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Behavior-Monitoring System for Infants Napping During Midday

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Abstract. In this paper, we propose a system to monitor infants' midday naps at a nursery school. The system is designed to detect an infant (1) leaving the mattress, (2) turning over on the mattress, or (3) ceasing their breath. The system comprises sensor pads for each infant and a server. Each sensor pad collects a set of pressure data via pressure sensors and sends the data to a server via wireless local area network. The server collects data from each pad and analyzes it to extract information about the infant's behavior.

1. Introduction

Nowadays, the workload of childcare workers has disproportionately increased with respect to their wages. Thus, many nursery schools are short staffed, which has led to a shortage of nursery schools. This has become an issue of public concern. [1, 2] One important task assigned to childcare workers is checking the health condition of each infant during the midday naptime to mitigate the risk of sudden death or catch critical situations early. They must check for infants' breathing and sleeping posture and identify any abnormal conditions.

Hence, we propose a care system for infants to assist childcare workers in this process. The proposed system monitors an infant's midday nap and, if any abnormal conditions are detected, notifies the childcare worker. To decrease the cost of the system, the number of sensors in the pad were reduced and the data from the sensors was analyzed to determine whether it is sufficient for checking the infant's condition. [3]

2. Comparison of the Previously Developed Monitoring Systems With the Proposed System

Many studies were conducted to develop monitoring systems for humans' sleeping conditions [4–7]. The approaches in most of the studies have the following common characteristics: first, the previously developed systems could monitor only one person at a time; second, the monitoring system required to be placed in a closed space such as a small room; third, the system used unusual conditions such as a hospital; fourth, the monitoring equipment was large and expensive. However, in a nursery school, 30 or more infants nap simultaneously in a classroom every day. Therefore, these previously proposed systems cannot be applied directly for this application. Since many of the previously developed systems used cameras to detect abnormal conditions based on visual information, many cameras would be required to simultaneously cover 30 or more infants. Thus, several monitoring systems designed for adults used small sensors to decrease the cost; however, a small sensor may not monitor infants effectively because infants tend to move frequently on the sensor pad, and if they leave the small sensor area, no sensing data will be obtained. Previous studies used about 200 pressure sensors, which provide detailed data; however, they are expensive and the data obtained is excessive in quantity for this purpose. Thus, the proposed system includes small number of sensors to decrease the cost.

The proposed system senses when an infant (1) leaves the mattress, (2) turns over on the mattress, and (3) ceases breathing. To do this, the system uses 16 pressure sensors per infant and analyzes the obtained signals from the sensors to detect movement. However, the current system is not capable of sensing heartbeat or sleeping posture.

3. Overview of the System

3.1 Specification of the pressure sensor

The pressure sensors are membrane force sensors (MF08-N-221-A01 from Taiwan Alpha Electronic Co., Ltd.[8]). Their specifications are shown in Table 1. The resistance of the sensor are changed based on the pressure applied to the sensor. Figure 1 shows the configuration of the sensors. The pressure sensor data is changed into its voltage with range 0-1.1v according to the analog input range of the microcomputer. In Fig.1, the analog multiplexer (MUX) is used to select one sensor out of the 16 sensors and the microcomputer acquires its pressure data.

Table 1 Specifications of the pressure sensor

Force sensitivity range	30–1000 g (0.3–9.8 N)
Active area	39.6 × 39.6 mm
Response time	<1 ms
Force resolution	Continuous (analog)
Price	500 JPY (via Switchscience WEB shop)

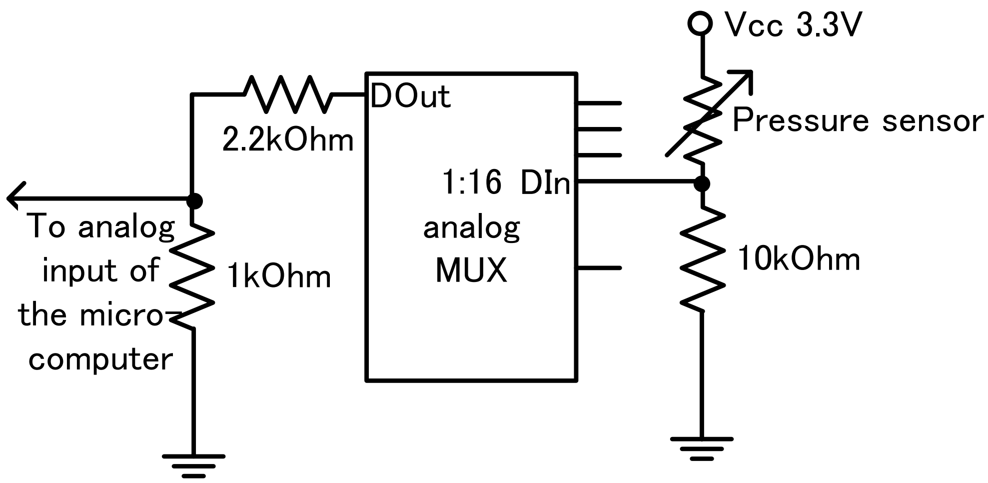

Fig.1. Configuration of the sensors.

3.2 Microcomputer

The microcomputer (ESP-WROOM-02 [9]) that we used includes a 32-bit-CPU core that can be programmed via Arduino sketch. Its specifications are provided in Table 2. To collect data from 16 pressure sensors via one analog input, the input connects to an output of a 16-input analog selector and the input data is chosen via a 4-bit binary counter.

Table 2 Specifications of ESP-WROOM-02.

MCU	Microcontroller up to 160 MHz
Flash memory	Up to 16 MB
Wifi protocol	IEEE 802.11b/g/n
Wifi frequency range	2.4 GHz
Operating voltage	2.5–3.6V
Analog input	1 port (with 10-bit A/D converter)
Digital input/output	8 ports

3.3 Configuration of the sensor pad

The sensor pad was 1350 × 600 mm. The upper board comprised 1-mm-thick polypropylene and the lower board was 3-mm thick. Previous systems [4] had many sensors, whereas our system uses only 16. To accurately measure the load on the upper board, the board was supported by wooden props attached with screws on the edge of the board. Each pressure sensor was placed between the upper board and a prop without a screw.

Each sensor pad was powered by 5 V of direct current using four AA dry-cell batteries or rechargeable batteries that conformed to the USB power supply norms. The batteries were stored in a casing on the edge of the sensor pad to remove the requirement for power cables outside the sensor pad. Because the sensor data was sent via Wifi, there were no cables outside the sensor pad casing.

The sensor pad comprised three light-emitting diodes (LEDs) to display the monitoring status or power status. If abnormal behavior was detected from the sensor data, one LED turned on.

The sensor pad also comprised a reed switch (operated by a magnetic field) embedded in the battery casing. If a childcare worker arrived near the sensor pad and cared the infant, the sensor pad sends a message to the server. When the server receives the message, the server recognizes that the abnormal condition has been resolved. Thus, there are no push-type buttons on the surface of the sensor pad.

3.4 Configuration of server

A commercial notebook personal computer was used as a server to analyze the sensor data obtained by sensor pad is. The computer comprised an Intel Core i5-2520M (2.5 GHz) CPU, 4-GB RAM, a 240 GB hard disk drive, and a Windows 10 operating system. The control and analysis program was built on Microsoft Visual Studio 2015. A Wifi access point was used to communicate with the sensor pads.

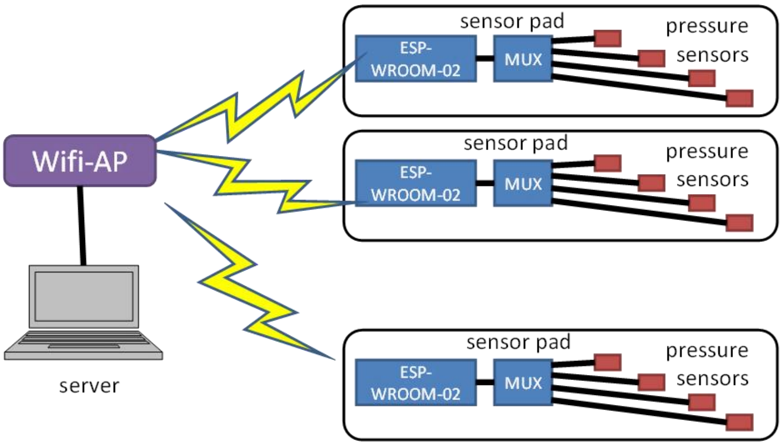

Fig. 2. Configuration of the system

4. Communication Protocol Between the Sensor Pads and the Server

In this section, we describe the communication between the sensor pads and the server. When the power of the sensor pads turns on, it tries to establish a connection between the sensor pads and a Wifi-access point and gets its IP address with a DHCP protocol. Each sensor pads send its own IP address to the server to establish the connection with the server.

The communication between the sensor pads and the server was executed as follows:

1. The server sends a packet with a “send data” message (or an “LED off” message) to a sensor pad.
2. The sensor pad collects sensor data from 16 pressure sensors.
3. The sensor pad sends a packet with 16 data signals to the server.
4. The server receives data from the sensor pad and analyzes it.
5. If the server detects abnormal behavior from a set of sensor data, it sends a packet to the sensor pad with the “LED on” message.

The server repeats above communications until the program which runs onto the server is terminated.

5. Methods to Detect the Infant’s Movements

In this section, we describe how abnormal conditions were identified from the sensor data. We used the weight data that were sensed by the pressure sensors in the sensor pad. Since this paper only proposes the detection methods, some thresholds or specific expression to detect those situations cannot be given. To settle those parameters, we have to carry out many experiments with infants at the nursery school. Here we introduce the concept of judgments.

(1) **Leaving the mattress**: If an infant leaves the mattress, the sum of the weights on the sensors and thus, the sum of the pressures on the sensors in the pad will decrease. Thus, the system detects when an infant leaves the mattress, based on the sum of the collected weight data is decreased drastically.

(2) **Turning over on the mattress**: The center of gravity of the infant can be calculated based on the weight data from each pressure sensor together with the given positions of the sensors. If the center of the gravity moved rapidly, the system could detect when an infant moved on the mattress.

(3) **Ceasing breath:** When a person lying down breathes, their center of the gravity shifts, as reported previously [4]. The proposed system applied this concept to detect whether an infant stopped breathing. This system will detect the situation when the center of the gravity does not shift. Because the total weight of an infant is small, analyses must be performed to determine whether the proposed system can detect these shifts.

The experimental results collected from the proposed system with one infant were reported previously [10]. As shown before, we have to carry out many experiments with many infants to increase accuracy to detect those situations.

6. Conclusion

In this paper, we proposed a system to monitor an infant while it was asleep. The system comprised sensor pads for each infant and a server. Each sensor pad collected a set of weight data using an array of pressure sensors and sent the data to the server via wireless local area network. The server collected the data from each pad and analyzed it. From these data, the system monitored the sleep condition of up to 30 infants. It was confirmed that the proposed system could collect a large amount of monitoring data simultaneously and analyze the infants’ sleeping conditions.

Acknowledgements

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