Infant Monitoring System Using Wearable Sensors Based on Blood Oxygen Saturation: A Review

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Abstract. This paper investigates the monitoring of infants using wearable sensor networks technologies based on blood oxygen saturation. Wearable sensors are suitable for the diagnostic and monitoring of "applications". Their miniaturization as well as that of electronic circuits play a vital role in the development of wearable systems. On the other hand, bBood oxygen content is now considered as one of the vital signs for infant monitoring based on temperature, respiratory rate, heart rate, and blood pressure. One of the main advantages of pulse oximetry is that measurements are taken non-invasively through optical measurements. The system consists of a sensor module, a monitor, and an alarm. The sensor is to be placed on a peripheral tissue bed such as the child's ankle. The monitor should be able to receive telemetric data through a signal from a sensor. The monitor and an alarm could be placed in a different room, for instance, the parents room. The alarm must sound if an abnormal level of oxygen or pulse rate is detected. This paper reports on the usability of such monitoring system. This paper discusses on a general architecture for infant monitoring system using wireless body area network based on oxygen saturation.

Keywords: Wireless sensor networks · Pulse oximetry · Sensor module · Monitor

1 Introduction

In the literature, several care systems have been developed for monitoring the health status of elderly people, but these systems are not necessarily applicable to infants since infants are most likely at a great risk of death and such risk cannot be predicted in advance using the above-mentioned systems. In addition, it has been reported [1] that most such systems are not necessary suitable for monitoring the oxygen blood content. These drawbacks have prompted the research community to investigate the design of systems capable of monitoring the infant's oxygen saturation. In such system, a wireless sensor device can be placed on the thin part of the patient's body-earlobe, across a foot or fingertip or on the infant body part, then used for monitoring the amount of oxygen carried in the patient's body. In such systems, a monitor component is designed to receive the signal from the sensor component, and an alarm is incorporated, whose function is to raise some sounds whenever some abnormal changes

I. Traore et al. (Eds.): ISDDC 2017, LNCS 10618, pp. 162–168, 2017.
https://doi.org/10.1007/978-3-319-69155-8_12

occur in the patient's blood saturation level [1]. In the recent years, several devices and sensors have been developed for clinical research and health monitoring. Meanwhile, several wearable sensor devices have also emerged as sensing technologies, which have high accuracy in terms of measurements. Examples of these are baby vest which includes fully-integrated sensors for measuring various body conditions of infant. In [2], a monitoring system was developed, which can be used to monitor the breathing, fever and volume of a baby sleeping in the crib. In [3], a wearable hardware gadget was developed, which can be used to capture the biological status of the baby such as motion, temperature and heart rate. In [4], an infant monitoring system was developed, which can be used to monitor the exhaled air from an infant, in order to reduce the potential risks of the Sudden Infant Death Syndrome (SIDS). In such system, which includes a sensor network to monitor the heart rate, temperature and humidity under clinical observation and home condition, CO2 sensors are placed around the cradle in order to check the carbon dioxide level. Considering the resulting output, it is possible to detect unusual infant's respiration. Indeed, an alarm is raised if something unusual happens. In [5], a monitoring system based on GSM networks was developed, which are suitable for measuring the heart rate and blood pressure using a transmitter and a receiver. Sensors are placed on the infant's chest and the above-mentioned parameters are sensed and the results are reported to a microcontroller. The data is received by the GSM module and send to the server, which makes them available via a Web browser. Typically, the use of such system typically triggers an audible alarm/message so that immediate actions can be taken whenever a problem occur.

2 Existing Infant Monitoring Systems

Several monitoring systems for infant monitoring have been proposed in the literature [1]. Here, our focus is on systems based on the ZigBee technology such as the one depicted in Fig. 1, which are mainly used for collecting and transferring the monitoring information using temperature sensor and heart beat sensor. In fact, Zigbee is low-cost and low-powered network deployed for controlling and monitoring the applications. In such system, the network is usually operated in a mode where the battery power is conserved all the time. The considered system consists of five modules, namely the data acquisition module, the data processing module, the health status detection module, the wireless communication module and the power supply module. The data acquisition module collects the data from the infant by using various types of sensors. The data processing module includes some data processing methods such as A/D conversion, feature extraction and few data processing algorithms. The health status detection module is usually meant for comparing the results obtained from the sensors. In determining the health status of the infant, a threshold is usually predefined. The wireless communication module is meant to achieve the transmission of information between infants, the base station, and the parents, which are the three entities usually involved in the communication. The power supply module provides the necessary energy for the entire system. There exist at least one coordinator for the network, which is responsible for handling and storing the information while performing the receiving and transmitting data operations. In such system, Zigbee routers act as intermediary devices that permit the data to pass to/from other devices. Zigbee operates in two modes, namely, beacon mode and non-beacon mode. In a beacon mode, the coordinators and routers continuously monitor the active state of incoming data, yielding more power consumption. In this mode, the routers and coordinators are always in the active mode because at any time, any node can wake up and communicate. In a non-beacon mode, when there is no data communication from the end-devices, the routers and coordinators enter into the so-called sleep state. Periodically, the coordinator wakes up and transmits the beacons to the routers in the network whenever it is deemed necessary. All nodes in this network are connected as a star topology and a central node is assigned the role of network controller.

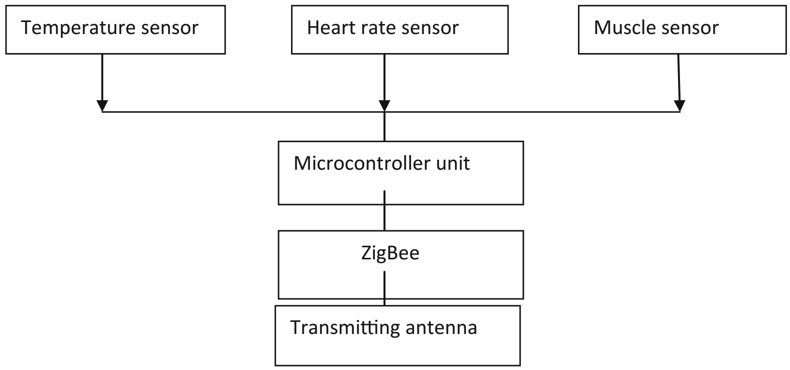

Fig. 1. Block diagram of the transmitting section

Based on specific targeted requirements, the system's hardware can be modified to deploy more sensors. Typically, when the measured data exceeds the allowable normal range, the system triggers an alarm message to the concerned healthcare professionals. Furthermore, the system depicted in Fig. 1 is meant to measure different physical parameters of an infant using three different sensors. The microcontroller receives the signals from the sensors and processes them before sending them to a ZigBee transmitter module. This transmitter module then transmits the signal, which is received at the other end by the receiving antenna of the ZigBee receiver as illustrated in Fig. 2.

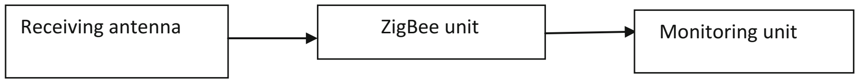

Fig. 2. Block diagram of the receiving section

Next, the receiver antenna receives the data sent by the transmitting antenna and the data are sent to a Monitoring unit for display.

3 System Design

In a nutshell, a wireless sensor network can be defined as a set of autonomous sensor nodes that are meant to monitor the physical conditions such as sound, temperature, and pressure. These sensors communicate the data directly to a centralized processing station, as well as with the base station. A sensor node is typically composed of four basic components, namely, a sensing unit, a transceiver unit, and a power unit as shown in Fig. 3.

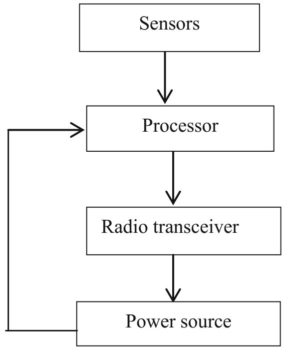

Fig. 3. Components of a wireless sensor network

In the above-mentioned infant monitoring system, the use of a wireless sensor module (as shown in Fig. 4) is to monitor the important signs of the infant such as respiration rate, body temperature, and blood pressure. The output of these deployed pressure sensors is then converted into digital signals using an analog to digital converter (ADC). These signals are processed using a microcontroller and the resulting output is transferred via a wireless module to the monitor.

In the monitoring module of Fig. 4, the body part activity and facial expression of the infant are taken into consideration and various sensors such as wet sensors are placed on the infant to monitor its respiration rate and other vital signs. This module consists of a cradle made of sensor nodes. The infant is placed in the cradle and sensors are placed on various parts of the cradle and the infant's body (for instance, his foot or ear lobe). An embedded application is invoked to process the information collected by these sensors. While doing so, an alert message is trigger if something abnormal occurs. It should be noted that the sensors motes that are used to monitor the oxygen in the infant's body transmit the data in pulse intervals once every second, and the frequency of the generated waveforms is analyzed and sent wirelessly to a microcontroller which processes them. Other key components of the infant monitoring system depicted in Fig. 4 include: (1) the respiration rate sensors – example applications of these sensors in practice are given in [6, 7]; temperature sensors – which typically fall in two categories, namely those that produce a voltage as indicator and those that generate other types of physical responses that should be converted into a voltage for measurement purpose [8]. Well-known examples of such sensors include

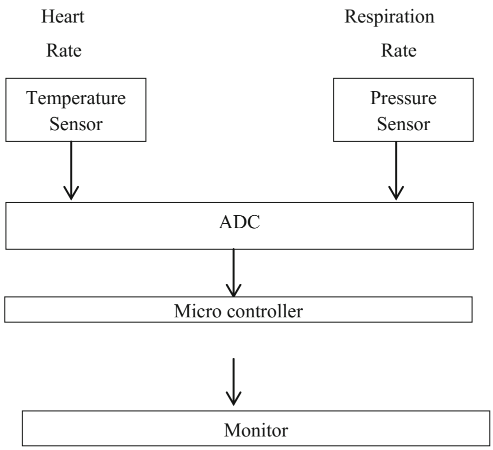

Fig. 4. Wireless sensor module

thermocouples, resistance temperature detectors, thermistors, infrared, and semiconductor sensors [9]. In using the aforementioned monitoring system, a pulse oximeter is also involved (as shown in Fig. 5), which is used for measuring how much of the hemoglobin in the blood of the patient is carrying the oxygen. This is referred to as measuring the oxygen saturation level (Spo_2) [10]. This is done by measuring the absorption of different wavelengths of light that undergo preferential absorption by the oxyhemoglobin or the deoxyhemoglobin [11].

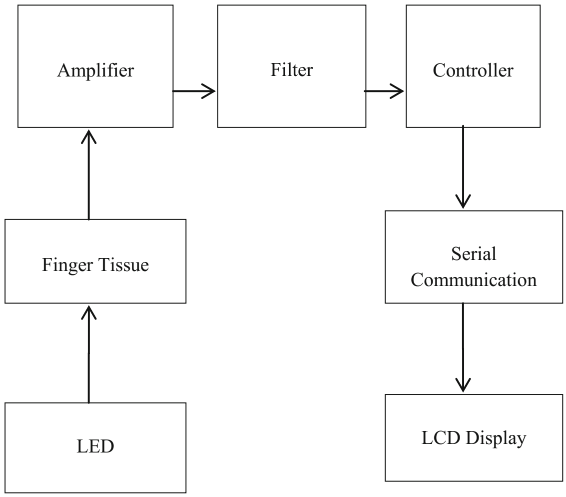

Fig. 5. Block diagram of the pulse oximeter

The heart rate is determined by measuring the elapsed time between peaks of the IR signal [11]. The pulse oximeter used for measuring the blood oxygen saturation and heart rate consists of sensors (see Fig. 5), a led driver, a microcontroller, and a LCD module [12, 13]. The signals from the sensors are amplified and sent to the microcontroller which then measures their levels. Next, the data is sent from the microcontroller to the LCD module. In this system, two types of light are considered, one referred to as transmitted light and the other referred to as reflected light. Both types of lights include probes, transmittance probe, and reflectance probe. Transmittance probe are composed of two LED's on one side and a light detector on the other side. Thus, the tissue which needs to be analyzed for blood saturation and heart rate is placed between the two types of light. On the other hand, the reflectance probe consists of two LED's and a light detector on the same side. Thus, it can be placed over any body tissue of the infant. The light is then emitted with the help of LED and passes through the body tissues and the same light is reflected by the bone, then is detected. In this process, the use of the reflectance probe is more complex than that of the transmittance probe.

4 Conclusion

This paper has provided a review of sensor systems for infants, including monitoring methods and techniques based on some of the recent research on wireless sensor networks' applications. As future work, the following points will be explored: (1) illustrating the proposed infant monitoring system using a case scenario which involves data collection and analysis; (2) qualitative comparison of existing state-of-the-art infant monitoring systems, including a discussion on metrics or measurements methods which can be used to evaluate the above-discussed sensor systems for infants; and (3) Discussion on how the collected data could be used for analytics or insights.

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