Research on Distributed Intelligent Mattress on the Internet of Things

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Abstract. Intelligent mattress is a hot research topic in the smart health care field based on Internet of things technology. At first, Non-contact sensor, BCG signal extraction, human life signal analysis, and large data analysis technologies are introduced, and then cloud platform storage and extraction technologies are also integrated into the system. Secondly, the function analysis, application principle, application network, interface design, and application cases of intelligent mattress are proposed in detail. This research is of great significance to intelligent health care and intelligent medical treatment.

Introduction

The distributed intelligent mattress on the Internet of things (hereinafter referred to as "intelligent mattress") involves the technologies of mattress structure, bio-medicine, big data, and cloud computing. The prototype system mainly implements the following tasks: to investigate the functional requirements of the products; to optimize performance of the related subsystems and modules; to design related control circuits; to realize the transmission of the sensor data; to deploy the cloud platform; to analyze the medical information and vital signs. On the premise of matching sleep recognition algorithms, the monitoring of physical signs is realized, such as sleep quality, respiratory rate, heart rate, etc. [1,2,3].

In the following sections, relative issues are discussed, and our system and cloud platform are proposed as well.

System Functions

The main system functions are listed below:

(1) Sleep quality tracking. It records the duration of deep sleep, shallow sleep, wake-up period and time during the whole sleep cycle, draws fluctuation line chart, and then generates the weekly & monthly sleep quality reports in text or charts.

(2) Heart rate and respiration rate. In resting state, the heart rate and respiration rate of the sleep period are monitored in real time. The highest, lowest, and average values of each time period are analyzed by comparing with the long-term values.

(3) Nocturnal activity. It monitors the number of wake-up times at night to determine the abnormal leaving bed time and in-bed time. If abnormal, it sends alarms and reminds carers.

(4) Body movement. It means the number of body movements during sleep cycle.

(5) Sleep apnea. It is the number of apnea and related time during sleep cycle.

(6) Snoring monitoring and intervention. It monitors the frequency of snoring through a sound sensor, and interferes with a similar vibration sensor device in a timely manner.

(7) Temperature control. It can independently heat different area of the mattress, and adjust temperature according to the user’s sleeping condition.

(8) Smart alarm clock. It wakes up users in shallow sleep state according to the degree of sleep in the set time of wake-up call.

(9) Sleep-aid music. It plays the role of music to help sleep, and adjusts the music volume automatically, considering the state of sleep.
Basic Principles of System Realization

Non-contact Sensors and Contact Sensors

At present, the piezoelectric sensor with Poly Vinlylidene Chloride (PVDC) is commonly used to collect the vital signs of human body in a non-contact way [4]. As long as people lie on the intelligent mattress with piezoelectric sensors inside, without wearing any equipment directly, BCG signal containing piezoelectric signal is collected [5]. And then Ballistocardiogram (BCG) signal is stored and analyzed. Heart rate, respiration, sleep quality, body movement, and other data are hidden in BCG signal [6]. A sample data of non-contact BCG signal is shown in Figure 1. However, traditional medical devices are normally based on contact mode. It means that people have to wear equipment or paste the patch directly on the human body to detect Electrocardiogram (ECG) signal[7,8]. A sample data of contact ECG signal is displayed in Figure 2.

Comparing with contact ECG mode, Non-contact BCG mode has less restriction and interference to users, so they have better experience in normal situations. Non-contact BCG devices are especially suitable for long-term monitoring of the human vital signs, so they have achieved rapid development in health care [9]. At the same time, the processing of BCG signal is more difficult than ECG when filtering interference from surrounding environment.

Figure 1. Non contact BCG signal.

Figure 2. Contact ECG signal.

Development Trend of Intelligent Hardware for Monitoring

In consideration of comfort and professionalism, the development of sign monitoring technologies are displayed in the Figure 3. Generally speaking, the health care sector tends to use non-contact technology, while medical devices tend to use contact technology instead. Non-contact equipment relies on BCG signal, while contact equipment uses ECG signal. Currently, the accuracy of BCG is quite close to ECG for signal vital signs data [10].
Smart Mattress Structure Based on Non-contact Sensor

The structure of the non-contact smart mattress is described in Figure 4. Lots of non-contact sensors are embedded in the mattress to collect original BCG signal, and then the data are transmitted to the cloud platform through distributed wireless network. After that, algorithms are called to generate results and stored in the platform. The transmission mode of network can adopt many modes such as WiFi or 4G. The results are able to be displayed on different channels, such as smart screens, PCs, or mobile phones [11,12].

Through BCG signal, we can obtain heart rate, respiration, body movement, sleep, or other extra information. Dependent on pathological analysis of medicine, comprehensive and continuous information of human vital signs and waves come out in real time [13].
For instance in Figure 5, the heart rate is 70, and the respiration is 11. Furthermore, body movements are normally distributed in green areas for a whole night sleep cycle.

Cloud Platform Data Analysis and Alarm

Basic Modules

The cloud platform contains three basic modules: algorithm library, data model, and sample database. Firstly, the algorithm library module is implemented to calculate the heartbeat, breathing, and body movement indicators through BCG signal. Secondly, data model module is triggered to generate the health index, sleep quality, pathological information, and other deep-seated information from above indicators. At last, sample database module is used to store and retrieve all the individual data by complex cloud computing architecture. After setting carefully on the platform, alarms could be send to users in SMS, email in real time or proper time. All abnormal situations are recorded by log.

Alarms from the Platform

Two types of alarms from the cloud platform are shown in Table 1 and Table 2 below.

| Event Time: | 2018.1.2 |
|------------|----------|
| Location:  | XX apartment XX room. |
| Personnel: | Mrs Song |
| Alarm:     | Abnormal heart rate alarm |
| Intervention: | Nurses were sent to the room in time. Residents checked that night, the elderly had atrial fibrillation, and the condition was relieved after treatment. |

| Event Time: | 2018.4.2 |
|------------|----------|
| Location:  | XX hospital. |
| Personnel: | Mr Li |
| Alarm:     | Out of bed timeout alarm |
| Intervention: | The old man was not in bed, sitting alone in the chair at night. Afterwards, the nurses examined the elderly, and found that the elderly were suffering from sleeping pain and insomnia |
Summary
In this paper, relative research topics of distributed intelligent mattress are discussed and analyzed. The non-contact and contact sensors technologies are compared, and development trend of intelligent hardware for monitoring are also investigated. And then our non-contacted mattress system based on the cloud platform are proposed in detail. The system is of great significance for scientific research and industrial application promotion.

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