Intelligent Remote Respiratory Monitoring System Based on Deep Learning

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ABSTRACT. *Based on depth learning, a wearable elastic band embedded with grating strips is tied to the chest or abdominal cavity of a patient. Due to volume changes generated during breathing, the position changes of grating strips in the elastic band are caused. Accurate detection of the position changes of grating strips through grating sensors can realize monitoring of respiratory process. Firstly, the application program is developed based on LabVIEW virtual software platform, and the remote monitoring and control functions are realized by using the network mode based on Browser/Server (B/S). Then, the impedance signals and blood oxygen saturation of human body are collected through simulation experiments for system test verification. The system realizes the wireless transmission and monitoring of respiratory signals, which enables patients to get rid of the bondage of electrode connection and does not affect sleep quality. With the characteristics of small volume and low power consumption, it provides a new idea for community medical remote monitoring.*

KEYWORDS: *in-depth study, Rip, Rbm, blood oxygen saturation, Sleep apnea syndrome, B/s*

1. Introduction

Sleep apnea syndrome,(SAS) can be divided into obstructive sleep apnea according to the characteristics of sleep apnea, that is, apnea caused by upper airway obstruction during sleep, which is manifested by the cessation of airflow in the mouth and nasal cavity while thoracic and abdominal breathing still exists [1]; In clinical practice, respiratory monitoring is mainly used for preliminary detection of diseases such as heart failure, anxiety disorder and sleep disorder. However, in fact, reliable respiratory monitoring methods are almost free of sleep respiratory disorders in home and outpatient monitoring, which are the main factors affecting sleep quality. Obstructive Sleep Apnea Syndrome (OSAS) is the most common sleep respiratory disorders, and it is easy to cause diseases such as hypoxemia, hypercapnia and heart

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loss. Deep learning can realize the approximation of complex functions by learning a deep nonlinear network structure, characterize the distributed representation of input data, and demonstrate a strong ability to learn the essential characteristics of data sets from a few sample sets [2]. In recent years, there are many methods for monitoring sleep apnea at home and abroad, but the vast majority of methods are based on wired transmission to send respiratory signals to the processor. As electrodes and wires seriously affect sleep quality, they not only cannot obtain scientific detection data, but also bring inconvenience to the daily life of the monitored person [3].

At present, the gold standard for the diagnosis of sleep apnea syndrome is sleep monitoring by Polysomnography (PSG), but it has the disadvantages of high price and complicated operation, which is difficult to meet the needs of daily health care in families or communities. According to statistics, SAS occurs in about 4% of men and 2% of women between 30 and 60 years old, and the prevalence rate over 65 years old is as high as 20% ~ 40% [4]. At present, sensors that can detect respiratory signals can be found on the market, but the most common respiratory detection device as a wearable garment is an experimental prototype, and no general commercialization has been found yet [5]. The concept of deep learning originates from the research of artificial neural networks. Multilayer perceptron (MLP) with multiple hidden layers is a deep learning structure. Deep learning forms more abstract high-level representations (attribute categories or features) by combining low-level features to discover distributed feature representations of data [6]. This paper designs a portable sleep respiratory disease remote monitoring system based on deep learning algorithm. The system adopts a network mode based on Browser/Server (B/S) to realize remote monitoring and control. The collected sleep respiratory signals are transmitted and received in a radio frequency mode, and the received data are sent to a PC through a serial interface, so that the monitoring terminal can monitor sleep conditions in real time.

2. Detection Method

The diagnosis standard of sleep apnea syndrome is that apnea or hypopnea occurs more than 30 times repeatedly during nighttime sleep, or apnea and hypopnea occur more than 5 times per hour on average with somnolence. Judging the breathing process by detecting the position of the permanent magnet; The principle of strain sensor detection is to use strain sensors to detect the deformation caused by respiration during respiration, thus detecting respiratory signals [7]. Obstructive refers to chest and abdomen movement still exists when apnea occurs. Mixed type refers to the central feature in the first half and obstructive feature in the second half of a apnea. Among them, the analog signal processing circuit includes respiratory detection circuit, preamplifier circuit, low-pass filter circuit and main amplifier circuit. Hypoventilation refers to the reduction of sleep respiratory airflow by more than 30% accompanied by a reduction of blood oxygen saturation ⩾4%. Thus, the main parameters of sleep respiration detection are respiratory signals and blood oxygen saturation.

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Deep learning has the deep structure of multi-layer nonlinear mapping, and it is one of the advantages of deep learning that it can complete complex function approximation. In addition, depth learning can theoretically obtain distributed representation, i.e. the main driving variables of input data can be obtained through layer-by-layer learning algorithm. A typical example based on local matching is the kernel method [8].

$$f(x) = b + \sum_{i} \alpha_i K(x, x_i) \tag{1}$$

DBN consists of a series of restricted Boltzmann machine (RBM) units. RBM is a typical neural network. The visual layer and hidden layer elements of the network are interconnected with each other (there is no connection in the layer), and the hidden elements can obtain the high-order correlation of the input visual elements. The joint distribution of RBM under given model parameters is as follows:

$$p(v,h,\theta) = \exp(-E(v,h,\theta)) / Z \tag{2}$$

Among them:

$Z = \sum_v \sum_h \exp(-E(v,h,\theta))$ is a normalization factor or partition function.

The marginal probability given by the model to the visual vector V is

$$p(v,\theta) = \sum_h \exp(-E(v,h\theta)) / Z \tag{3}$$

According to the apnea of chest and abdomen movement during sleep apnea, sleep apnea syndrome is clinically divided into central, obstructive and mixed type, of which obstructive is the most common. Common detection methods for sleep respiratory signals include: pressure method, which detects respiratory signals according to instantaneous pressure changes generated by respiratory movement monitored by pressure sensors [9]; The temperature method uses a temperature sensor to capture the change in electricity detected by the detection circuit to obtain the breathing signal when the temperature of the component changes [10]. During expiration and inhalation, the volume of the abdominal cavity or chest cavity changes, which causes the bandage. The long change causes the movement of the position of the grating strip on the strap, and the change of the position of the grating strip is detected by the grating sensor circuit. The system uses impedance method and transmission non-invasive detection method to detect human respiratory signals and blood oxygen saturation as monitoring parameters.

3. General Framework of the System

The overall framework of the system is shown in Figure 1. The system consists of two parts: hardware and software. The hardware is to collect human physiological

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data by using the American Biopac physiological recorder. Software: LabVIEW software is used to realize data reading, analysis, storage, remote warning and other functions. And the ZigBee sending unit sends the acquired sleep respiration signal to the terminal in a wireless manner. The community monitoring terminal is installed in the intensive care unit of the community (within 70m distance), and the wireless receiving unit transmits the received data to the PC. When the grating bar is displaced with the change of chest and abdomen, the grating sensor will output two digital pulse signals with phase difference of 90 degrees, A and B respectively. Real-time waveform display, alarm and other functions can be realized through monitoring programs.

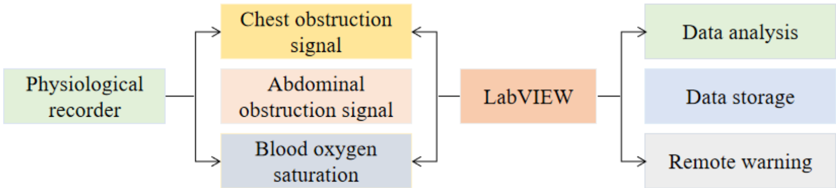

Fig.1 Overall Frame Diagram of the System

This system will realize the monitoring, analysis and identification of human respiratory system status, and finally realize the remote monitoring of the system. Its functions include: it can timely and reliably send the respiratory system parameters of the monitored object to the monitoring station of the hospital center, and the medical staff and expert system of the monitoring center can make timely diagnosis according to the data provided by the monitoring system. The singlechip control system discriminates the process of exhaling and inhaling, and calculates the displacement of the grating strip, thus analyzing the respiratory frequency and ventilation. The generation mechanism of ECG signals shows that the acquisition of ECG signals needs to determine the position of the electrodes on the body surface of the human body, and at the same time, the electrodes are connected with ECG monitoring equipment through lead wires, which is called ECG connection. The phase frequency feature can be used to distinguish the movement direction of the grating strip, thus accurately distinguishing the exhalation and inhalation processes of the user. The number of pulses is proportional to the displacement. However, the respiratory process is an extremely complex physiological process. Respiratory information is generally very weak and low in frequency, and is easily affected by physical activities and other factors. Therefore, it is difficult to accurately sample, reproduce in real time, and automatically calculate functional indicators of respiratory waves.

4. Hardware Design

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The collection of human physiological data in the system is realized by Biopac physiological recorder in the united states. If the temperature sensor is attached to the lower part of the nose, the temperature change generated when breathing or inhaling will cause the resistance of the sensor to change (see fig. 2). When the system is used, the respiratory sensor module converts the variation generated during breathing into electrical signals and digital signals. Thermistor Rt is a measuring arm of the bridge. Before use, adjust potentiometer R3 to make the bridge balanced and the output terminal zero. The respiratory airflow changes the heat transfer condition when flowing through the thermistor. EBI100C dual channel module with excitation current of 100μA and 50kHz is used to measure the impedance signal of thorax and abdomen. OXY100C amplifier and TSD123 series sensor are used to collect the blood oxygen saturation. The relationship model between cause and result is established through sample data, and the probability of sleep apnea syndrome of patients is detected according to the relationship model.

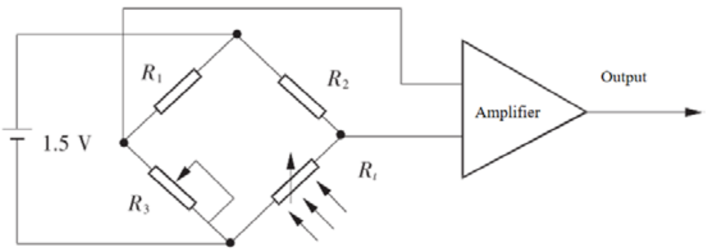

Fig.2 Respiratory Detection Circuit

Using this principle to detect whether breathing and breathing frequency, subjects are not affected by any body position and posture, and can record ideal curves, which provides many convenient conditions for testing. Before collecting data, calibration of blood oxygen saturation module should be carried out in advance. The MCU control system stores the preprocessed data and uploads it to the intelligent terminal via Bluetooth. The intelligent terminal uses RIP technology to calculate and display physiological parameters such as respiratory frequency and ventilation volume in real time. It is proposed on the basis of the research results of modern neuroscience, and attempts to process information by simulating the brain neural network processing and memorizing information. The detection circuit has high sensitivity and large output signal. when the power supply voltage of the bridge is 1.5V, the voltage for measuring the respiratory movement of human body can reach 30-50mv, and the inspiratory phase and expiratory phase can be accurately recorded. In order to accurately measure the temperature change of the respiratory airflow, it is required that the thermal response time of the thermal sensor is small, the sensitivity is high, and the sensor can quickly respond to the temperature change. At the same time, it is required that the sensor is relatively small in size, easy to be placed near the

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respiratory tract, and convenient to detect the temperature change of the respiratory airflow.

5. Software Design

LabVIEW virtual program is used as the development platform to realize the functions of data acquisition, transmission, calculation, result display and remote warning. The detection process of sleep apnea hypopnea is shown in fig. 3. It has the characteristics of differential input, high input impedance, variable gain output, high common-mode rejection ratio, and is very suitable for amplifying weak voltage signals. At the same time, the intelligent terminal can transmit the corresponding data to the back-end server through the Internet, and professionals can store, analyze and compare the data. It is also possible to remotely monitor the respiratory status of acute respiratory disorders or elderly people through APP terminals or mobile social platforms. It overcomes the defects of traditional artificial intelligence based on logical symbols in processing intuitive and unstructured information, and has the characteristics of self-adaptation, self-organization and real-time learning.

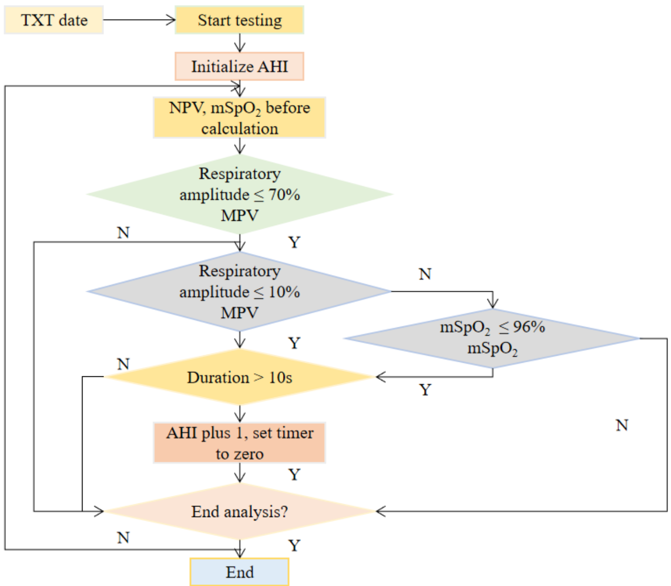

Fig.3 Sleep Apnea Hypopnea Detection Process

The system adopts a network architecture based on B/S mode. For patients with sleep respiratory diseases requiring long-term monitoring, medical personnel can remotely access and dynamically monitor the development trend of sleep respiratory

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diseases of patients in real time through a browser. The circuit uses an unbalanced antenna, and the antenna performance can be better by connecting the unbalanced transformer. Hardware circuits are used here to identify waveform changes. When the breathing speed and depth are different, the waveform and amplitude of each airflow temperature change signal are different, but in each breathing process, the signal waveform must fluctuate up and down the baseline, so Schmidt comparator is designed to transform the waveform. The respiratory signal can be detected by measuring impedance. When the physiological parameters of the monitored object are abnormal, the system software will prompt the abnormal situation in the form of an alarm splash screen to facilitate medical personnel to provide remote medical assistance in time. The smart terminal in this system is a PC or smart phone with Bluetooth transmission function and uses a 5 V button cell, which has the characteristics of small volume, low power consumption, high precision, etc.

6. Test Validation

Relevant researches show that the experiments simulating respiratory obstruction or apnea have certain reference value for simulating real sleep apnea syndrome. In this experiment, normal people are recruited to simulate respiratory obstruction or pause, and respiratory motion signal amplitude changes and blood oxygen saturation data are collected to verify the credibility of the system. Due to the presence of sensor phase error, a direction finding counting error correction algorithm is applied to judge the directivity and effectiveness of a single pulse by using a counting window variable with a length of 5 counting pulses. During the implementation process, the evaluation data fluctuated around the test data, which better reflected the changes of patients. Taking polysomnography data as reference, it provides a good supplement for measuring the sleep status of patients and recording the information in sleep in detail. In this study, 10 subjects were selected for simulation experiment. All subjects were students, aged 24-31 years old, with body index (21-24, no respiratory diseases or other major diseases. Explain the process of this experiment to all subjects before the test starts. See Table 1 for measurement data.

Table 1 Statistics Of Test Data

State	Chest impedance amplitude			Abdominal impedance amplitude			Oxygen saturation		
	Normal	Respiratory obstruction	Apnea	Normal	Respiratory obstruction	Apnea	Normal	Respiratory obstruction	Apnea
Mean value	0.336	0.304	0.261	0.335	0.274	0.352	98.314	95.127	98.604
Variance	0.121	0.074	0.038	0.094	0.023	0.037	0.474	1.247	0.752

For sleep breathing test, in order to test the breathing frequency under different sleep postures, the test is simulated in three different sleep postures of lying on one's back, lying on one's side and tossing and turning. Through statistical analysis (paired t test), it is concluded that there is a significant difference between the average

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respiratory impedance amplitude values of the subjects in each state ($p < 0.05$).Blood oxygen saturation has significant difference between normal state and apnea state, but there is no significant difference between occlusion and apnea state. The accuracy of dynamic typing results is relatively high, which is close to the clinical doctors' experience analysis results and provides reference for clinical staff. It is wirelessly transmitted to the receiving unit of the terminal for waveform display and other monitoring functions.

7. Conclusions

With the continuous enhancement of people's awareness of family health care, community family-based sleep apnea syndrome detectors have broad application prospects. According to the difference of people with sleep respiratory diseases, taking respiratory impedance signal and blood oxygen saturation as monitoring parameters, this paper develops an application program based on LabVIEW virtual software platform to build a remote monitoring and early warning evaluation system. The wireless transmission of respiratory signals is realized, and the monitoring end can be made into a portable watch type, which enables patients to get rid of the bondage of electrode connection and does not affect sleep quality. The single chip microcomputer can calculate the pulse signal digitally with an accuracy of 0.07mm, which improves the stability and accuracy of respiration detection. The system has low power consumption, the maximum current consumption is only 42mA, simple structure and low hardware cost. It can only be helpful for differential diagnosis of the patient's condition. At the same time, it can predict the prognosis of the patient and realize the classification and identification of asphyxia during sleep, thus providing basis for clinical treatment and reference for differential diagnosis of similar diseases.

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