Design and Implementation of a Remote Diagnosis System for Congenital Heart Disease Based on DjangoRestFramework

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ABSTRACT

Congenital<fn id="fn5" fn-type="other">
</fn> heart disease, referred to as CHD, is a disease that seriously harms the health of children and adolescents. The earlier the treatment, the better the effect. The distribution of domestic medical resources is uneven, and the level of medical staff's auscultation is uneven, and it is impossible to provide accurate initial diagnosis results for patients with congenital heart disease. Many remote hospitals are not equipped with cardiac color ultrasound equipment and cannot make a final diagnosis of congenital heart disease. Therefore, the research integrates DjangoRestFramework and other framework technologies to design a set of congenital heart disease database management and remote auscultation system, adopting a front-end and back-end separation architecture to achieve low coupling and high cohesion procedures, which is convenient for later maintenance and management of the system. The system includes modules such as personnel management, collection information management, data statistics visualization, and uses wavelet to denoise the signals collected by Bluetooth heart sound devices. The algorithm effectively filters out environmental noises and physiological noises such as patient breathing, making the doctor's remote auscultation effect consistent with the effect of using a stethoscope. After the stress test, the system works well and can provide remote diagnosis services for congenital heart disease over the Internet for people in economically underdeveloped areas.

CCS CONCEPTS

• Software and its engineering; **• Software creation and management**; **• Designing software**; **• Software design engineering**;

KEYWORDS

Congenital heart disease, Remote auscultation, Heart sound, Djangorestframework, Cloud platform

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1 INTRODUCTION

Congenital heart disease, referred to as congenital heart disease, is the most common type of congenital malformations, accounting for about 28% of various congenital malformations [1]. If the congenital heart disease is not treated in time, it will affect the development of the child, and it will induce malignant arrhythmia or sudden death. Therefore, the diagnosis of the patient as soon as possible is of great significance for subsequent treatment. According to data released by the Yunnan Provincial Health Commission, in 2018, children with congenital heart disease born each year in the province accounted for 0.95% of newborns, that is, about 6000 children with congenital heart disease were born each year, much higher than the international children with congenital heart disease. It accounts for 0.6% of newborns [2]. Currently, screening for congenital heart disease mainly relies on the provincial medical team to go to the countryside to carry out cardiac auscultation. The medical team has a difficult journey and is understaffed, and it is difficult to cover all remote areas. The use of electronic heart sound acquisition equipment to upload heart sounds to the cloud for analysis allows congenital heart disease diagnosis experts to perform congenital heart disease screening without going out, thereby saving human and material costs in congenital heart disease screening. Therefore, it is very necessary to use electronic assisted auscultation and cloud services for initial diagnosis. In terms of electronically assisted auscultation, Huang Mei and others designed a new electronic stethoscope system for computer-aided diagnosis, but did not use the network platform, which greatly restricted the scope of use [3]. Zhao Xiao from Xihua University and others designed a heart sound management and diagnosis system based on the SSH framework [4]. Although the system uses a network platform, it

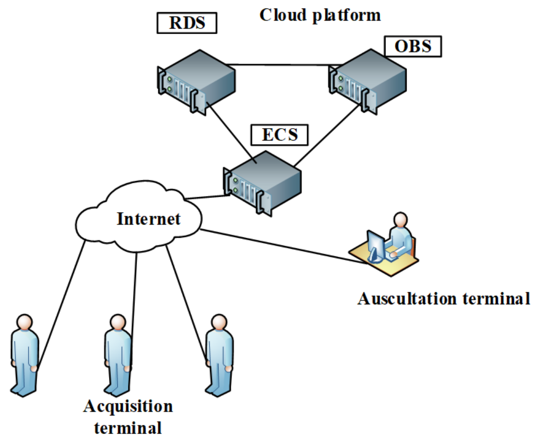

Figure 1: System Usage Diagram.

does not configure cloud services. When multiple users access at the same time, the system may crash.

Aiming at the above shortcomings, this paper designs a remote auscultation and heart sound database management system for congenital heart disease based on DRF framework (DjangoRestFramework) technology (hereinafter referred to as the system), which is based on a set of Bluetooth heart sound collection equipment developed by the research team in this laboratory and Android APP[5], and then upload the data to the HUAWEI CLOUD platform. The system has the characteristics of high concurrency, real-time remote diagnosis service, visual statistics function, table data export, heart sound environmental noise filtering, etc. The system deployment uses 3 cloud service tools, and the reasonable division of labor between different tools greatly improves the reliability of the system. It can be used on the computer side, and can also be used on smart mobile terminals such as smart phones and tablet computers. It makes up for the shortcomings of the previous heart sound management diagnosis system of weak concurrency and lack of centralized data management functions. The system is used for the diagnosis of congenital heart disease in poor medical conditions and economically backward areas. Provides convenient remote services.

2 SYSTEM REQUIREMENTS ANALYSIS

System function brief description: The doctors of the township health center upload the heart sound signals to the cloud platform through the system's heart sound collection equipment, and the auscultation doctors use computers or mobile devices to perform remote auscultation via the Internet. The system usage is shown in Figure 1

The system requirements are as follows:

The system divides users into three categories: primary doctors (signal acquisition), auscultation doctors, and system administrators. Data modification and data statistics are functions shared by the three users, but the scope of data statistics that can be viewed by different accounts is different. Collection information management is a function shared by the administrator and the signal collector, but the administrator can view the data used, and the collector can only View the data under this account. The auscultation doctor has a unique online auscultation function to complete the initial diagnosis of congenital heart disease through the web. The administrator can add, delete, modify and check the account information of all signal collectors and medical staff. The system can carry a large number of concurrent users: it can still operate normally even when multiple users access at the same time. The system is also equipped with a heart sound denoising function: in the process of heart sound collection, environmental noise is often mixed in, so it is necessary to denoise the collected heart sounds [6].

3 SYSTEM DESIGN

3.1 Digital Stethoscope Design

This design uses Thinklabs One heart sound sensor, which has a frequency response range of 20-2000 Hz and supports a maximum magnification of 100x. Using this sensor can better retain the frequency characteristics of the heart sound signal, so that the heart sound signal collected by the system can be further used for doctor auscultation.

The heart sound sensor outputs an analog signal, which is converted into a digital signal through the AD conversion circuit in the Bluetooth acquisition device, and then transmitted to the Android smart device through the Bluetooth acquisition module.

3.2 Cloud Platform Architecture Design

The cloud platform used by the system consists of three cloud computing tools, namely Elastic Cloud Server (ECS) [7], RDS (Relational Database Service, RDS), and Object Storage Service (OBS) [8], as shown in Figure 2

(1) ECS: A cloud server that can be automatically acquired at any time and the computing power is elastically scalable, used to deploy the front and back end programs of the system server.

(2) RDS: A stable, reliable, and elastically scalable online database service, with a complete automatic data backup mechanism, connected to the elastic cloud server intranet to maximize data security, and used to store collected information and data.

(3) OBS: An object-based mass storage service that provides customers with massive, safe, highly reliable, and low-cost data storage capabilities for storing auscultation audio data.

The cloud platform architecture design separates the deployment program, database, and heart sound audio data storage, which greatly increases the stability of the system [9].

3.3 Function Module Design

According to the demand analysis in the first section, the system function module analysis is as follows:

The administrator can view all data in the database, while the signal collectors and medical staff of local township hospitals can only view the data of this account. Strict access control can better protect patient information from being leaked. The doctor conducts remote auscultation on the patient's heart sounds on the web page through an external headset, and fills in the diagnosis results into the system table. After seeing the results of the initial diagnosis, the local township hospitals collecting heart sounds notify the patients for further examination or inform the patients of precautions.

The remote auscultation operation process is shown in Figure 3:

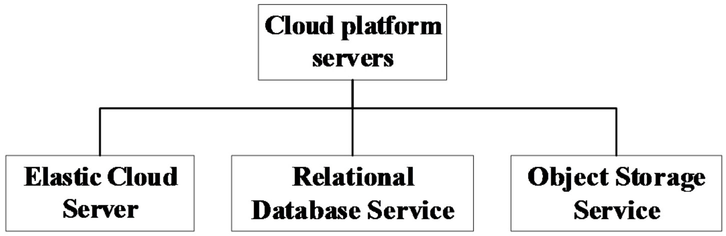

Figure 2: Cloud Platform Architecture.

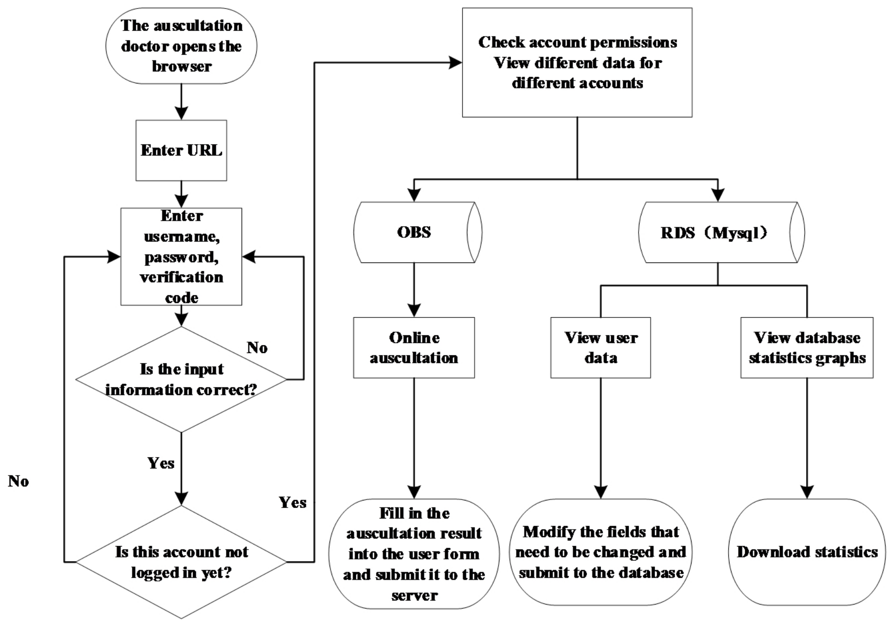

Figure 3: Remote Auscultation Operation Flowchart.

The auscultating doctor opens a browser, enters the website where the cloud platform is located, and enters the account and password. After the authentication is correct, he can perform online auscultation, view the information of the collected person, statistical charts and other functions.

4 SYSTEM IMPLEMENTATION

4.1 System Front-End Implementation

The front-end homepage of the system is the back-end management page of the heart sound system. This page is the main function page of the system. As shown in Figure 4, it is mainly used to add, delete, modify and check patient information, and part of the privacy column data has been hidden.

On the data statistics page, four statistical graphs are designed, which respectively count the age distribution, the number of diseases, the gender ratio, and the ratio of whether to operate or not. As shown in Figure 5 and Figure 6, two of the graphs are displayed. The age distribution uses Nightingale's rose chart, the size of the data is expressed according to the length of the fan radius, and the histogram with sliding window is used for the number of disease types, so you can slide to view more data [10].

The online auscultation page is implemented using Xgplayer, as shown in Figure 7, by laying out 5 players on the page, the realization of 5 areas of heart sound auscultation is completed [11]. The 5 areas are:

(1) Point M, the area of the mitral valve, is located at the strongest point of the apex, and is normally located at the 5th intercostal space on the inner side of the left midclavicular line.

(2) Point P, the pulmonary valve area, is in the second intercostal space on the left edge of the sternum.

(3) Point A, the aortic valve area, in the second intercostal space on the right edge of the sternum.

(4) Point E, the second auscultation area of the aortic valve, is in the third intercostal space on the left edge of the sternum.

(5) Point T, tricuspid valve area, at the left edge of the lower end of the sternum, that is, the 4-5th intercostal space on the left edge of the sternum.

Hide pagination | Refresh | Show card view | Fullscreen | Columns | Export data

Search | Search | Clear Search

	Gender	Age	Collection Date	Surgery or Not	Diagnostic Result
	Male	4	2020-11-18 11:03:03	YES	ASD
	Female	15	2020-11-18 10:55:48	YES	VSD
	Male	6	2020-11-18 10:41:56	YES	VSD
	Male	1	2020-11-16 11:13:50	NO	VSD
	Male	3	2020-11-16 11:05:41	NO	ASD
	Male	18	2020-11-13 12:31:17	YES	ASD
	Female	15	2020-11-13 12:27:25	NO	VSD
	Female	17	2020-11-13 12:17:55	YES	PDA
	Female	10	2020-11-13 12:12:54	NO	ASD
	Male	5	2020-11-13 12:06:43	NO	VSD

Figure 4: Patient Information Management Form.

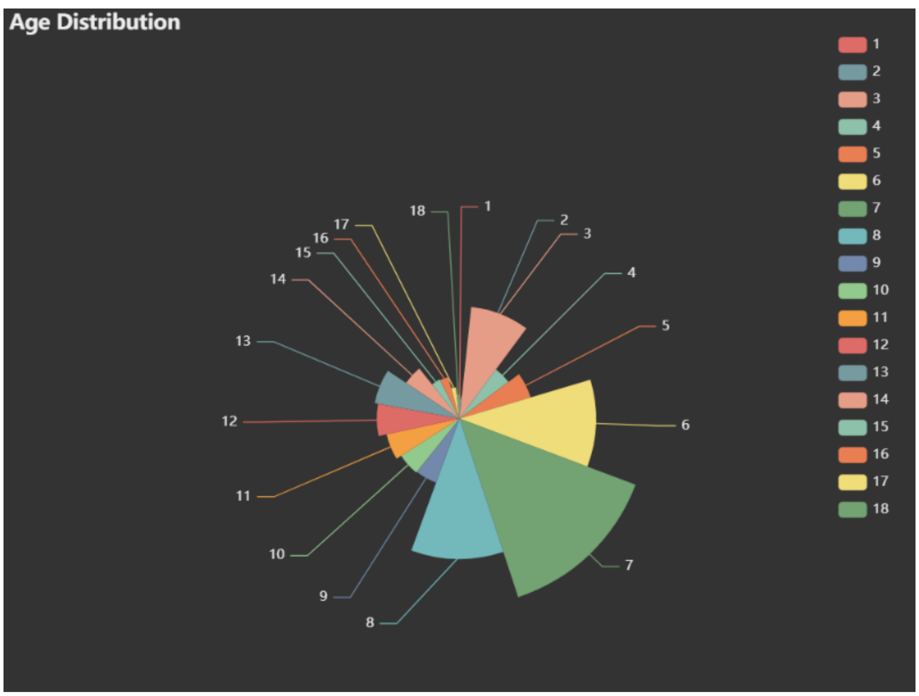

Figure 5: Age Distribution.

4.2 System Back-End Implementation

Django is a heavyweight framework. Its MTV framework, built-in ORM, admin background management, as well as the SQLite database and the server for development and testing have improved the developer's ultra-high development efficiency. The disadvantage of the Django framework is that if the system does not have many functions, it is easy to be bloated. The main features of the Flask framework are small and light, with almost zero native components, easy to get started, and you can clearly understand the running process of Flask through the official guide. The disadvantage of the Flask framework is that for large-scale website development, routing mapping rules need to be designed, otherwise it will lead to code confusion. The main feature of the Tornado framework is that

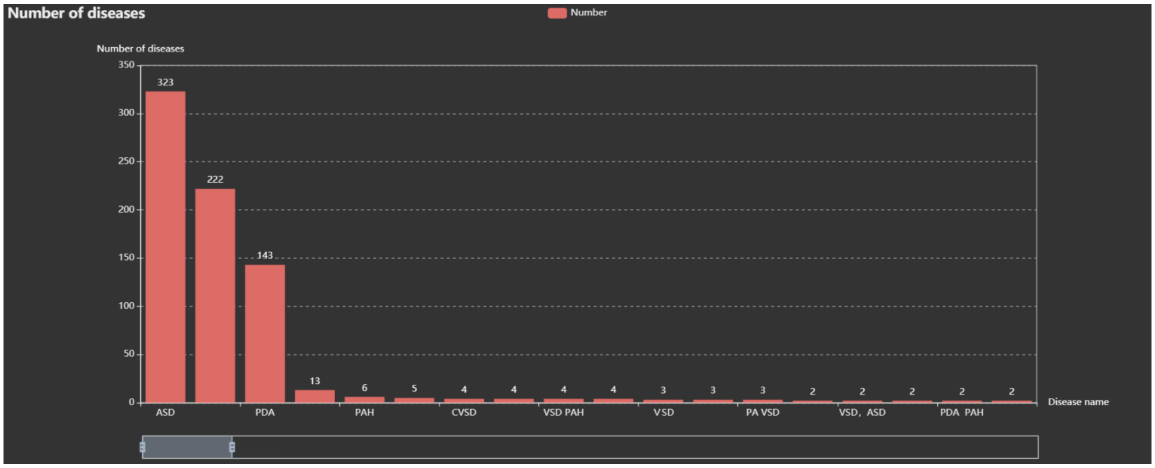

Figure 6: Number of Diseases.

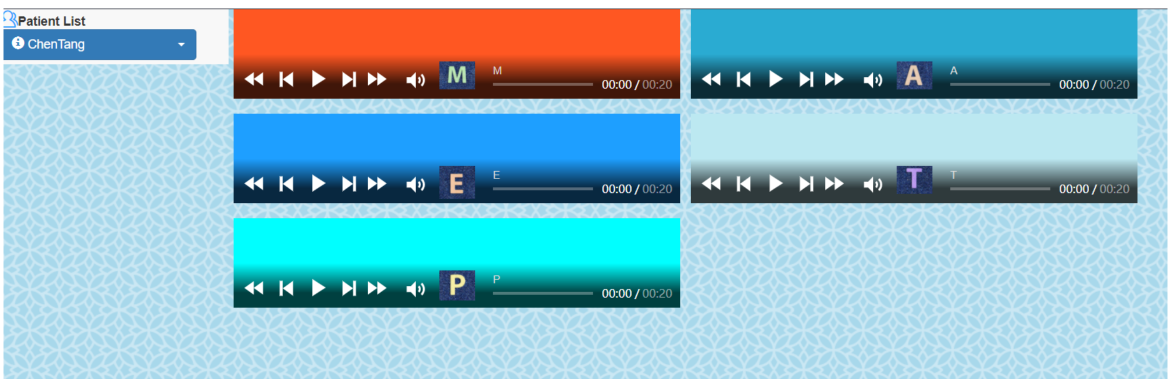

Figure 7: The Page of Online Auscultation.

it is natively asynchronous and non-blocking. It has an absolute advantage in IO-intensive applications and multitasking. It is a dedicated framework. Its disadvantage is that there are many third-party modules to choose from in the template and database part, which is not conducive to packaging as a functional module . The back end of the system uses the DjangoRestFramework framework, which is a framework developed based on Django based on REST[12]. The biggest features of REST are: resource, unified interface, URI and stateless [13].

Table 1 lists the main interface design in this system. The function of the interface is illustrated as follows. For example: http://127.0.0.1/api/v1/update_passwd/+username means: the server request interface address is 127.0.0.1, the port is 80, and api is the interface root route, v1 is the interface version control, which is convenient for later interface maintenance and management. The next parameter, such as update_passwd, is the interface function description, and the last parameter username is the user who performs the interface function. If the interface does not have this information, it is to find all data. For example, the third interface in Table 1 is to find all users in the group.

4.3 Heart Sound Denoising Algorithm Design

Heart sound signals are generally collected in hospital wards or school health care rooms, so they are easily disturbed by voices, the sound of the patient's skin rubbing against the collection equipment, and the patient's own breathing. The sensor is mixed with the above noise, which is not conducive to the doctor's remote diagnosis. Therefore, the heart sound needs to be denoised.

Heart sound denoising algorithms commonly used include Butterworth filter, Kalman filter, wavelet denoising, etc. [14]. Wavelet denoising uses the Mallat algorithm and has the following important steps: determining the wavelet base, determining the number of wavelet decomposition layers, and determining the denoising threshold. The wavelet base is divided into Daubechies, Symmlets and Coiflets wavelet clusters. Among them, Symmlets is an improved Daubechies wavelet, but its symmetry is poor. After denoising based on the 5-layer db2 wavelet, it can better retain pathological murmurs and heart sounds. , The system uses db2 wavelet base for heart sound denoising.

In Figure 8, a_i (i = 1, 2, . . ., n) represents the approximate vector when the number of decomposition layers is the i-th layer, and d_i (i = 1, 2, . . ., n) represents the number of decomposition layers when

Table 1: Interface Design

URL of Interface	Interface function
http://127.0.0.1/api/v1/update_passwd/+username	Update user password based on user name
http://127.0.0.1/api/v1/delete_info/uuid	Delete database information based on UUID
http://127.0.0.1/api/v1/Usernamelist/	Get the list of users managed by the administrator or group leader
http://127.0.0.1/api/v1/AgeChart/	Get age distribution chart

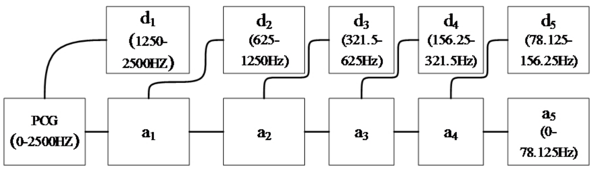

Figure 8: Mallat Algorithm Wavelet Denoising 5-Layer Decomposition Block Diagram.

the i-th layer is Detail component. It is pointed out that the main frequency of heart sound signal is concentrated in 40-105Hz, the main frequency range of heart murmur is between 80-200Hz, and the effective information of heart sound distributed at frequencies above 1000Hz is extremely rare. In order to make the heart audio band of the subsequent feature extraction step concentrate on a unified Scope, when the heart sound signal is reconstructed by wavelet, the d_1 signal component with the most extensive environmental noise distribution is directly set to zero. Since the heart sound signal involves analog-to-digital conversion in the acquisition process, the process must meet the Nyquist sampling law, that is, the highest effective frequency of the stored digital signal is 1/2 of the sampling frequency, then the wavelet decomposition layer n is determined by the formula (1)determine.

$$\begin{cases} \frac{f_s}{2^{n+1}} \leq 80 \\ n = \min(n) \end{cases}, n \in N^* \tag{1}$$

Among them, fs represents the sampling frequency. The heart sound sampling frequency in this paper is 5000Hz. From the formula (1), it can be concluded that when the decomposition layer number n is 5, the obtained frequency components can be better focused on the principal component details of the heart sound.
According to the wavelet decomposition theory, the reconstructed heart sound signal can be expressed by formula (2).

$$PCG = a_5 + d_5 + d_4 + d_3 + d_2 + d_1 \tag{2}$$

It can be seen from Figure 9 and Figure 10 that the heart sound denoising algorithm used in the system can effectively remove noise and retain pathological information. In order to verify the effectiveness of the denoising method used in the system in real scenarios, 30 cases of normal signals and 30 cases of abnormal signals were randomly selected from the heart sound database constructed in the laboratory. After denoising, 60 cases of signals were mixed with undenoised signals. There is a total of 120 cases of signals. Professional auscultation doctors in Fuwai Yunnan Cardiovascular Hospital are invited to listen blindly under the condition of unknown signal

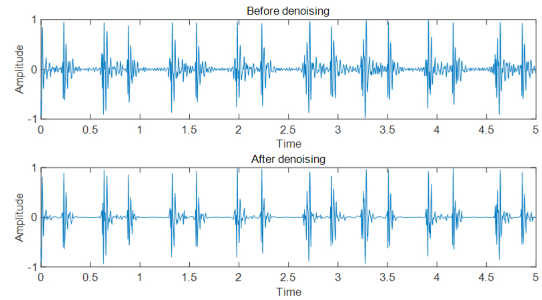

Figure 9: Abnormal Signal Filtering Effect.

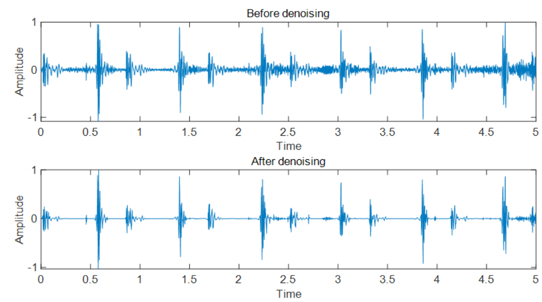

Figure 10: Normal Signal Filtering Effect.

echocardiographic diagnosis results. Each heart sound is marked and the result is marked as abnormal or normal. TN represents the number of normal heart sounds marked by auscultation doctors as normal signals, TP represents the number of abnormal heart sounds marked as abnormal signals, FP represents the number of normal heart sounds marked as abnormal signals, FN represents the number of abnormal heart sounds marked as normal signals. The marking results are shown in Table 2. As shown, the evaluation indexes are shown in Table 3. The evaluation indexes used are Specificity, Sensitivity, Accuracy, and the formulas are shown in (3)-(5).

$$Specificity = \frac{TN}{FP + TN} \tag{3}$$

$$Sensitivity = \frac{TP}{TP + FN} \tag{4}$$

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{5}$$

It can be seen from Table 3 that after the system uses the heart sound denoising algorithm, the accuracy of auscultation by professional

Table 2: The Signal Result of The Doctor Marked

	TN	TP	FN	FP
Before denoising	21	20	10	9
After denoising	26	25	5	4

Table 3: Comparison of Evaluation Indexes of Doctor Auscultation Results

	Specificity	Sensitivity	Accuracy
Before denoising	68.7	69.0	68.0
After denoising	83.9	86.2	85.0

doctors is significantly improved, and the increase in specificity and sensitivity enables doctors to ensure the accuracy of auscultation even when the positive and negative samples are imbalanced.

5 SYSTEM STRESS TEST EXPERIMENT

The system is deployed using Nginx, and the elastic cloud server is configured with 8G memory and 4-core CPU. Use Siege to stress test the cloud platform to evaluate how many users can use the system at the same time.

Siege is a stress testing and evaluation tool that can perform concurrent multi-user access to a website according to the command configuration, record the response time of all request processes for each user, and perform repeated concurrent access under a preset number. Table 3 shows the performance of the website. The main parameters in Table 4 include:

(1)Response time: Response time refers to the complete time for the system to respond to the request. This indicator is very consistent with people's subjective perception of software performance, because it completely records the time taken by the entire computer system to process requests.

(2)Throughput rate: Generally, the number of requests processed by the server per unit time is used to describe its concurrent processing capability. Called the throughput rate, the throughput rate specifically refers to the number of requests processed by the Web server per unit time.

(3)Transactions: The number of transactions or transactions that the system can process per second. It is an important indicator to measure the processing capacity of the system.

(4)Concurrencies number: The number of users who simultaneously send requests to the server at a certain time.

Test parameters: 255 concurrent users, lasting 1 minute, respectively, test 3 pages of the website.

It can be seen from Table 4 that with the increase in the number of visits, the success rate of visits can be maintained above 99.80%, the average response time is about 1 second, and the number of concurrencies is above 200, that is, the website can meet the maximum of 200 users at the same time. Although there may be a small probability of more than ten failed requests, users can still use the website smoothly.

6 CONCLUSIONS

The entire system has passed the stress test, showing good service quality and can meet daily use. Compared with the previous electronic assisted auscultation system, the system is deployed on a cloud platform, which improves the security of data storage and the stability of website services, and at the same time expands the scope of use of the system. The application scenarios of this system can be in hospitals and schools, requiring heart sound sensors and Bluetooth heart sound collection device and Android devices with Internet access. The next step is to add a real-time communication module to make remote communication between patients and doctors more convenient. Our research team has cooperated with 7 township health centers on pilot projects, and we will expand to the whole province and even the whole country in the next step.

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Table 4: Test Results of Siege

Test content (Page)	Login	Chart	Form
Transactions(hits)	9923	17546	11098
Availability(%)	99.86	99.94	99.87
Elapsed time(secs)	59.37	59.15	59.57
Data transferred(MB)	31.60	25.61	31.24
Response time(secs)	1.23	0.76	1.10
Transaction Rate(trans/sec)	167.14	296.64	186.30
Throughput(MB/sec)	0.53	0.43	0.52
Concurrencies	205.86	226.25	204.39
Successful transactions	9923	17716	11266
Failed transactions	14	11	15
Longest transaction	55.28	57.76	54.57

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