a response within a time frame specified in advance is defined as a real-time system. In practice, such systems are built on the basis of an engineering assumption of deals with "sufficient resources on the stock". It should be pointed that real-time requirements are necessary in the monitoring system responsible for the human functions maintenance, especially newborns.

The system is designed for Microsoft Windows XP and was developed in Visual C++ Environment. The modular system architecture is seamlessly supported by Component Object Model (COM) and was developed with the help of Active Template Library (ATL). Almost all components maintain own thread and resource space. System collects incoming digital signals in Real Time FIFO Buffers (Fig. 3, RT FIFO). The RF FIFO buffers are placed in Data Acquisition COM Module. Such solution fulfils the real-time monitoring system requirements. Next, data are transported into Data Stream Management Monitoring Subsystem (Fig. 3) [5]. This subsystem contains parts of developed Standalone Data Stream Management System [2,3]. Each recorded signal is paced in Cyclic Stream Structure (Fig. 3, CSS). The CSS is a cyclic buffer that contains data from tree days. The older, archive data are destroyed. Data in these structures are periodically synchronized with disk data storage. The method of proper synchronization and data set consistency insurance has been developed [2]. The Monitoring System User Interface was designed with the help of Microsoft Foundation Classes (MFC). All visual COM components are managed by one standalone application. This application maintains patient's personal data. Data are stored in XML data file. The XML file is managed by built-in Document Object Model (DOM) Parser – MSXML (Fig. 3). Beside patient's data this document supports configuration properties and information about on-line data and physical locations of archive stream on disk.

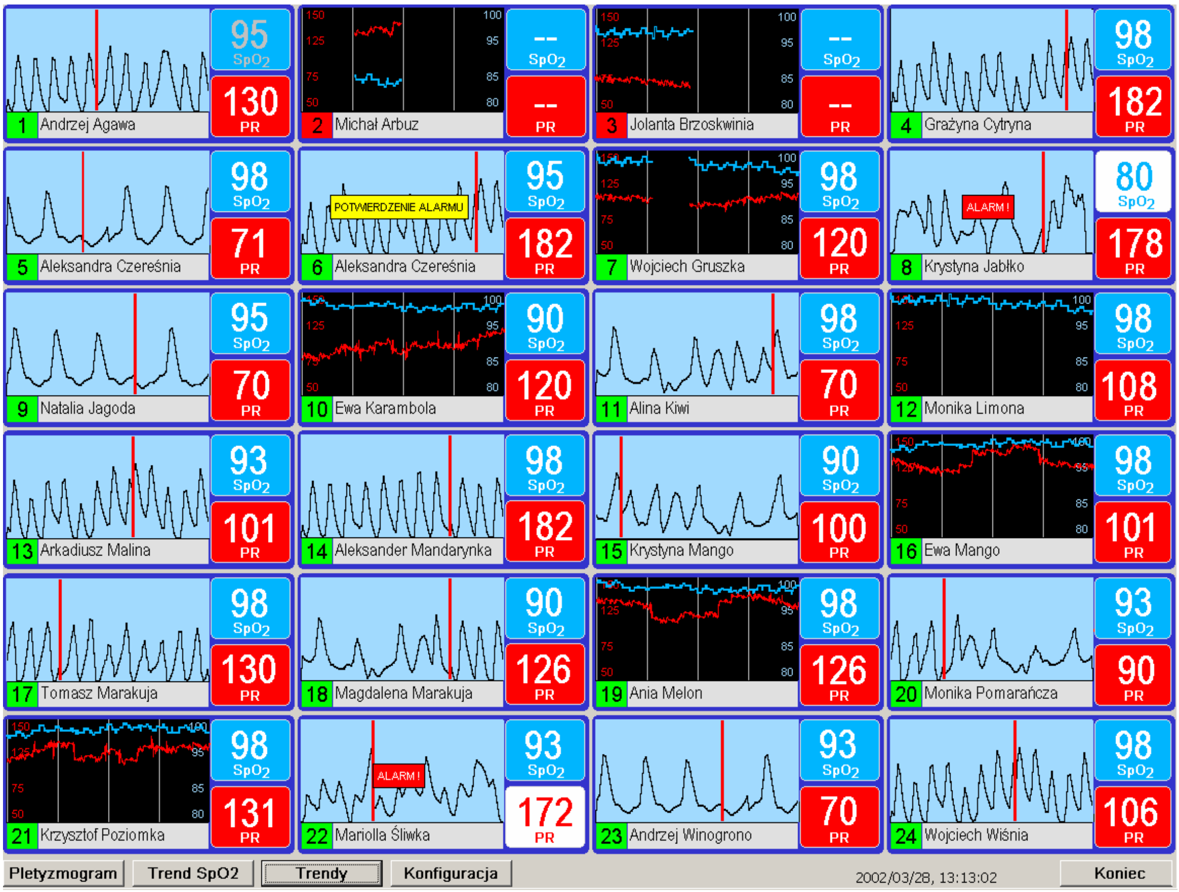

Fig. 4. The main screen of central monitoring station presents 24 monitors

3.1. USER INTERFACE

User Interface Modules enables on-line signals and trends. A part of signal that is not older than 3 days can be archived. The Archive Data Access COM Module supports visual management of on-line and archive information. Information about each archive record has a tag in XML document. On-line Signal Visualisation COM Module is a main visual element of user interface. A set of Signal Visualisation COM Modules create the main screen of central monitoring station (Fig. 4). Each module presents similar colours and views as presented by bedside monitors. Each module can present Plethysmogram and trends of Pulse Rate and Oxygen Saturation. The layout and ratio of information presented on both the monitor and central computer station is identical. In prototype version each module has own thread. This causes that 24 bedside monitors create 24 additional simultaneous threads. Such solution as this turned out ineffective. Therefore we sequentially push each module by central timer. This makes possible to achieve 5-6% processor usage level in normal work of application mode. The User Interface Application controls the Printout Manager Application. This is the standalone application that enables functionality of data printing. This application communicates with data set with the help of procedures of Data Stream Management Subsystem.

One of the main advantages of the system presented is its maintenance simplicity. For the user convenience all possible settings are placed together in one dialog. The functions of individual monitors are called by context menu. The crossing of alarming thresholds is signalized by audible and visual signals. As a simplification, we have introduced a possibility of defined preset alarms set. For instance: standard set or set for newborns feed by additional oxygen. Apart from so-called critical alarm, system submits technical alarms. These are device depended alarms, e.g. wrong sensor position. Each alarm requested by the system needs a personnel acceptance. The visual and audible methods of alarming were consulted with NICU staff and with the use of referenced medical technology standards.

4. CONCLUSIONS

Application of central monitoring system decreases the risk of undetected threats to patients' life and health. Thanks to this system the medical stuff is less burdened by routine procedures; therefore the NICU is perceived as child- and mother-friendly.

Developed system for the centralized monitoring of a neonatal condition based on pulse oximetry signal initiates a new method in neonatal monitoring field. During its development, a few novel methods of monitoring system design have been accomplished. The most important ones are as follows: Application of data stream processing model in physical system and application of multilayer structure of monitoring system. The methods specified have enabled the considerable improvement of system development techniques in relation to previously used methods [4].

The most important function of medical monitoring systems is the real-time processing and recording of the biomedical signals. Presented system has fulfilled real-time requirements. Additionally provides much more information than conventional pulse oximeter, allows easy and fast access to archival records and convenient observation of their longitudinal changes.

BIBLIOGRAPHY

[1] LAING I.A., GRIEVE S.H. ,TARVET F., LOGIE L.J.: Pulse oximetry in newborn intensive care, IEE Colloquium on Pulse Oximetry: A Critical Appraisal, vol. 8, pp.1-3, 1996

[2] WIDERA M., WRÓBEL J., WIDERA A., MATONIA A.: A method of the ensuring data integrity in the data stream management system, Journal of Medical Informatics & Technologies vol.8, pp.141-148, 2004

[3] WIDERA M. , JEŻEWSKI J. , WINIARCZYK R. , WRÓBEL J. , HOROBA K. , GACEK A. : Data stream processing in fetal monitoring system: I. Algebra and query language, Journal of Medical Informatics & Technologies, vol.5, pp.83-90, 2003

[4] WROBEL J., JEZEWSKI J., HOROBA K., GACEK A., GRACZYK S. (1998): System for centralized fetal monitoring, Proc. of the 2nd IMACS CESA '98, pp.772-775, 1998

[5] L. GOLAB, M.T. OZSU: Issues in data stream management, ACM SIGMOD Record vol.32, pp.5-14, 2003

This study is financed by the State Committee for Scientific Research resources in 2003-2005 years as a research project KBN Grant No. 4 T11F 002 25. Adam Matonia is a fellowship holder of the Foundation for Polish Science.