Research on Health Monitoring System Based on Computer Artificial Intelligence Technology

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Abstract. In this paper, a real-time monitoring system of human health data in a household environment is designed. The system applies Zigbee wireless communication technology to transmit real-time data and establishes family members' health records on the server. After processing by central processing unit(CPU), the system sends the temperature and heart rate data collected by the terminal to the coordinator and realizes real-time data monitoring through the serial port on the PC side. The system can be divided into a system microprocessor, digital system module, human-computer interaction module, signal acquisition module, and wireless communication module, etc., according to the human heart rate, blood oxygen, temperature, and other critical physiological parameters processing and analysis, and then real-time monitoring of the human body. System processor STM32F103C8T6 as the CPU, display module selected OLED; The MAX30102 sensor and Pulse sense sensor were selected for the physiological parameter acquisition system to collect the heart rate of the wrist and finger, respectively. After physiological parameters were collected, A/D transformation was further performed. Through the software and hardware design test of one terminal of the system, the system can accurately measure the physiological information of different patients. By comparing the data, the accuracy can reach 2%. It can be proved that the system has an excellent medical application prospect.

Keywords: Computer; artificial intelligence technology; Health Monitoring System; health monitoring system.

1. Introduction

According to a survey by the Ministry of Civil Affairs, the number of older adults in China exceeded 200 million in 2016, 300 million in 2025, and 400 million in 2034. With aging, the function of human organs gradually declines, and the existing medical monitoring equipment usually adopts wired transmission. Patients with Noncommunicable diseases (NCDs), such as diabetes, cardiovascular and cerebrovascular diseases, and lumbar disc herniation, cannot live in proper health condition without long-term physiological parameter monitoring [1]. The characteristics of medical monitoring are low-latency and consistency. With the help of medical instruments, physiological characteristics and parameters can be monitored in real-time. The large size of traditional monitoring equipment limits the movement range of the warded, and all kinds of cables are connected to the body, causing emotional anxiety among the warded, leading to the delay of the condition and the prolonging of the recovery time. This paper proposes a physical health monitoring solution based on ZigBee technology, which can collect physiological information (pulse and body temperature) of the monitored person within 24 hours in the home environment, transmit the collected information to the monitoring base station in real-time, automatically warn and alarm the elderly with abnormal physiological parameters, and notice the family, community, and hospital to help in time.

2. Design of health monitoring system

2.1 System Structure Design

The system integrates physical health monitoring and environmental detection functions. It comprises the sensor module, positioning module, STM32 main control module, LoRa gateway, and a terminal application. The terminal node comprises a heart rate, blood oxygen sensor, temperature sensor, ultraviolet sensor, and positioning module, which MCU drives to detect physical sign data and position information [2]. The wireless sensor network is composed of a LoRa gateway to realize the communication between terminal nodes in the wireless sensor network. LoRa gateway sends the detected data to the community elderly safety monitoring system center through wireless communication for storage and processing. It uses the positioning module to check the location of the elderly in the community on the upper computer, realizing the health monitoring of the elderly in the community. (Figure 1).

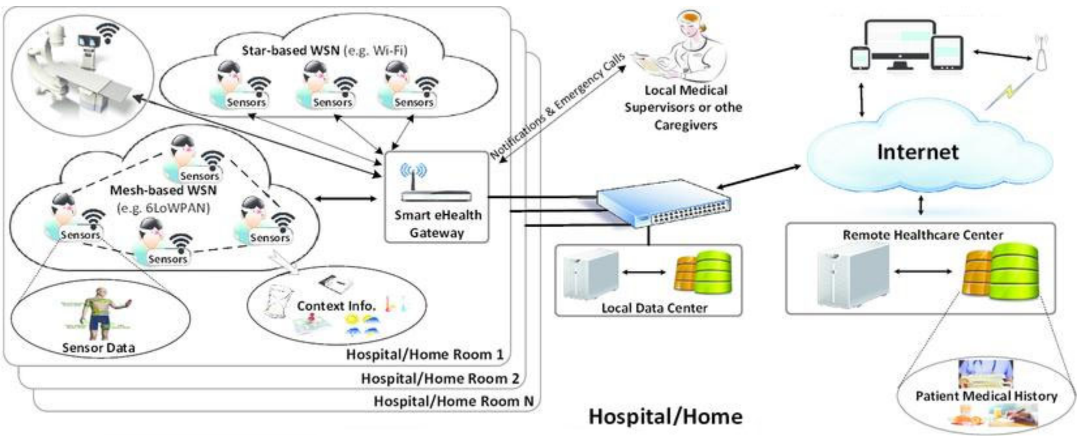

Figure 1. Health monitoring system architecture

2.2 Main hardware design of the system

In the system design, the STM32 chip is used as the processor for the coordinator and acquisition node. The wireless communication modules of the coordinator node, acquisition node, and routing node are the same in hardware. CC2530 module is adopted to realize ZigBee communication, and the BLK-MD-BC04-B Bluetooth module realizes the function of Bluetooth 4.0 communication between the coordinator and mobile terminal. Based on the STM32 platform, the system completes the development of the system physiological signal collection program, system control, display, storage, wireless module communication, Bluetooth module communication, and other functions. Complete the function development of the ZigBee network acquisition node, routing node, and coordinator node based on the CC2530 platform, and realize the construction of the ZigBee network. The acquisition node is the terminal of the ZigBee network, which is confirmed when the acquisition point receives the measurement command of the coordinator. The physiological parameter acquisition module collects human physiological signals and processes related signal hardware [3]. The acquisition device has its ZigBee communication node, displays the measured parameters such as blood pressure, blood oxygen, body temperature, and heart rate, and reads the physiological parameter data for summary. Upload data to the coordinator according to the coordinator's instructions. The whole terminal node structure design is shown in Figure 2.

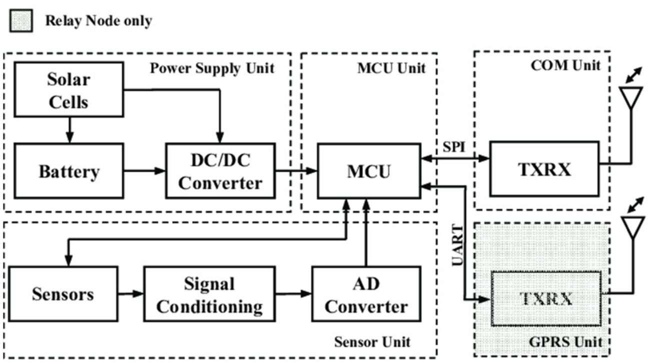

Figure 2. Hardware circuit structure diagram of system acquisition node

2.3 Design of health monitoring software

The program design flow chart of the CC2530 terminal node is shown in Figure 3. In the program design of the CC2530 terminal node, the sensor node program initializes parameters and receives commands. In the mean time, the heart rate and blood oxygen sensor module collect signals sent by the human body. The collected data is transmitted to the server through the CC2530 chip, and the alarm domain is set in the database platform of the server. In the process of software design, the A/D module of the CC2530 chip converts the incoming data information into digital signals [4]. The stability of the reference voltage and noise attribute of the CC2530 chip determine the accuracy of the conversion results. In the early stage, some human movements are fed back and set values, such as movement, walking, sitting, etc., and the binary return values of the corresponding three movements are 00, respectively. From 01, 10 to reduce error. The digital signal converted by the sensor is transmitted to the data acquisition terminal through the wireless transmission module. The data acquisition terminal carries out the following operation according to the control command transmitted by the server and then transmits the command of alarm or not to the sensor node for execution.

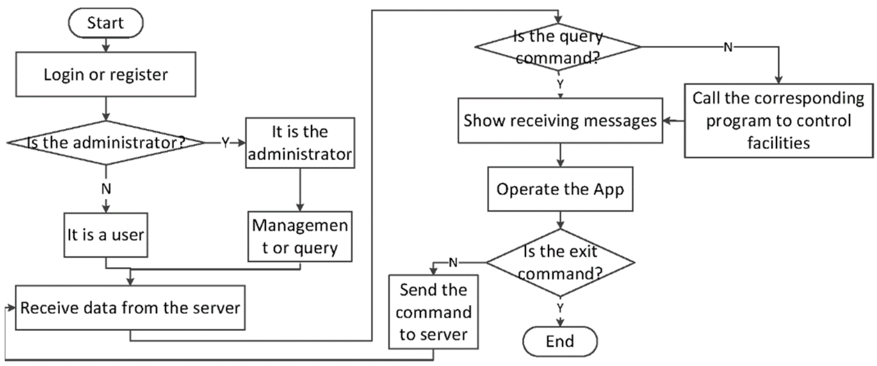

Figure 3. Programming flowchart of CC2530 terminal nodes

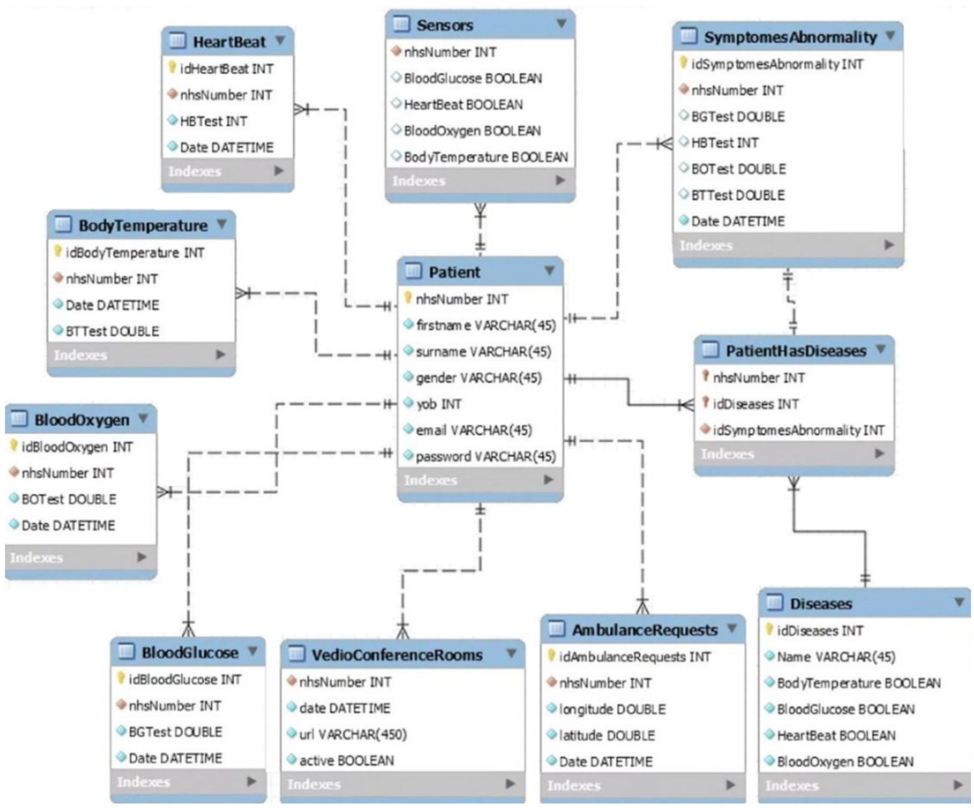

Figure 4. Health monitoring database design

The control terminal of the family member health monitoring system based on Zigbee technology can be used to control smartphones, touch screens, and PC terminals remotely. The CC2530 on the wearable device sends the collected data to the terminal computer via a Zigbee technology wireless network. During the study, the serial debugging assistant on the computer side was used to collect data records through the MySQL software and conduct real-time data transmission detection. The database establishment interface is shown in Figure 4.

3. Heart rate monitoring data processing algorithm

The heart rate sensor works by photoelectric volume, which drives two light sources of different wavelengths to shine alternately at the patient's radial artery in the wrist. The skin absorbs light because it contains vascular tissue. The periodic change of light intensity reflects the pulse cycle of the heart, forming a pulse wave signal [5]. The flow of the heart rate detection terminal is shown in Figure 5. During the actual operation of the system, after the initial operation, the MAX30102 heart rate sensor module first collects the patient's signal to obtain the photoelectric volume pulse wave signal. Then, the signal is transmitted to the Arduino processor, which processes the signal by differential threshold method and extracts feature points. Then, the patient's heart rate is calculated by the peak value of feature points, and OLED displays the information. After data collection, data is transmitted through ZigBee wireless communication network and finally uploaded to the leading computer platform for graphical display.

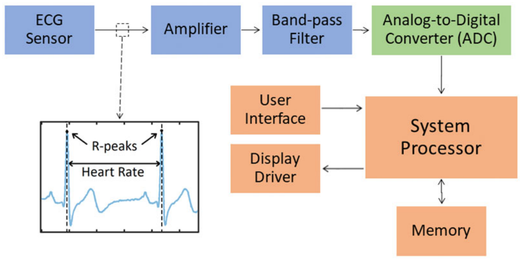

Figure 5. Flow of heart rate detection terminal

The system uses the differential threshold method to extract the feature points with steep falling or rising edges in the pulse wave signal to determine the peak coordinates and calculate the patient's heart rate. Let Us be the photoelectric volume pulse wave signal after filtering and de-noising and S1 be the primary differential value of S. The calculation formula is as follows:

$$S_1(i) = S(i) - S(i-k) \tag{1}$$

$$S_2(i) = \begin{cases} 0 & S_2(i) \geq S_2(i-k) \\ |S_1(i)| & S_2(i) \prec S_2(i-k) \end{cases} \tag{2}$$

Where: S_2 is the primary threshold processing signal; k is an empirical value, and k=2 is finally determined after multiple values in the experiment.

$$S_3(i) = \begin{cases} 0 & S_2(i) \prec H \\ |S_2(i)| & S_2(i) \geq H \end{cases} \tag{3}$$

Where, S_3 is the secondary threshold processing signal; The value of H is the value that selects all the values of S_2 in a period of time and intercepts half of the maximum value of S_2. The synchronous accumulation method repeatedly measures a certain point of the periodic signal. It accumulates the data obtained in each period to make the signal amplitude bigger and bigger, while the noise accumulation is not as apparent as the periodic signal accumulation to improve the signal-to-noise ratio and detect the signal from it. After repeated n accumulation for times, the output signal and noise are, respectively:

$$V_{n0}^2 = \sum_{-1}^{n} V_{ni}^2 \Rightarrow \sqrt{n} * \sqrt{\overline{V_n^2}} = \sqrt{2}E_n \tag{4}$$

$$V_{ns} = \sum_{-1}^{n} V_{si} n\overline{V_s} \tag{5}$$

Then the output signal-to-noise ratio after accumulation:

$$SNR = {V_{s0}^2 / V_{n0}^2} \Big/ {V_s^2 / V_n^2} = n \tag{6}$$

As can be seen from the above equation, the larger the cumulative number, the larger the signal-to-noise ratio. There are also many weak signal detection methods, such as the spectrum analysis method, but the traditional method to detect weak signals in strong noise background has certain limitations, mainly manifested in the detection of weak signals with a high signal-to-noise ratio threshold [6]. In addition, the special weak signal detection equipment is expensive, and its application scope is minimal.

4. System inspection

The ZigBee network designed by this system works in the 2.4GHz frequency band. The coordinator node is responsible for establishing the whole network, and the acquisition node and routing node join the network through the discovery coordinator. The diffraction and through-wall ability of the 2.4GHz frequency band are relatively weak. In order to ensure the ZigBee network stable and effective data transmission, Z-Network, the network topology monitoring software of TI, is used in the test process to conduct dynamic network monitoring and debug the stability of the network topology. The ZigBee network uses an AES-128 encryption algorithm for data integrity checks to ensure efficient network data transmission with a meager error rate [7]. Therefore, in the process of system development only need to carry on the packet loss rate test. The packet loss rate is the ratio of the number of packets lost during data transmission to the total number of packets sent. The test site is selected in the open grass flat, with one acquisition node, routing node, and coordinator node. The acquisition node continuously sends 1000 packets to the coordinator node through the routing node. Because the communication distance of 20m is sufficient for the single point activity range of patients when the acquisition node is used in the home or disease prevention, the communication distance can be continuously expanded by adding routing nodes, so the test distance is selected at 20m, 40m, and 60m respectively. The test results are shown in Table 1.

Table 1. ZigBee network communication test results

Transmission distance /m	Packet length/byte	Number of packets sent	Number of packets received	Packet loss rate /%
20	32	1000	1000	0
	64	1000	996	0.4
40	32	1000	988	1.4
	64	1000	984	1.6
60	32	1000	948	5.2
	64	1000	944	5.6

According to the experimental data, the packet loss rate reaches about 5% at 60m, and there is almost no packet loss when the 32-byte packet is sent at 20m, which can meet the design requirements of the system for wireless network data transmission performance and can be used in practical applications. The blood oxygen module of the acquisition node mainly tests the concentration of blood oxygen saturation, pulse rate, and pulse waveform of the human body [8]. Data is sent through the serial port during the measurement process, and the upper computer obtains trace waves according to the measured pulse data. The dynamic curve of the pulse wave is shown in Figure 6.

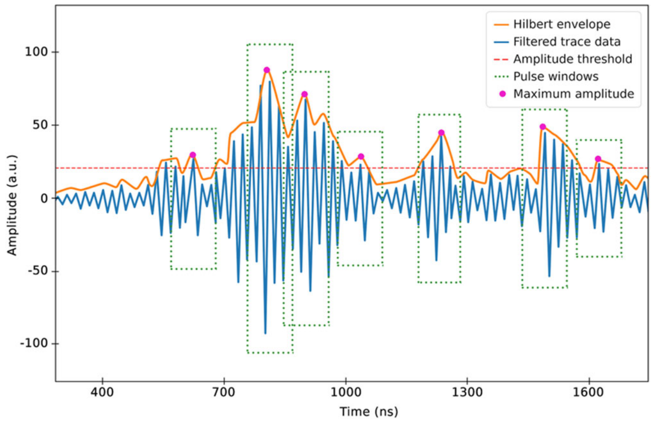

Figure 6. Pulse data are recorded

5. Conclusion

An intelligent wireless sensor network for the elderly based on LoRa is proposed, which is an integrated human health monitoring system composed of human physiological signals monitoring sensors, environmental detection sensors, and a LoRa wireless network system. In the system, environmental and physical health data information is collected by relying on an STM32 processor and sensor, and then LoRa technology is used to send the collected data to the gateway through the SX1278 module and then upload the data to the cloud server through the gateway. Then, the processed data is displayed to the user through the cloud server to realize real-time monitoring of the health status of the elderly in the community. The node communication adaptive system optimization algorithm is used to realize stable transmission of the elderly health data and achieve the monitoring effect of low power consumption, low latency, and high data transmission rate.

References

[1] Yang Gang, Feng Pengbo, Shi Yuxi,et al. Ultra low power consumption ANT wireless protocol elderly monitoring system. Chinese Journal of Sensor Technology,vol.86,pp.035-47,June 2022.

[2] Tian Yizong. Modeling of impacts of electromagnetic radiation pollution on environment and human health. Environmental Science and Management, vol.46, pp.137-140, 166, November 2021.

[3] Dong Hui, Ao Wencong, Luo Qiang, et al. Design and implementation of wearable intelligent posture system. Journal of Zhejiang University of Technology,vol.49,pp.79-84,January 2021.

[4] Chen Yuanxiang, Feng Jianqiang. Research on data classification model of wearable physical health monitoring for students. Automation & Instrumentation, vol.6, pp.18-24, June 2022.

[5] Zhu Guojian, Chen Aiying, Wang Ranran, et al. Research progress of wearable sensors for human health monitoring. Chinese Journal of Analytical Chemistry, vol.50, pp.120-127, November 2022.

[6] Ling Xinhang, Wang Hangshu, Wu Jun. Human health and home environment monitoring system based on Internet of Things. Electronic Devices, vol.45, pp.71-74, May 2022.

[7] Zhu Lingjian, Chen Jianhong, Wang Yuxin, et al. Research on Prediction method of pulse wave shape based on GRU neural network. Journal of Electronic Measurement and Instrument, vol.36, pp.67-72, May 2022.

[8] Li Feng, Lin Jingjing, Yun Jie, et al. Change characteristics of air pollution in Jining City observed by Lidar network. Spectroscopy and Spectral Analysis, vol.42, pp.99-104, November 2022.