Establish a smart healthcare system with AIoT for Chinese Medicine

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***Abstract*—This study establishes an intelligent medical system for diagnosis and treatment of Chinese medicine. Temperature and heart rate were measured using a variety of Internet of things technologies, including the WeMos D1 Mini with ESP8266 integrated and thermistors, and then the resistance was learned to relate to temperature via a neural network. In addition, the AD8232 biomedical sensor and the WeMos D1 Mini were used for ECG measurements and heart rate conversion. A self-written mobile application designed with multiple units to collect data from a variety of patients. The tongue diagnosis unit can recognize the characteristics of tongue substance and coating. The pulse examination unit adopts the five layer pulse method of Yaowangmai pulse. The inquiry unit adopts the syndrome differentiation method of Dr. Shaogong Shen. These IoT data, information if the patient's tongue diagnosis, five-layer pulse examination data and various inquiry data can all be read and transmitted to the cloud. The intelligent medical system of Chinese medicine in this study can also make preliminary treatment recommendations based on a variety of patient data and provide corresponding treatment drugs**

Keywords-Chinese Medicine; Smart Healthcare; AIoT; Artificial Intelligence Internet of Things; Intelligent Medicine

I. INTRODUCTION

Over the past few decades, the synergy between information technology and healthcare has attracted increasing attention around the world. Artificial intelligence has been widely used in research and development activities in many different fields, including healthcare. The Internet of Things and big data analysis are the technologies that will attract the most attention in the next generation of healthcare systems. Artificial intelligence-related technologies such as deep learning and many other innovations have transformed traditional medicine into smart medicine. Information technology and artificial intelligence can improve the quality of medical care in personal health management, diagnosis and treatment, nursing and other aspects[1]. Smart healthcare systems can extract critical information from vast amounts of patient healthcare data. Because of the limitations of the human brain, it can help doctors make better clinical decisions. In addition, smart healthcare systems can provide up-to-date medical guidance from journals, textbooks and clinical practice, helping doctors reduce diagnostic and treatment errors and make real-time inferences about faulty treatments.

According to Frost and Sullivan[2], the AI healthcare market will grow from $633 million in 2014 to $666.2 million in 2021. The compound annual growth rate is about 40-50% from 2013 to 2021. Imaging and diagnosis are becoming the main application fields of artificial intelligence medical technology. The imaging and diagnostics market is expected to grow at a compound annual rate of 40 percent from 2016 to 2024 [3].

Smart healthcare is often combined with the Internet of Things, called AIoMT(artificial intelligence for medical Things), which is the current research hotspot. AIoMT's architecture consists of four components, as follows:

(1).Perception components: physiological signals, patient information, Internet of Things data, wearable device data.

(2).Data components: electronic medical data, personal healthy data, electronic medical record.

(3).Technical components: artificial intelligence, big data analysis, AI image identification.

(4).Application components: disease prediction, image analysis and judgment, drug development and medical decision-making.

The world's elderly population is growing rapidly, with people over 65 now accounting for 8.5% of the world's population, or about 617 million. By 2050, this number is expected to reach 17%, or about 1.6 billion people[4,5]. In addition, global life expectancy is expected to increase by nearly eight years by 2050, from 68.6 years in 2015 to 76.2 years. Therefore, the increasing trend of chronic diseases in old age will lead to an increase in the demand for health care beyond the capacity and limits of the medical system. Therefore, the smart healthcare market combining artificial intelligence (AI), medical Internet of Things (IoMT) and telemedicine will grow greatly in the future.

The chronic diseases of the elderly population in the future will also lead to significant increases in health expenditure, which will increase the tolerance of countries for health insurance. Traditional Chinese medicine(TCM) is especially suitable for the health care and self-health management of the elderly. Elderly patients have a great demand for TCM. However, current research on smart healthcare focuses on western medicine.

Unlike western medicine, traditional Chinese medicine does not rely on blood test data or instrument tests. The diagnosis and treatment of TCM are based on the principle of syndrome differentiation(*Bian Zheng*). TCM syndrome differentiation is a comprehensive analysis of the clinical information obtained from observation, listening, asking and pulse four major diagnostic procedures to guide the treatment of TCM prescriptions. First, it collects tongue color, tongue coating texture features, pulse features, facial features, and asks about the characteristics of various physical symptoms. Then, it classifies patients into a certain syndrome, and then formulates drugs based on the syndrome.

There are few researches on smart healthcare of Traditional Chinese medicine. These areas include data classification, medical diagnosis and intelligent computing [6]. For example, Chen et al. used the tongue diagnostic instrument, pulse diagnostic instrument and other four-diagnostic auxiliary equipment to judge the difference between liver cancer patients and healthy population [7].

Therefore, the objectives of this study are as follows:

(1).Establish a smart healthcare system of Traditional Chinese medicine.

(2) The body temperature of patients was collected by AIoT technology. D1 microcontroller and thermistor sensing element are used to measure the temperature, and then the relationship between resistance and temperature is learned through neural network (CNN).

(3) AIoT technology was used to collect the heart rate of patients. AD8232 biomedical sensor and D1 microcontroller were used to measure ECG. A recursive neural network (RNN) was used to filter the wave and the heart rate was calculated according to the R wave.

(4) Build a mobile APP to read Internet of Things data (body temperature and heart rate) from the cloud platform. The app takes a photo of the patient with the tongue, sets up five layers of pulse to diagnose the patient's data, and builds patient inquiry data. This information can eventually be uploaded to the cloud via a self-written mobile APP.

(5) The smart healthcare system can conduct treatment based on syndrome differentiation, and finally provide preliminary treatment suggestions.

II. RESEARCH METHODS AND PROCEDURES

In this study, a variety of programming language technologies, including PHP and mySQL on cloud platform, Bootstrap, javascript, jQuery Mobile, Cordova, C language and Python language, were used to process the Internet of Things system.

A. Use AIoT technology to measure the patient's temperature:

(1) Establish AIoT circuit related materials include D1 miniature single chip (contains ESP8266 module, can online wifi network), NTC thermistor, 10 k Ω resistance. A bleeder circuit is formed by NTC thermistor and 10 k Ω resistance.

(2). Write mobile APP to communicate with Di min chip in real time, as shown in *Fig. 1*. Take the body temperature with an ear thermometer and also record the partial pressure of a 10K resistor.

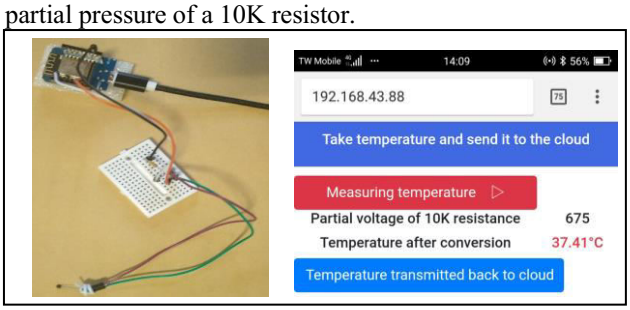

Figure 1. AIoT circuits and real-time measurement of body temperature is uploaded to the cloud

The protocol interface layer of the Internet of Things is generally divided into three types: HTTP, CoAP and MQTT protocols. In this study, we use HTTP protocol to handle the data transmission of interactive communication.

(3) Establish a neural network system: We use a two-layer CNN network to learn the relationship between resistance and temperature, as shown in *Fig. 2*. Because of the nonlinear relationship between thermistor and temperature, we use a two-layer neural network for deep learning. After training, it can predicts body temperature.

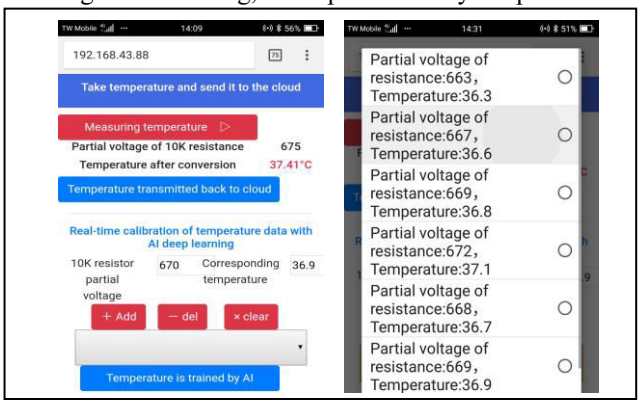

Figure 2. A two-layer CNN network is used to learn the relationship between resistance and temperature

(4) Upload measurement data to the cloud in real time to realize AIoMT system.

Because our recorded data is structured data, we receive it in the cloud using PHP with mySQL database rather than using Spark or MongoDB databases.

B. Use AIoT technology to measure the patient's heart rate

(1) Establish AIoT circuit: Related materials include D1 microcontroller, AD8232 biomedical sensor, and three electrode patches, which are attached to the left hand, right hand and left foot respectively, to form Einthoven's Triangle. The AD8232 biomedical sensor has a built-in filter to filter out some noise, but we also use a recursive neural network (RNN) to filter out noise, because RNN remembers the previous waveform and then uses the latest weighted average waveform, so the final wave will be smooth.

(2) The measured ECG was PQRST wave, and the amplitude of R wave was the highest. Heart rate is calculated as the mean time interval between R waves below 10 heartbeats.

(3). The real-time measurement data is uploaded to the cloud, as shown in *Fig. 3*, and the AIoMT system is implemented.

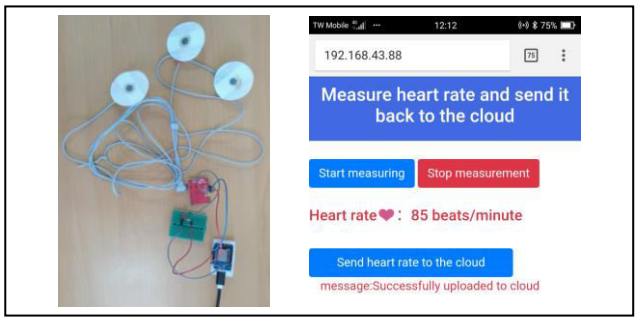

Figure 3. AIoT circuits and real-time measurement of heart rate is uploaded to the cloud

C. *Establishment of TCM mobile APP*

(1). Connect to the cloud platform Internet of Things database unit:

Establish a TCM mobile APP to read IoT data (body temperature and heart rate) from the cloud platform, as shown in *Fig. 4*.

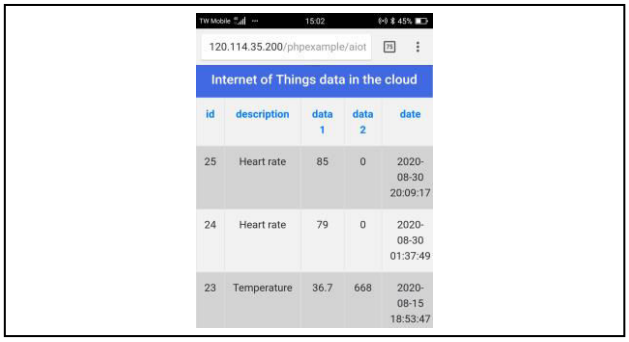

Figure 4. read IoT data from the cloud platform

(2) Pulse diagnosis Unit:

The TCM APP can record the tongue characteristics, pulse condition, inquiry, appearance observation and other medical information of patients on different dates, as shown in *Fig 5*.

Figure 5. The TCM APP can record or search for medical information of patients on different dates,

Since the current pressure sensor still does not have the sensitivity to measure the five-layer pulse on the wrist, the pulse condition is manually input. The AIoMT system of Traditional Chinese medicine will be improved after the problem of pressure sensor is solved in the future.

The pulse unit can input 34 kinds of pulse states, and finally display the pulse diagram of the left hand and the right hand on the wrist at 5 layers respectively, and display it with graphic symbols, as shown in *Fig. 6*.

Figure 6. Establish client's five - layer pulse.

We adopted the five-layer pulse method of Yawangmai [8], which is a structural pulse theory. The different levels of the combination pattern correspond to the relevant Chinese herbal medicine, so after the establishment of the five-layer pulse pattern, the corresponding medicine can be prescribed directly

(3). Unit of inquiry:

This unit will ask many questions about the patient's specific symptoms. It asks for the characteristics of various physical symptoms and then classifies the patient into certain syndromes. It is based on The syndrome differentiation method of Dr. Shaogong Shen, and it is also a structural system that can be directly applied in programming[9]. The traditional ten inquiries and syndrome classification are improved, and the deficiency syndrome is divided into four categories, and the excessive syndrome is divided into eight categories, and the concurrent and mixed syndrome is divided into eight categories.. It subdivides syndromes into minimum units, each of which has the corresponding symptoms and corresponding drugs.

For example: the main symptoms of qi deficiency are thin whitish coating of the tongue, pale tongue, fine and deep pulse, short of breath. The corresponding treatment drugs are codonopsis, astragalus, white atractylodes rhizome, agrimony and lablab bean, as shown in *Fig. 7*.

Figure 7. The inquiry data of the patients were established by the method of syndrome differentiation.

(4). Unit of tongue diagnosis:

Tongue examination unit can set the quality of tongue substance and the characteristics of tongue coating on the tip, middle, bottom, and sides. The patient's tongue can also be photographed directly, as shown in *Fig. 8*.

Figure 8. Establish the patient's tongue diagnosis data

These characteristics of tongue diagnosis are important parameters of the syndrome differentiation classification method within the inquiry unit.

(5). Unit of intelligent analysis:

This system can carry out the initial treatment of syndrome differentiation and provide preliminary treatment recommendations based on various patient data from the previous unit. At present, there are two prescription suggestion schemes available. The first one is based on method of syndrome differentiation classification by Dr. Shaogong Shen. Prescription suggestion can be given after the setup in inquiry unit and tongue diagnosis unit, as shown in Fig 7.

The second prescription suggestions can be given automatically after setting five layers pulse in pulse unit according to the Yaowangmai pulse method, as shown in Fig 9.

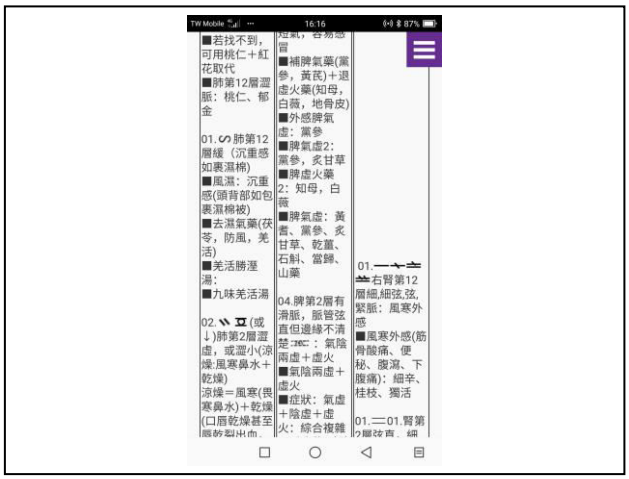

Figure 9. The prescription suggestions can be given automatically after setting five layers pulse.

The data from each unit can eventually be uploaded from the mobile APP to the cloud database.

III. Results and Discussion

This is a preliminary study of smart healthcare for Chinese medicine, and the overall structure has been successfully constructed. The system is able to collect physiological parameters, symptoms and various diagnostic data of patients and upload them to the cloud database for electronic medical record storage.

Doctors can consult patient information at any time, and obtain recommended treatment plans through intelligent analysis to provide reference for clinical prescription.

Artificial intelligence is widely used in many fields that require a lot of knowledge. For example, in western medicine, the accuracy of AI in medical image recognition is higher than that of human recognition. Therefore, the application of AI in TCM is imperative in the future, which cannot be avoided, because TCM needs more knowledge in the diagnosis and treatment process than other fields.

In the future, this study will continue to complete the incomplete part. For example, in the development of smart medical treatment, Traditional Chinese medicine will inevitably encounter the problem of how to accurately identify pulse diagnosis and tongue diagnosis.

Current pulse diagnostic instruments are not as accurate as the three - or five-layer sensation under an older doctor's finger.

We cannot make TCM scientific, but in the process, we gradually lose some of the key elements of TCM. For example, the original spirit of TCM syndrome differentiation will be lost if we simply use the current relatively single pulse diagnosis instrument. How to keep the core technology of syndrome differentiation in the intellectualization process of TCM is the key point of TCM informatization research. Otherwise, the final result is just a scientific and technological product quite different from TCM syndrome differentiation and treatment.

As the AI interpretation of tongue diagnosis are relatively simple subjects compared with multi-layer pulse instrument, image recognition of tongue diagnosis will be the focus of this study in the future.

IV. Conclusion

In this study, PHP, mySQL, Bootstrap, javascript, jQuery Mobile, Cordova, C language, Python language and other programming language technologies on the cloud platform are utilized to process the Internet of Things system. Finally, a smart healthcare system of TCM has been successfully established.

This study employs the Internet of things to collect patient data, including D1-Mini microcontroller and various sensors to measure body temperature and heart rate, and uses CNN to learn the nonlinear curve of temperature and RNN for filtering wave.

The tongue diagnosis unit can recognize the characteristics of tongue substance and coating, and also upload to the cloud by taking photos of the patient's tongue. The pulse examination unit is based on method the five-layer pulse method of Yaowangmai. The inquiry unit is based on method of syndrome differentiation classification by Dr. Shaogong Shen. Both the five-layer pulse method and the dialectical query method are structured and suitable for integration into computer programs

The intelligent medical system in this study can also interpret treatment based on syndrome differentiation according to all kinds of data of patients, and provide corresponding therapeutic drug suggestions in two ways. The intelligent medical system in this study can also make preliminary treatment recommendations based on a variety of patient data and provide corresponding treatment drugs in two ways.

V. Acknowledgements

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