International Core Journal of Engineering Volume 6 Issue 8, 2020
ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0041

Research on Sleep Quality Evaluation Method Based on Intelligent Nursing Bed

Xiangchun Meng[1,a], Xianqi Yuan[1,b], Yaser Mohammed Ahmed Al-Rubaei[1,c] and Shengcheng Zhang[1,d]

[1]Institute of robotics and intelligent equipment, Tianjin University of Technology and Education 300222, China.

[a]319656708@qq.com, [b]1668365676@qq.com, [c]ysrrub2020@gmail.com, [d]10501436@qq.com

Abstract

Sleep quality has become an important indicator of human health. In this paper, we conduct research from a real-time monitoring system for a smart mattress, monitor and collect physiological signals such as body movement, rollover, and breathing during sleep in real time through sensors on the mattress, and then stage sleep based on the multi-sensor information fusion algorithm to achieve sleep Evaluation of quality.

Keywords

Sleep staging, Sleep quality monitoring, Physiological signal monitoring, Physiological signal extraction algorithm.

1. Introduction

It is extremely important for a person to have healthy sleep. It can make the body get rid of sub-healthy state. Good sleep quality can eliminate human fatigue, restore physical strength, relieve mental stress, delay skin, promote human growth and development, enhance immunity and Protect nerves and other functions[1]. Conversely, if a person's sleep quality is poor, metabolic balance will be disrupted. In addition, poor sleep may also lead to coronary heart disease, arrhythmia, heart failure, three highs and other diseases. Sleep quality not only affects the body's health, but also threatens life safety[2]. Therefore, the evaluation of sleep quality becomes more and more important. The sleep quality evaluation is obtained through long-term sleep monitoring. On the one hand, this evaluation method helps people understand their sleep conditions, detect sleep problems as early as possible, and change bad sleep habits to improve the sleep status. On the other hand, it helps humans discover some related diseases caused by sleep quality as soon as possible and master the best treatment time. There are many methods for monitoring sleep quality on the market, such as PSG detection technology, sleep monitoring pillows, body movement sleep monitors, wearable devices, and micro-motion mattress monitoring systems. However, traditional sleep monitoring methods are lacking in accuracy, accuracy, and practicality. Therefore, it is particularly important for us to choose a suitable sleep monitoring system for sleep quality evaluation methods[3].

Considering that the effect of sleep monitoring on the human body must be small, the Yu Mengsun team developed a micro-motion sensitive mattress detection system to collect physiological information[4]; Zhang Lili's team has developed sleep stage discrimination based on changes in body movement pressure; Han Bo et al. The results of the second comparison sleep monitoring verified the practicability and accuracy of the non-contact monitoring system and algorithm proposed by them. Omron production company obtains some physiological parameters through the application of microwave technology, but this method is expensive and not easy to be implemented on a large scale. Although the traditional sleep detection method is still widely used in the study of sleep staging, its

Volume 6 Issue 8, 2020
DOI: 10.6919/ICJE.202008_6(8).0041

complicated operation and the binding of the collected information bring great inconvenience to the human body. Therefore, we have developed an intelligent nursing bed to collect human body information without restraint, and then evaluate the quality of sleep[5].

2. Construction of the Experimental Platform

The monitoring system monitors the physiological information such as the person's out-of-bed, body movement, breathing, etc., to establish the relationship between body movement, breathing and sleep staging, and then obtain a sleep quality evaluation report.

The mattress monitoring system consists of two parts: hardware part and software part. Hardware part: The hardware part includes the monitoring mattress, signal conversion box, central control box, control computer, etc.; the software part: consists of the acquisition part and the processing part. Because the pressure signals fed back by each area of the mattress are inconsistent, the electrical signals converted by the sensors will also be different. Determine the structure of the monitoring system according to the physical map, as shown in Fig. 1.

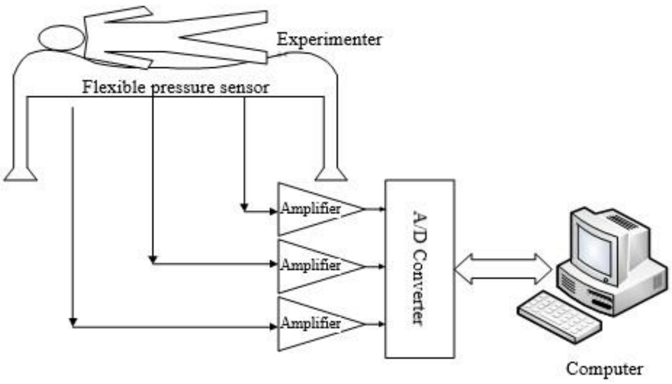


Fig. 1 The overall structure of the system.

The flexible pressure sensor SR SVZA4545L pressure sensors array manufactured by Tokai rubber industries, LTD in Komaki, Japan (Fig. 2) was used to collect pressure signals for the signal extracting.

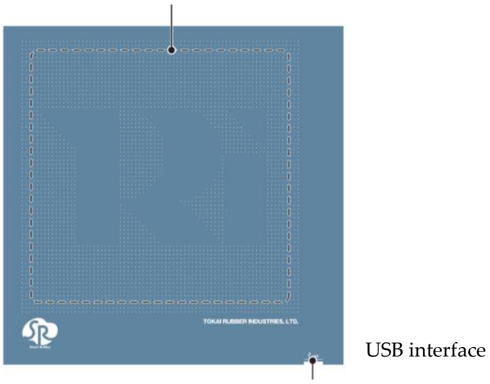


Fig. 2 SR SVZA4545L pressure sensors array.

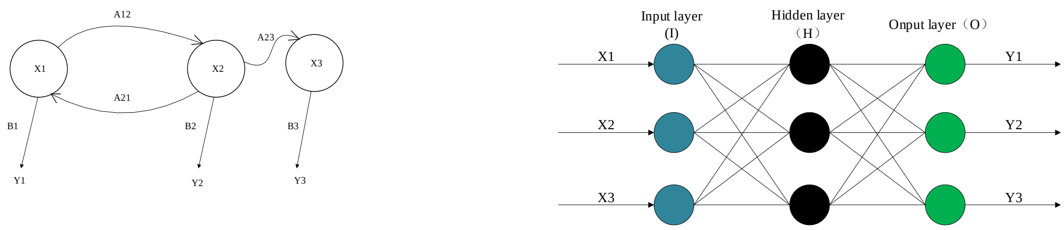
3. Research on Sleep Staging Algorithm

3.1 Research on Sleep Staging Algorithm of Respiration Rate

The sleep monitoring method of mattress without unbound flexible tactile sensor is a new idea in the home environment. In the first step, it uses the mattress to collect the breathing information of the human body while in bed, and in the second step, it uses the algorithm to obtain the sleep stage.

The HMM model (shown in Fig. 3a) and the BP neural network model (shown in Fig. 3b) mixed algorithms can achieve the functions proposed above.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0041



a) HMM Model diagram structure b) BP Schematic diagram of neural network model

Fig. 2 HMMBP Neural network model mixed graph.

First, introduce the algorithm steps of BP neural network as follows:

1. If the node that starts the access layer is set to $x_1, x_2, x_3, \cdots x_m$, the number of hidden layers is set to p, the number of output layers is set to n, the weight between the hidden layer and the access layer is V_{ih}, and the weight between the output layer is $\mathrm{V_{ho}}$;

2. Random values, ranging from -1 to 1, the algorithm steps:

3. Hidden layer A series of input values are obtained after weight calculation:

$$h_i = f\left(\sum_{k=0} V_{kh} x_k\right) \tag{1}$$

In the formula h_i Represents the output value of the hidden layer $i = 1,2,\cdots p$, $f(X) = (1+e^{-x})^{-1}$.

I. Output layer formula:

$$c_j = f\left(\sum_{t=0} V_{jt} x_t\right) \tag{2}$$

Where, c_j represents the size of the output value, $j = 1,2,\cdots n$

II. Generalization error:

$$d_j = c_j (1-c_j)(o_j{}^k - c_j) \tag{3}$$

In the formula, d_j represents the generalized error of the output layer $J = 1,2,\cdots n$, $o_j{}^k$, and is the desired output.

III. The error of the hidden layer relative to the generalized error of each output layer is:

$$e_i = h_i (1-h_i) \Sigma_j d_j W_{ho} \tag{4}$$

In the formula, $j = 1,2,\cdots p$

IV. Connection right adjustment:

$$\Delta W_{ho} = \alpha d_j h_i \tag{5}$$

In the formula, ΔW_{ho} represents between the hidden layer and the output layer.

V. Connection right adjustment:

$$\Delta V_{ih} = \beta e_i h x_h \tag{6}$$

In the formula, ΔV_{ih} represents between the input layer and the hidden layer.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0041

Repeatedly (1-6) step of Until $j = 1,2,\cdots n$, $i = 1,2,\cdots P$ In other words, the calculated error is within the specified range.

Therefore, combined with the advantages of the two, the HMM-BP neural network model hybrid classification algorithm was selected to process and extract the respiratory signal, and then determine the level of sleep quality.

3.2 Research on staging algorithm of body movement sleep

Collecting body motion radio frequency signals is the basis of the sleep staging identification algorithm. The specific algorithm flow is shown in Fig. 4.

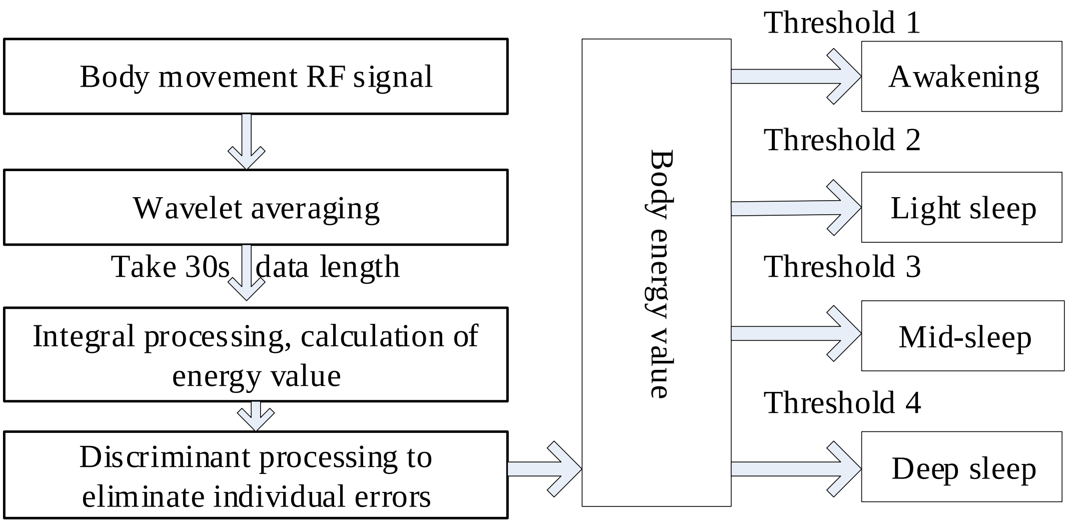


Fig. 3 Flow chart of body motion recognition algorithm

According to the algorithm flow chart, the RFMS body motion signal for the whole night is taken as a section of 20s data, and the signal integration of this section is obtained, and the calculation of body movement energy is realized:

$$BDM_{(n)} = \int_1^{20} |s(30n + t - 1)d_t|, \quad \text{where,} \quad n = 1,2,\cdots,\frac{length(s)}{20 f_s} \tag{7}$$

Where s represents the original signal, $length(s)$ the length of the original signal s, and the sampling frequency.

Take the logarithm of the body kinetic energy value and get the function to determine the stage:

$$SS(n) = \lg(BDM(n - i)) \tag{8}$$

In the formula: n refers to the signal point with 20 s as an integration interval.

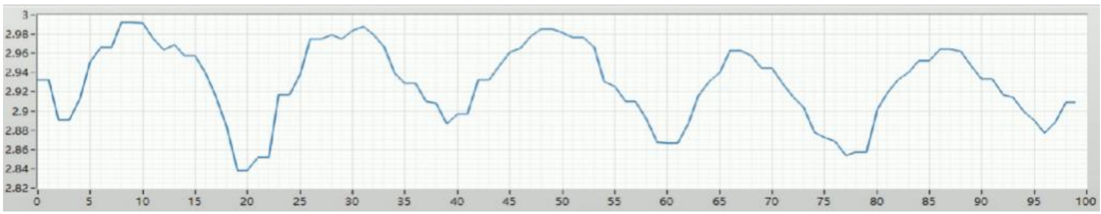
4. Sleep Staging Results

4.1 Sleep stage based on respiratory signal

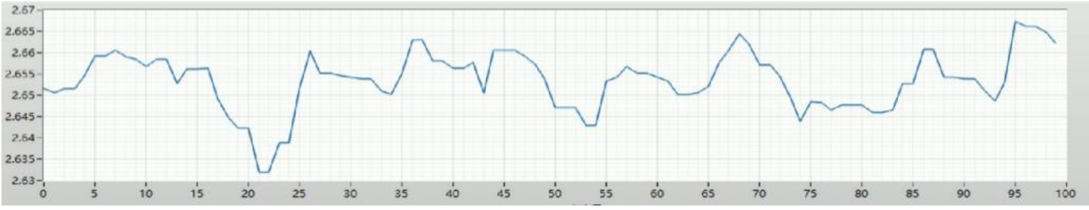
Generally speaking, the amplitude of the respiratory signal changes most stably during non-rapid eye movement, and the regularity and periodicity of breathing are strong; the variability of breathing in the awake period and the rapid eye movement period increases significantly, and the amplitude and rhythm of breathing. The change is also greater. Studies have shown that it is both a reference for sleep staging and a basis for judging apnea syndrome. Therefore, the following is an introduction to

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0041

using sleep signals to stage sleep. The respiration signals at different time periods are shown in Fig. 5.



a) Breathing signals during deep sleep



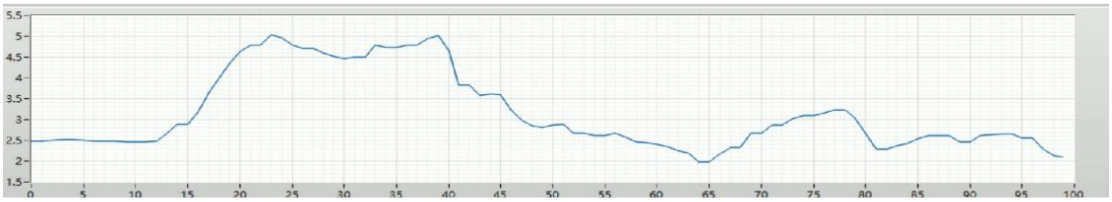
b) Breathing signals in light sleep

Fig. 4 Respiratory signal

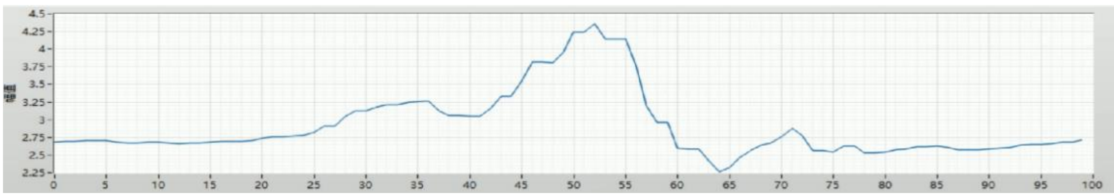
Based on the above information, make a judgment: in the process of light sleep, respiratory variability is greater. During deep sleep, breathing is regular.

4.2 Sleep staging based on body movement signals

The body movement signals include turning, leg movement, arm movement and other signals. Different calculations of the number of body movements and turning over a certain period of time can determine the state of deep sleep and light sleep. The leg movement and turning signals extracted through experiments are shown in Fig. 6.



a) Signal measured when the leg moves.



b) Signal measured when turning over.

Fig. 5 Leg movement and rollover signals

Judging from the above information: during the period of light sleep, the frequency of body movements has increased, including the movements of legs, arms, and turning; during the period of deep sleep, the phenomenon of body movements occasionally occurs.

Through experiments, the evaluation of sleep quality is shown in Table 1.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202008_6(8).0041

Table 1 Sleep Quality Evaluation Form

Sleep cycle	Time of falling asleep (min)	Ratio of deep sleep to total sleep(n)	Ratio of light sleep to total sleep	Number of body movements	Sleep quality evaluation
4~6	5~15	20%~25%	5%~10%	<10	excellent
4~6	15~25	15%~20%	10%~15%	10~20	good
4~6	above25	n<15%,n>25%	>15%	>20	poor

5. Conclusion

1. The mattress based on the flexible pressure sensor monitors the physiological characteristics such as breathing and body movement during sleep in real time, and achieves satisfactory results. The main work and research results of this article are as follows:

2. Build an experimental platform for unbound sleep monitoring.

3. The classification rules and characteristics of sleep stages are studied, and the physiological signal characteristics such as breathing and body movement are taken as the criteria for dividing sleep stages. Achieve sleep stages and sleep quality evaluation.

Funding

This research was funded by the "Innovation and entrepreneurship training plan for college students" project, “Design of intelligent nursing bed monitoring system based on distributed sensor”, Granted No.201910066055; “University project of TianJin University of technology and education”, “Development and implementation of key technologies for plant protection six rotor UAV”, Granted No. KJ2004; “University project of TianJin University of technology and education”, “Research and Practice on the training mode of college students in precision education poverty alleviation and internship”, Granted No. SK2003.

References

[1] Xin Zhu,WenxiSleep[J]. IEEEChen,Nemoto T. Transaction OnReal-Time Monitoring of Respiration Rhythm and Pulse Rate DuringBiomedical Engineering,2006,53(12): 2553-2563.

[2] Gaddam A,Kaur K,Gupta G S,et al. Determination of sleep quality of inhabitant in a smarthome using an intelligent bed sensing system[C]. Instrumentation and MeasurementTechnology Conference. IEEE, 2010: 1613-1617.

[3] Samy L,Huang MC,Liu JJ,et al. Unobtrusive sleep stage identification using a pressure-sensitive bed sheet[J]. IEEE Sens J,2014,14(7): 2092-2101.

[4] Kiriazi J E,Boric-Lubecke O,Lubecke V M. Dual-Frequency Technique for Assessment of Cardiopulmonary Effective RCS and Displacement[J. 2012,12(3): 574-582.

[5] Kurihara Y, Watanabe K. Sleep-Stage Decision Algorithm by Using Heartbeat and Body-Movement Signals[J]. Systems Man&Cybernetics Part A Systems&Humans IEEETransactions on,2012,42(6): 1450-1459.