

Basic Developing Environment of Microcontroller-based Monitoring System for Physiological Signals

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Abstract— In this study, an apparatus for basic physiological signal acquisitions sent to Could for monitoring and computation has been designed and implemented. The basic physiologic signals included user's temperature, breath rate, and heart rate. The Bluetooth communication technology was employed to connect between the microcontroller module and notebook computer or smart phone. The recurrent neural network was employed to precisely detect the respiration rates. Through the measuring of thermistor, the accuracy is over 90% for breath rate. The range of temperature error was 0.5°C. The previous output of the neuron network feedback and weighting averaged with new input. The method is precise. However, the complex neuron network should be discussed in the future work

for improving the accuracy of the system. The uncertain of computations was affected by the selections of computing durations. Because the raw data has been converted to values of heart and breath rates, the communication volume between client and cloud can be much reduced, as well as this technology can be employed for the other physiological signals to elevate the performance of this system in the near future.

Keyword—physiological signals, cloud, computation, Bluetooth communication, microcontroller.

I. INTRODUCTION

Physiological signals are the important signs to response the states of human health. Therefore, the preliminary diagnosis of medical doctors usually base on some of the basic physiological signals such as temperature, heart rate, and breath rate. However, the development of computer network is very close to one's living. Therefore, an idea of cloud computing-aided monitoring system has developed. In 1983, the concept of "The network is the computer" was announced by Sun Microsystems. In March 2006, Amazon proposed the flexible computing cloud service. Furthermore, Eric Schmidt, the CEO of Google, first proposed the concept of "cloud computing" at the Search Engine Conference (SES San Jose 2006). Thereafter, "cloud computing" is a new application of the technology of networking.

In the previous studies, the physiological signals have been distantly measured for the health care of elders, miners, patients and so on [1]-[9]. However, the record and data process of the physiological signals in cloud is a new technology in recent years [10]-[15]. Consequently, we developed a system of cloud aided monitoring of basic physiological signals as a beginning of the study of cloud aided health care with much reduced communication volume. Microcontroller-based physiological monitoring system (MBPMS) owns the advantages of small-scaled, moveable, flexible and reliable. Therefore, many previous studies presented various applications of MBPMS. For example, Istepanian et al. studied on an acoustic communication

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system to measure the underwater human electrocardiography (ECG). The results provided the information of the health of the underwater worker to aid the underwater safety for workers. The microcontroller was Intel 8751 which is a very popular microcontroller in the industries [16]. Thakor et al. employed MSP 430 which is a famous microcontroller for digital signal processing (DSP) to record and analyze human ECG, especially for the patients of cardiovascular disorder [17]. However, the technology of semiconductor manufacturing is still rapidly developing. Some advanced microcontrollers are with multiple functions of control, communication, computation, and compatibility. Therefore, some modern studies focused on integration of the physiological signals. For examples, Shalihah et al. employed Arduino as the microcontroller to collect the data of human ECG. The results showed 86.40% of accuracy, 87.38% of sensitivity, and 98.89% of positive predictive of the R-peak detection, respectively [18]. Hendra et al. used Arduino nano as the microcontroller to analyze the drowsiness detection using heart rate variability. The results presented 79.26% of accuracy of the drowsiness detection [19]. Singh et al. developed a microcontroller-based online nerve parameter estimation for diagnosis of healthy subject using real-time nerve conduction study signal acquired using voltage controlled neurostimulator. The microcontroller was PIC18F45K22 which is also famous in the industries. The circuit design of this system is less power consumption to extend the cycle of battery recharging [20].

He *et al.* [10] have proposed a 6-layer structure of a private cloud to serve the home health care. The communication media includes internet and cable TV networking. Pham *et al.* [21] studied on the home health care cloud. The communication media is internet network to connect cloud, user ends, and hospitals. In the user end, the physiological signals are transmitted by sensors with wired or wireless technology, and collected by personal computers (PC) or smartphones. Moreover, Fabiano *et al.* [22] collect a big volume of physiological data in cloud to aid the recognition of patients' emotion. Therefore, the acquisition of physiological signals with cloud computation is a modern model of the distant home health care. In our study, the microcontroller is ESP32 whose development board, NodeMCU-32S with the devices of WIFI and Bluetooth communications was employed to integrate the physiological signals.

Additionally, the strategies of the signal processing decide the accuracy and efficiency of the data acquisition. Artificial neural network (ANN) is a modern artificial intelligence (AI) method to process the signals. Many previous papers indicate the de-noising of respiration signals. Shi et al. have published a paper which indicated that lung sounds were de-noised by Wavelet method, and recognized by backpropagation neural network (BPNN).

A recurrent neural network (RNN) is one of the types of ANNs. In the viewpoint of digital logic design, the BPNN can be analogue as a combinational logic design, but the RNN can be regarded as a sequential logic design. Because the inputs and the outputs are independent of each other in BPNN, but the output in RNN is feedback to the data sequence. RNN also share parameters across each layer of the network. In feedforward networks, there are different weights across

each node. Whereas RNN shares the same weights within each layer of the network and during gradient descent, the weights and basis are adjusted individually to reduce the loss. Liu et al. proposed a dual-stage two-phase attention-based recurrent neural networks on four datasets in the fields of energy, finance, environment and medicine, respectively [23]. Sheikhan et al. employed RNN to classify 4 clusters in the application of information communication technology [24]. Noor et al. used RNN to analyze the multiple-channel signals of ECG [25]. The model gives 97.24% accuracy of abnormal heartbeat detections. Therefore, RNN is a simple and practical algorithm to be implemented in the microcontroller. In addition, the algorithm was widely used in many fields.

In the AI era, the combination of the technologies of AI, cloud, and big data is a trend to the future. Consequently, this study provides a basic environment for the applications of the 3 advanced technologies.

II. METHODS

The system was designed, implemented, and tested by the following procedures:

A. System structure

The system block diagram is presented in Fig. 1 which displayed four parts included sensors, microcontrollers, client, and cloud. The sensors contained the sensing of temperature, respiration, and heart beats. The microcontroller, ESP 32, connected with sensors, and processed the signals from the sensors. The RNN technique was employed for de-noising of the signals of respirations and heart beats. Consequently, the processed data was transmitted by Bluetooth communication module to the client which might be a PC or smartphone. Finally, the data sent to the Tencent cloud for data storage, monitoring, and management.

The communication system of this system concluded 2 parts. One is the Bluetooth communication technology which connected the data stream between sensor modules and ESP 32. The other is WIFI communication technology to connect the data stream between ESP 32 to the cloud. Therefore, the scale of the system can be reduced.

B. Sensors

The sensor for detecting temperature is thermistor which is a small volume epoxy resin produced by new materials and new processes. NTC thermistor has the advantages of high accuracy, small size, fast response, high stability, good interchangeability, and good consistency. For measuring the oxygen concentration in blood (OCB), The MAX30102 was employed to sense the physiological parameter. The MAX30102 is an integrated pulse oximetry and heart-rate monitor module composed with internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection. For measuring the blood pressure, XGZP6847A precise pressure sensor module integrating a silicon piezo resistive pressure sensor (XGZP SOP6) under PC board in a DIP6 package has been employed. For the applications of medical and healthy equipment, it is very suitable for blood pressure test and monitor, patient monitoring and so forth.

C. Microcontroller

The microcontroller is ESP32 whose development board, NodeMCU-32S with the devices of Wi-Fi and Bluetooth communications was employed. The features of the board are as follows,

(1) Solutions for Wi-Fi & Bluetooth technology

ESP32 can be used as an independent system to run applications or as a slave device of the host MCU, providing Wi-Fi and Bluetooth communication technology through UART interfaces.

(2) High integration

ESP32 integrates functions such as antenna switch, RF balun, power amplifier, receiving low-noise amplifier, filter, and power management module. ESP32 requires very few peripheral components to achieve powerful processing performance, reliable security performance, and Wi-Fi and Bluetooth communications.

(3) Ultra-low power consumption

ESP32 is specially designed for mobile devices, wearable electronics and IoT applications. It has the industry's high-level low-power performance, including fine-resolution clock gating, power saving mode, and dynamic voltage adjustment.

(4) Stable performance

The performance of ESP32 is stable, and the operating temperature range is -40°C to $+125^{\circ}\text{C}$. The integrated self-calibration circuit realizes dynamic voltage adjustment, which can eliminate the defects of external circuits and adapt to changes in external conditions.



Fig. 1. The system structure

D. Client

The client means the user end of the communication between cloud and user. The client can be PC or smartphone

which received the data by Bluetooth communication technology and sent data to cloud on the internet or mobile communication stream.

This Bluetooth module, HC-06, is mainly used in the field of short-distance wireless data transmission. It can be easily connected with the Bluetooth device of the PC and can also communicate with the data between the two modules.

E. Cloud

Tencent Cloud, a cloud computing brand created by Tencent Group, provides world-leading cloud computing, big data, artificial intelligence and other technical products and services to government agencies, enterprise organizations and individual developers in various countries and regions around the world. Excellent technological capabilities create a wealth of industry solutions, build an open and win-win cloud ecosystem, promote the construction of the industrial Internet, and help all walks of life to achieve digital upgrades. Tencent Cloud Server which works as a Cloud Virtual Machine (CVM) provides safe and reliable flexible computing services. Users can real-time expand or reduce computing resources, adapt to changing business needs, and only need to charge based on the resources actually used. CVM can much reduce the software and hardware resources and simplify IT operations and maintenances for users [26]. Many studies pointed out the performance and flexibility of the cloud computation [27-29]. Therefore, we choiced Tencent Cloud as a server for this study.

F. De-noise method

The microcontroller computes the breath and heat rates. Because of the environmental noises, the microcontroller has to cancel the noises of the signals. The RNN is a kind of neural networks. The training method is similar to the BPNN. However, the acquisitioned data from measurand is usually not enough for a BPNN. Therefore, RNN performs an observer to feedback the dataflow of neurons and enhance the computing convergence.

Besides, human respiration is not always stable. Some disturbances in the human airway makes the signals of respiration noisy. To count the respiration rate precisely, a filter is necessary to compute the real rates. In this study, the RNN was employed to be an AI filter for precision. The model of RNN is presented in Fig. 2 where $x[n]$ is the input signal and $y[n]$ is the output signal at the point n in the time sequence. The model can be interpreted as:

$$y[n] = w_1 x[n] + w_2 y[n - 1] \quad (1)$$

where w_1 and w_2 is the weights of the connection of the neurons. In addition, $\delta[n - 1]$ operates as a sampler of $y[n-1]$.

The neuron was activated by the function of Sigmoid. That is:

$$s(x) = \frac{1}{1+e^{-x}} \quad (2)$$

The nonlinear functions typically convert the output of a given neuron to a value between 0 and 1.

G, Experimental test

To show the performance of the system, some designs for experiments has been recorded. There were 4 cases for measuring the body temperature, blood concentration, heart

and respiration rates, i.e. the subjects (1) took a rest and (2) did an exercise. The 4 physiological signals of 3 subjects were measured before and after they did the exercise. The exercise was that the subjects walked up- and down- stairs from 1st floor to 3rd floor at the First Teaching and Learning Building, Guangdong University of Petrochemical Technology.

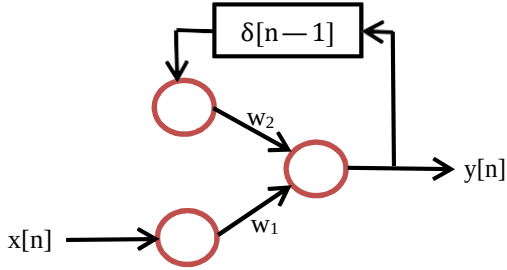


Fig. 2. The RNN model

III. RESULTS

A. RNN

After the training of ANN, the weights, w_1 and w_2 , were 0.4 and 0.6 respectively. Through the measuring of thermistor, the accuracy is over 90% for breath rate. The uncertain of computations was affected by the selections of computing durations.

B. Data transmission

Figure 3 displayed the transmitted data in the client. The data format is user number, week day, day (month/day), time (hour : minute : second), signal types (heart rate / temperature / breath rate/ concentration of blood oxygen), and value of the data. The sequence of the data was acquisitioned from the sensors, and processed by the microprocessor, then sent the data sequence to client by Bluetooth communication technology.

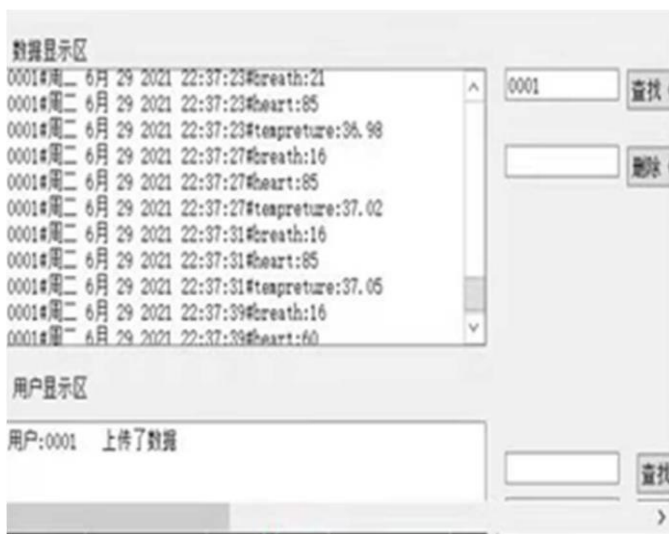


Fig. 3. The transmitted data in client

C. Data analysis

The users such as medical doctors in hospitals, patients and so forth can read the analysis of the data from Tencent cloud. The demonstration of the results is presented in Fig. 4. The

red line was denoted for breath rate, blue line indicated heart rate, green line indicated the user's temperature, and pink line is for the concentration of blood oxygen. Furthermore, the digital form of the corresponding data also displayed in the top of the screen. However, if the basic physiological signals show the higher or lower values which indicate the abnormal sign, it will activate the alarm function to remind the medical staffs or patients to avoid the accidents. The remind information was displayed in Fig. 5. The respiration rate of the subject was 50 times/second which was more than the limitation of normal rate, i.e. 25 times/second. The information displayed and reminded the subject to take a rest.

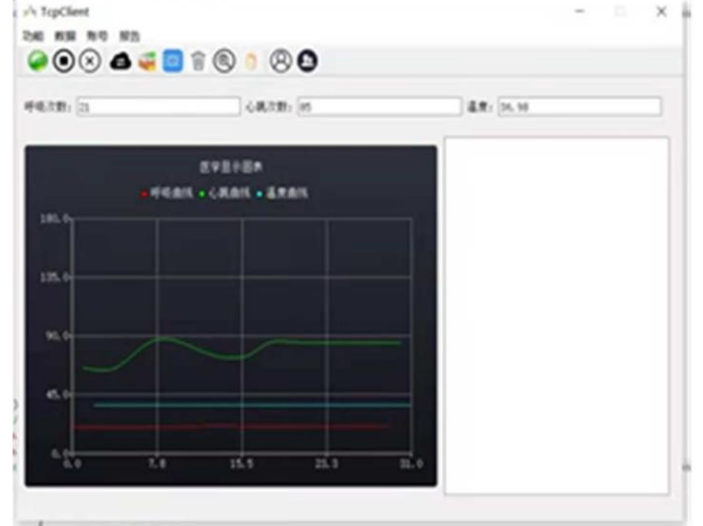


Fig. 4. The demonstration of the results

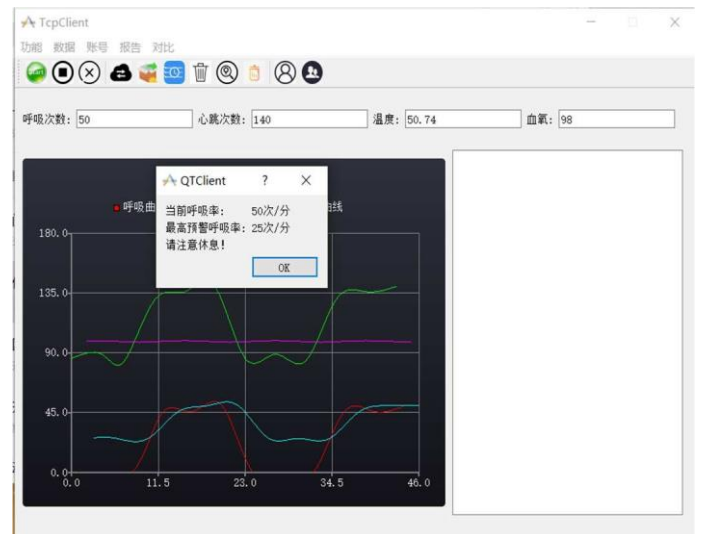


Fig 5. The remind information

D. Experimental results

The experimental results presented the excellent performance to present the comparison of the difference between before and after doing the exercise. An icon was specifically designed for measuring the 4 physiological signals before and after doing the exercise at the user end. Some of the results were illustrated. In Fig. 6, the compared results of the respiration rate in curves before and after doing the exercise have been presented. Both of the digital and graphical presentations aided the user to observe the parameters simultaneously and to read out the data clearly.

IV. DISCUSSION

The sensors of this study were the lower precision devices. Because of the preliminary study for the physiological monitoring system. It exists a large range for improving the precision of the devices. However, the structure of the system keeps the availability for the improving new sensors. The filtering technology for counting the breath rates is still an interesting problem for improving. The RNN model can be improved by spanning the number of the neurons to elevate the precision of counting the rates. It will be implemented in the new version of this system. Besides, the other ANN structures being possible to embed in microprocessor such as Fuzzy neuron network (FNN), FNN are going to be discussed to be implemented in ESP 32.

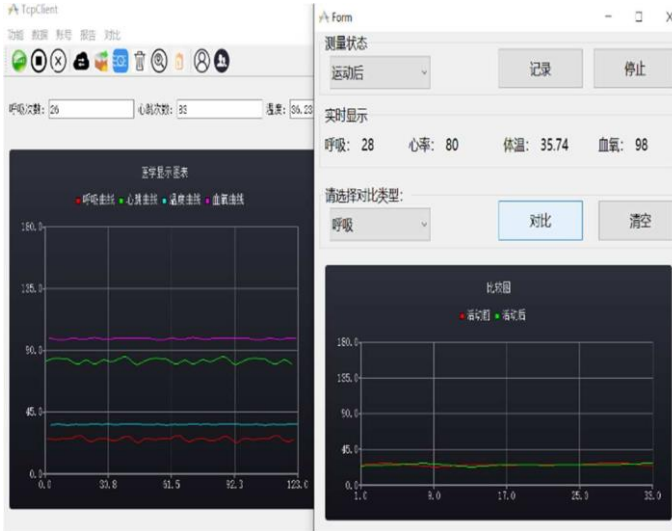


Fig 6. Comparison of the respiration rate in curves before and after doing the exercise

The accurate computations of breath and heart rates are interfered by the noise. Therefore, some de-noise techniques is necessary to be employed in the system. In this study, the algorithm was embedded in the microcontroller for de-noising. The advantages of the design are as follows:

- (1) The heart and breath rates are mainly regular, so that the BP algorithm can cancel the noise accurately.
- (2) The data communication volume between cloud and client can be much reduced, because the raw data has been converted to breath and heart rates. However, the data communication is not always free charge. Reduction of the communication volume is necessary on the point of business or green energy views.
- (3) The previous output of the neuron network feedback and weighting averaged with new input. The method is precise. However, the complex neuron network should be discussed in the future work for improving the accuracy of the system.

Based on the preliminary model in this study, we can add the other sensors to increase the functions of this system, and will expect to the cooperation in hospitals.

Tencent Cloud, a cloud computing brand created by Tencent Group, provides world-leading cloud computing, big data, artificial intelligence and other technical products and services to government agencies, enterprise organizations and individual developers in various countries and regions around the world. Excellent technological capabilities create a wealth of industry solutions, build an open and win-win cloud ecosystem, promote the construction of the industrial

Internet, and help all walks of life to achieve digital upgrades. Because much commercial software and many libraries are well-done at Tencent Cloud, many applications of AI, big data, and IoT are much reduced the operations of coding. The other famous clouds such as google, Badu, Ali, and so forth are also providing many servicers to the users. This study also supports the easier methods for the readers to build the platforms in cloud for the research.

The software design for the experiment is an entity for special purpose in this system. Therefore, some special purpose entities can be developed for the diagnosis, rehabilitation, healthcare or therapy, if they are necessary. Consequently, the system is very possible to be special and multiple purposes for users.

V. CONCLUSION

In this study, the special purposed entity for the software was developed for the experiment. The method can be widely used to create the special purposed entities for medical use. The distant healthcare of monitoring the basic physiological signals was implemented. The preliminary system can be added functions for increasing monitoring of the physiological signals. The RNN algorithm for filtering was embedded in the microprocessor ESP 32 and performed well in the experiments. Some errors occurred, but they depended on the selections of computing durations. The results were reliable. Because the raw data has been converted, the communication volume between client and cloud can be much reduced, and this technology can be employed for the other physiological signals to elevate the performance of this system in the near future. The transmission data volume can be reduced to be less than 10% of the raw data. Furthermore, because of the flexibility of cloud, the web site of the central computing unit was built as a simple form. Besides, RNN performs well to identify the noise of breath rates. The AI technology aid the small scaled system to increase the accuracy. The performance of the system is stable. In addition, the experiences of employing this system can conclude some firing rules. Therefore, the membership function can be designed much precisely. The applications of the methods of AI such as Fuzzy logic and other neuron networks will be applied for the auto diagnosis in the next version of this system to follow up the AI era.

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