A Medical Wearable Device with Wireless Bluetooth-based Data Transmission

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Abstract. *A medical wearable device has been developed within a project co-funded by the European Community (Karma2 – IST 2001-32320), whose aim is to create a network for the management of Home Care activities in brain-injured children. The device can measure the blood oxygen saturation, the heart rate, the respiration rate and the patient's quantity of movement. Measured data are stored into a Multimedia Card, and then transmitted to a PC at prescribed time intervals through Bluetooth wireless radio-communication technology. From the PC the measured data are finally transmitted through Internet to a Service Center and hence made available to all professionals involved in patients' care.*

Keywords: Wearable Medical Instrument, Non-invasive Sensors, Wireless Bluetooth Communication, Virtual Community, Telemedicine

1. Introduction

Brain-injured children are patients which require long-term, probably non-ending, assistance activities. In order to improve the quality of the Health Care services, and especially the Home Care activities, for this population of patients, a project has been developed by a Consortium of Partners, from research, industrial, and no-profit world. The project is co-founded by the European Commission (Karma2, IST Project 2001-32320).

The Health Care sevices that are necessary for brain-injured children involve many actors: all the professionals involved in the health, social and psychological care delivery on one hand, such as hospital specialists and general practitioners, but also administrative personnel of the health organizations, and the patients, the families and their associations on the other hand. Karma2 creates a telemedicine network [1] that coordinates and manages all the persons and activities, delivering the appropriate information when and where they are needed, and keeping in touch all the persons involved in the project.

Part of this project consists in the development of a medical device, that measures some fundamental physiological variables: the blood oxygen saturation, the heart rate, the respiration rate. In fact, it can be of great importance to keep these variables under control in brain-injured children: for instance, they could suffer for nocturnal apnea, sometimes also leading to death, that could be promptly detected by the medical device [2].

In addition to the above-mentioned variables, another variable is measured: the patient's quantity of movement. This is an innovative type of measure in this class of patients, which can provide some indications about the patient's degree of health.

In order to leave maximum freedom to the patient, the medical device was designed to be wearable. Thus, the patient is free to move while measurements are performed. Measured data are stored into a Multimedia Card and then transmitted to a Personal Computer inside the patient's house at prescribed intervals, through an innovative radio-communication technology called Bluetooth. Finally, data are transmitted to a Service Center via Internet.

2. Materials and Methods

A block diagram of the medical wearable device is reported in the Figure 1:

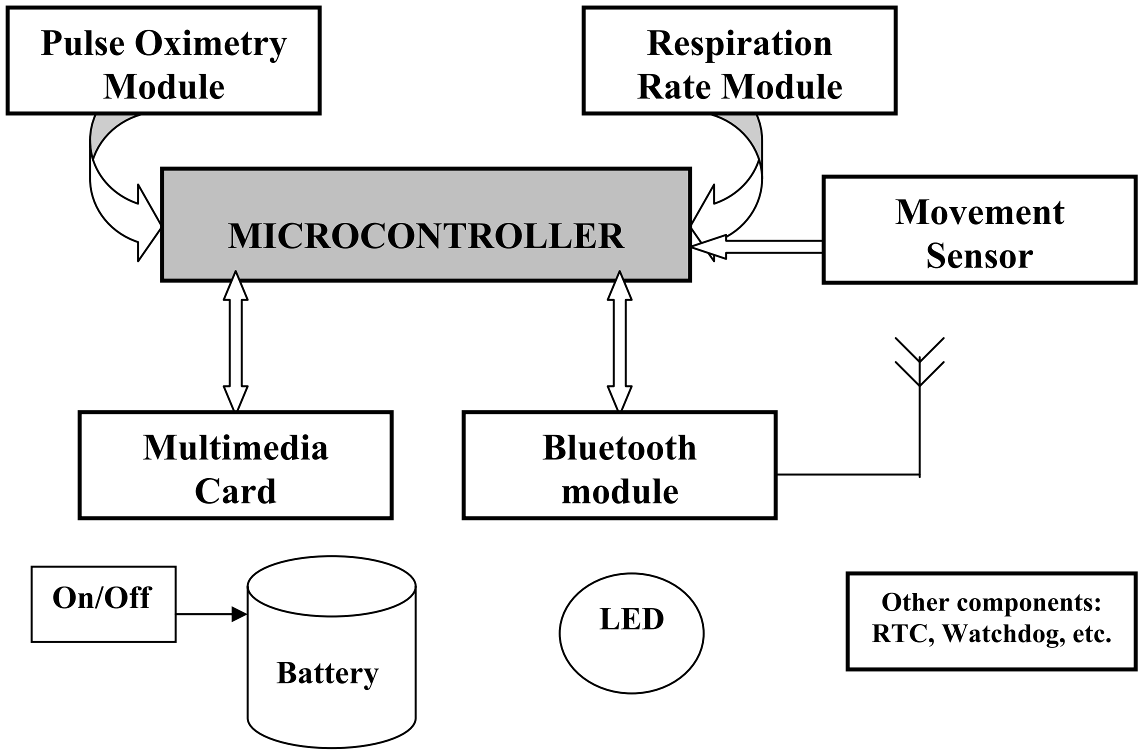

Fig. 1. Block diagram of the main components of the medical wearable device.

The microcontroller selected is from the Mitsubishi M16C/62 family, and the exact model is the M30624FGNFP. It is a 16 bit microcontroller, with many peripherals onboard: we chose to maximize the number of peripherals already included in the microcontroller for reasons of more compact design and lower board dimension, and also for power consumption reasons.

The OEM pulse oximeter board is the Nonin OEM II Module. The most interesting features of this board, for which it was preferred to other trademarks, is its very compact dimensions (34x46mm), and its low power consumption (70mW). On the other hand, the Nonin board has higher cost than that from other manufacturers, but we believe that its advantages fully compensate for its price. Regarding the measured variables, the features of the Nonin board are: 1) blood oxygen saturation range: 0-100%; 2) heart rate range: 18-300 beats per minutes. The accuracy for oxygen saturation is ±2 units (standard deviation), at least in the common measurement range (70-100%) with the usual finger sensor probe, and it is ±4% in the worst case for the heart rate.

For respiration rate, the chosen module is RESP-EZ Respiratory Effort Monitoring System from EPM Systems. A piezoelectric sensor is encased in a box, which has a plastic strip connected to it on both sides; then, a belt allows attaching the sensor to the patient. During breathing, the piezoelectric sensor is subjected to stress due to the expansion of the thorax or the abdomen, thus providing information on the breath rate. The advantage of this technique is that it is energy saving, as the piezoelectric sensor does not require power supply, producing the signal by itself. On the other hand, the output signal of this kind of systems is low: the piezoelectric sensor produces typical output of ±2 to ±4 millivolts.

The patient's quantity of movement is measured through a dual axis thermal accelerometer, MEMSIC MXD205. Measurement range is ±5g, fully sufficient for our application, with a resolution in the order of mg. The advantage of this component is that the output is already in digital format (PWM signal), and it has lower cost compared to different accelerometers. The signal provided by the accelerometer is integrated over a prescribed time interval, in order to get an index of the quantity of movement of the patient in that period.

All the measured data are stored into a data buffer, realized through Multimedia Card (MMC). The advantage of a MMC compared to different memory components, such as EEPROM, is that MMC can be easily removed and changed, if necessary (for instance, in the case it is full).

At prescribed time intervals the measured data are read from the MMC and transmitted to a Personal Computer inside the patient's house through Bluetooth technology. Bluetooth is nowadays the most promising technology for wireless communications in an indoor environment (10m range). Bluetooth operates within the ISM band between 2.402–2.480 GHz, it is based on GFSK modulation and hopping over 79 channels, each displaced by 1 MHz, at 1600 hops per second, which makes difficult to intercept Bluetooth signal. This can be important when managing sensitive data such as clinical ones. The data speed is currently 1 Mbps. Furthermore, one of the major benefit of this technology compared to other radio-communication solutions is low consumption; thus, using Bluetooth make sense for low power application (as it is for the presented medical device, that works with batteries), whereas other technologies are necessary for communications on distances greater than 10 meters. When compared to infrared technology, the advantage of Bluetooth is that it does not require being in line of sight: within its communication range, also the presence of an obstacle (such as a wall) does not prevent Bluetooth communication, differently from infrared. Moreover, Bluetooth technology implements some features related to security of the communication, such as encryption and authentication. A Bluetooth module is made of two main components: the radio transceiver, which is the part that, with the antenna, physically realizes the radio communication, and the baseband controller, which is an ASIC where the Bluetooth protocol is implemented. In our medical device, we have used the ConnectBlue OEM Bluetooth Enabler, which implements both the above-mentioned components. The module is interfaced to the microcontroller through a serial port, and communication occurs through a high-level protocol (called ACI Protocol) implemented on both sides.

3. Results

At the moment, the clinical trial on patients has just started, and hence there is not a large amount of data to be studied. However, a first result is that patients and families seem to accept the device, which is considered easy to use and to wear. In fact, the device, despite the several functionalities, has acceptable dimensions (150x100x40mm) and an ergonomic shape that helps in wearing it in confortable manner through a belt.

With regard to the first collected data, the professionals find useful to have them easily displayed through Internet. In fact, measured data, downloaded through Bluetooth to the patient's Personal Computer, are then transmitted to the Service Center through ADSL connection (UMTS will be used as soon as it becomes available), where it is made available over the Internet through the project portal. Currently, the portal is still for internal use, but in future it will be made available also outside the project community, providing obviously appropriate mechanisms of security and different levels of priviledge. Although still under development, measured data are displayed at the project portal in windows similar to that reported in the Figure 2.

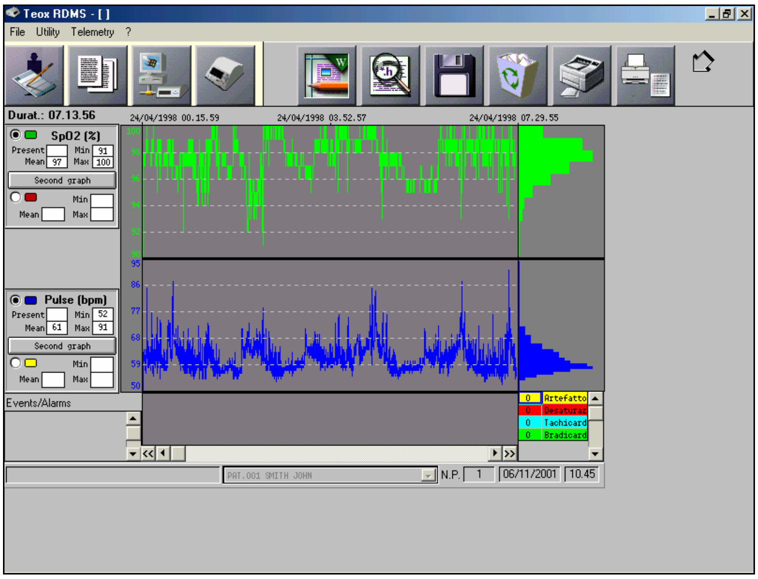

Fig. 2. Example of display of measured clinical data.

4. Discussion and Conclusions

The device is generally well accepted by the patients, but some limits have been indicated: the presence of three wires in some way is an obstacle to the patient's freedom of moving. In fact, one wire connects the device to the belt for respiration rate (put over the patient's chest); the second wire connects the device to the pulse oximetry probe over the patient's finger, and the third to the accelerometer located inside a velcro belt at the patient's wrist. Future improvements of the device will face these problems, and explore the possibility to design a device integrated in a jacket, separating the board and the battery package.

With regard to the measured data, the Clinical Partners of the project are strongly interested in the quantity of movement, since it is a parameter not studied on brain-injured children yet. Clinical Partners believe that a large decrease in the total quantity of movement performed in a prescribed (sufficiently long) period, compared to a previous period of equal length, can be an indication of a worse health condition: when the patient feels bad, he tends to stay in bed and not to be active. However, many data must be examined before drawing conclusions.

In summary, a new medical wearable device has been developed as part of a project targeted to brain-injured children. Final goals of the projects are reducing the hospitalisation and assistance costs, and increasing patient's and families quality of life, making them feel inside an organized and efficient community. Furthermore, we believe that other populations of patients, such as elderly people [3], may benefit of the creation of similar networks.

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