Designing Online Diabetes Diagnosis System Based On Chinese Health Information Platform

Kaiyu Wan, Suming You, and Yiqi Fang

***Abstract*—Providing high quality health care to people is a challenge for almost all the countries in the world. Chinese government also carries on medical reform and takes actions on developing Health Information Platform, which can support Electronic Health Record (EHR) as well as tiered regional health information database. Diabetes is one of the four priority non-communicable diseases identified by the World Health Organization. It has become a serious, burgeoning epidemic in China. Nowadays in China, there are two problems in diabetes diagnosis system, i.e., realizing real time diabetics blood glucose monitoring and health information transmitting between patients and EHR database. To solve these two problems, in this paper, an online diabetes diagnostic system, consisting of patient side and EHR interface side, is discussed. The patient side monitors diabetic blood glucose continuously and transmits data to EHR interface. Specifically a Personal Blood Glucose Monitor System (PBGMS), which consists of an Android application and its corresponding server interface, is designed and implemented to record the diabetes patients measured blood glucose indexes and send the data to an EHR interface. In addition, this application supports the data analysis, data review, and data storage for the measured data. This application allows users to set alarms for themselves and check feedbacks obtained from the doctors. Thus, the software can be used as a tool for diabetes diagnosis based on Chinese Health Information Platform(CHIP).**

***Index Terms*—health information platform, EHR, diabetes diagnosis system, android application**

I. Introduction

Almost all the countries in the world are facing the challenge of providing quality health care to people [1]. By 2009, the average number of doctors for one thousand urban population were 1.75, while for agricultural population the number was only 0.47 in China, comparing to 3.59 in United States in 2005, 3.37 in French, 2.2 in UK and 1.6 in South Korea [2].In April 2015, Chinese national medical and health institutions provided diagnosis and treatment for 640 million patients, which was increased 1.6%, comparing to the same time in previous year [3]. Doctors and medical institutions are not able to cope with large amount of patients. Due to the insufficient and uneven distribution of medical service, work intensity of doctors is high, but reception time of each patient is shortened, which means the quality of treating a patient can not be guaranteed.

Although large amount of health care knowledge is generated based on medical services every day, these data are not systematically documented [1]. As a result the data format is not compatible among different services. Moreover, the current health care platform has not considered the current situation of medical resource distribution. Therefore many countries including China decided to build up a unified health information platform which can computerize health care records, and thus to avoid serious medical errors, reduce costs, and improve the quality of medical treatment.

Diabetes has become a serious, burgeoning epidemic in China. Nowadays in China, there are two problems in diabetes diagnosis system, i.e., realizing run time diabetics blood glucose monitoring and health information transmitting between patients and EHR database. To solve these two problems, in this paper, an online diabetes diagnostic system, consisting of patient side and EHR interface side, is discussed and presented. The patient side monitors diabetic blood glucose continuously and transmits data to EHR interface. Specifically a Personal Blood Glucose Monitor System (PBGMS), which consists of an Android application and its corresponding server interface, is designed and implemented to record the diabetes patients measured blood glucose indexes and send the data to an EHR interface. In addition, this application supports the data analysis, data review, and data storage for the measured data. This application allows users to set alarms for themselves and check feedbacks obtained from the doctors. Thus, the software can be used as a tool for diabetes diagnosis based on Chinese Health Information Platform(CHIP).

The paper is organized as follows : in Section II, background of this research is discussed. In particular, current situation of building up EHR in different countries are investigated. Chinese Health Information Platform(CHIP) is presented and the current diabetes diagnosis condition in China is also investigated. In Section III diabetes diagnostic system design is discussed. In Section IV system development and testing is presented. In Section V future work is discussed.

II. Background

A. Electronic Health Record (EHR)

Electronic Health Record (EHR) is defined as a comprehensive collection of health information about individual patients and populations, which is electronically stored in a digital format [4]. These records could be accessed through different medium and devices, such as hospital and clinic web sites and patients' end devices etc. The general medical health records include three parts, i.e., personal health records, family health records and community health records [5]. Personal health records are frequently used in general health care, and have the highest value in practice [6]. Family health records are established according to the actual family situation. Community health records do not have unified

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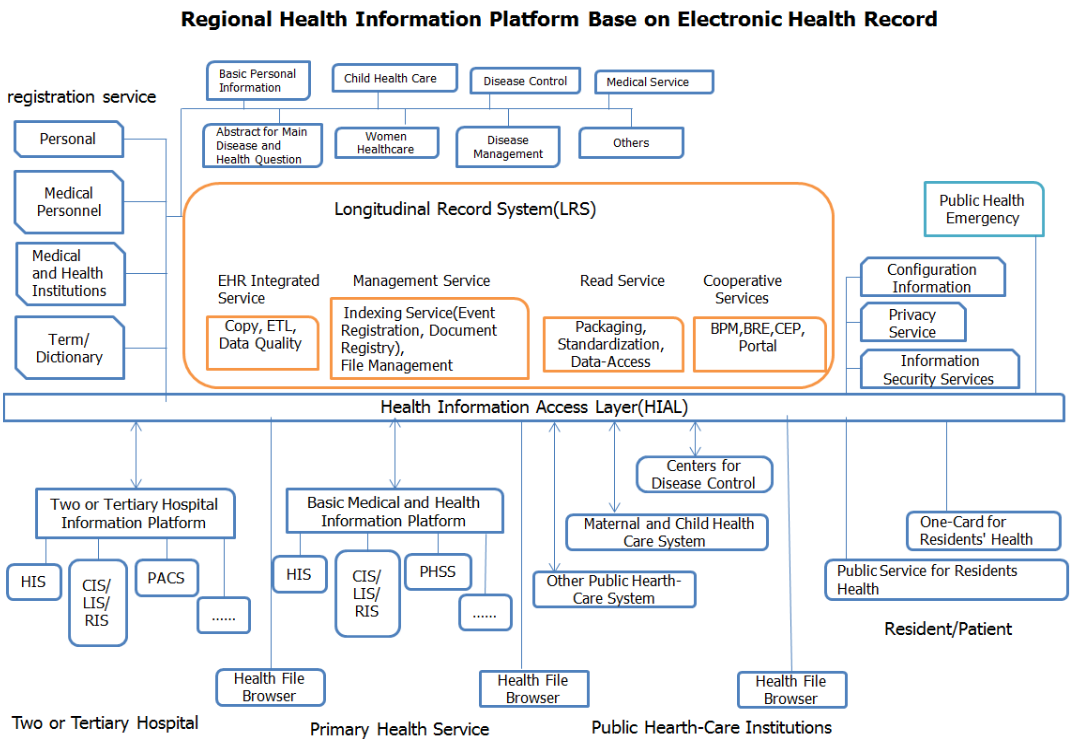

Fig. 1. Regional Health Information Platform Based on Electronic Health Record

requirements, and are mainly used for assessing physicians' knowledge to the health state of residents in community [6].

In the mid and late 1990s, with the increasing research on electronic medical record system, the western developed countries devote to the study of EHR [7]:

- In 1995, Japan introduced common specifications on saving electronic medical image, and set up a special committee to the development of electronic health records. The committee consists of the government officers, academia and industry people;
- In 2004, American former president Bush emphasized on hospital information system construction and pointed out computerizing health care records. He also demanded that in the next 10 years the vast majority of Americans could share EHR.
- In 2007, the United Kingdom invested 6.4 billion pounds on establishing a general practitioner data system, doctor network software system, and Europe EHR etc in 10 years.
- The ministry of health of Canada spent $140 million on establishing a national electronic health file sharing system. The target was to complete 8 categories of EHR system.
- In 2009, U.S. President Barack Obama announced investing $20 billion on developing EHR information technology system.
- Chinese government formulated a tiered Health Information Platform, which is based on EHR, to make medical treatment easier and cheaper [8]. Zhejiang province covering 22 counties (or districts) started a pioneer project in 2012 [9]. The project established electronic medical record system, and set up a standard on sharing EHR information among 12 million residents in Zhejiang area [9].

B. Chinese Health Information Platform (CHIP)

Chinese government started to build up a Health Information Platform to manage the electronic health records (EHR) in order to achieve effective communications among clinicians, community doctors and patients in a local area [10]. The platform supports data transmission among different medical organizations, which mainly consist of electronic health record, point of service system, and primary medical institutions [10]. Point of service system is the information system used in medicinal institutions, which refers to hospital information system [18] [19], basic health service information system [20], and public health system [21] [22]. The primary medical institutions contain community health service centre, health clinics in towns and village clinics. These three components contribute to collecting and managing the health information to reduce the stress of health care. The general structured for the platform is shown in Figure 1.

The platform provides the following service: *Registration service*, *EHR integration service*, *EHR store service*, *EHR management service*, *EHR read service*, *EHR cooperative service*, *Data warehouse*, *Information Security Services*, *Health File Browser*, *Public Service for Residents Health*, *One-Card for Residents' Health* and *Health Information Access Layer(HIAL)*. This platform has not been widely established in China yet. However, many companies have already worked on developing software to support the platform [11]. Furthermore, some softwares have already been developed and used in hospitals [12]. For example, Sanming built the first public health information service management platform in China in 2015 [12]. This platform has integrated unified electronic medical records and residents' health records, which are considered as the core of the underlying database, in order to provide medical service and health monitor service etc. [12].

C. Diabetes Diagnosis in China

Diabetes is one of the four high priority non-communicable diseases (NCDs) identified by the World Health Organization [13]. It is a common, chronic, and costly illness which characterized by hyperglycaemia (high levels of glucose in the blood). There are two types of diabetes. Type 1 diabetes is due to lack of insulin. Type 2 diabetes is due to insufficient insulin and insulin resistance [14]. Diabetes has become a serious, burgeoning epidemic in China. In 2013, the international diabetes federation reported that there were 371 million people with diabetes, and approximately 100 million patients were from China [15]. China has proposed treatment and regulatory schemes for diabetes in recent years to prevent and treat diabetes. However, diagnosis system for diabetes is not broadly available in China. The first reason is that regular diagnosis and treatment can not be guaranteed. In China, a health management mode, i.e., hospital-community-family three-level health manager mode, has been executed to provide diabetics with convenient treatment [16]. In this mode, hospital is responsible for the diagnosis and hospitalization of diabetics. Family should be responsible for blood glucose measurement and providing the data to doctors. Community should focus on providing common therapeutic regimens with diabetics, and timely checking the measured data via telephone contact. Therefore, it is quite possible that the blood glucose of diabetics has not been monitored all the time and the patients do not realize the abnormal situation of their blood glucose index (especially at midnight) [17], which may lead to emergent circumstances. On the other hand, although CHIP (mentioned in section II-B) is being constructed to manage the diagnosis and treatment information, which is shared among hospitals and communities [10]. Doctors in hospital and community should be able to check the patients information via this platform, understand the health status of the patient and give proper feedback. However, this platform integrate different data formats with various history data, which makes data accessing and exchanging difficult. It is required to provide certain methodology to solve these problems.

In this paper, a software system is designed and developed. The system consists of two components, one is for the patients side, and the other is for EHR interface, i.e., for doctors (community and hospital) to access data through CHIP. Specifically a personal Blood Glucose Monitor System (PBGMS), which consists of an Android application client and its corresponding server program, is designed and implemented. The client side records the diabetes patients measured blood glucose indexes and sends the data to the server, which serves as EHR interface. The client side program supports the data analysis, data review, and data storage for the measured data and allows users to set alarms for themselves and check feedbacks obtained from the doctors regularly. The server checks the data regularly, and gives some feedbacks according to the patients illness state.

III. Diabetes Diagnosis System Design

In this paper, a Personal Blood Glucose Monitor System (PBGMS) is designed, seeking to support monitoring the diabetic blood glucose regularly and obtain feedbacks from doctors. This system consists of an Android application and its corresponding server program. The patient side monitors diabetic blood glucose continuously, saves the real time data, analyzes the measured data through a simple algorithm and sends the blood glucose indexes to the EHR interface. The server checks the data regularly, and gives some feedbacks according to the patients illness state. Below are some issues that were investigated before system design.

A. Some Design Issues

- *Fundamental treatments for diabetes blood glucose control* Major monitoring indexes for diabetes blood glucose control include fasting plasma glucose (FPG), postprandial glucose (PPG), nocturnal glucose, glycated hemoglobin (HbA1C) and dynamic glucose monitoring [23]. Table 1 [23] provided a general description of the glycemic control target for patients in different ages. In this paper, the integrated data are collected according to the table in order to design the analysis algorithm for the measured data. Specifically, the measured time could be divided into four category, which are before meals, after meals, before sleep and dawn. The normal range for these four category are respectively in the range of 3.9 to 9, 4.5 to 14, 4.4 to 11, and 4.0 to 11.
- *Glucose Detectors* In this project, the measured data for blood glucose should be transmitted to PBGMS. Therefore, a glucose detector [24], such as a sensor or glucometer, which supports the data transmission, is needed. Many devices have been invented to measure the blood glucose. Some available glucose detectors are listed below:
  - Diasensor 1000 [25]: a blood glucose monitor sensor invented by Biocontrol Technology Company, which uses near-infrared technology and multivariate regression to estimate blood glucose level.
  - GlucoWatch Biographer [26]: a glucometer provides automatic, frequent and noninvasive blood glucose measurements for up to 12 hours.
  - Noninvasive Glucose Meter [27]: an apparatus developed by Pindi Products Company for noninvasive detection and quantitation of analyses which utilizes special membrane electrodes.
  - GlucoNIR [28]: a blood glucose measurement system developed by CME Telemetrix Company, which uses infrared spectroscope in near-IR spectrum. In addition, this product is equipped with a LCD display and powered by battery. It has a combination port which supports the acquisition of measured data.
  - Abbott Free style Navigator [29] [30]: This product, equipped with wireless receiver, supports continuous real-time detection of blood glucose and simple analysis function.
- *Smartphone Operating System Investigation* In 2013, the ZOL in China has conducted a survey on the peoples smartphone operating system [31]. The result

shows that the majority of mobile phones use Android operating system. Thus, the personal blood glucose monitor system is designed as an Android application so that majority of people in China are able to utilize this system.

- *Java Servlet and Apache Tomcat* Servlets are small, platform-independent Java classes complied with an architecture neutral bytecode that can be loaded dynamically into and run by a web server [32]. Apache Tomcat, is an open-source web server developed by the Apache Software Foundation (ASF) [33]. Tomcat implements several Java EE specifications including Java Servlet, JavaServer Pages (JSP), Java EL, and WebSocket, and provides a pure Java HTTP web server environment in which Java code can run [33]. In addition, Apache Tomcat is also regarded as the servlet container that is used in the official reference implementation for the Java Servlet and Java Server Pages technologies [34]. Therefore, Apache Tomcat is chosen to publish the servlet in this project. In addition, a free dynamic domain name service resolution software called Oray Peanut Hull is utilized in this project [36]. This software helps developers to build a fixed domain Internet host with their personal computers. Then, clients in different areas are able to access the system server via the Internet.

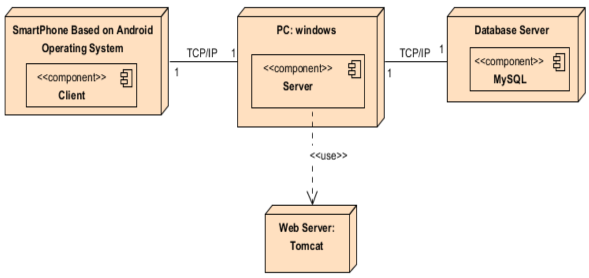

Fig. 2. System Deployment Diagram

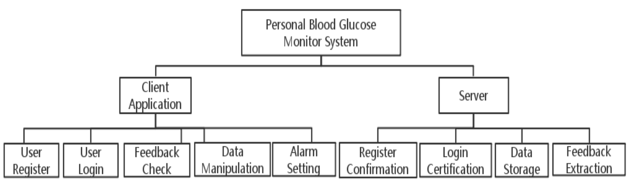

Fig. 3. Structure of the Program

B. System Design

- Figure 2 is the deployment diagram of the system. The system is based on client-server architecture. The client side is the smart phones based on Android operating system, and the server side is the personal computer based on Windows. In addition, all servers in server side should be published to a web server, which is Tomcat in this case. The server side also need to connect with a database server.
- Figure 3 illustrates that designed system is split into subsystems. In particular, the client program supports the user register, user login, data manipulation, feedback check and alarm setting. The server program includes register confirmation, login certification data storage and feedback extraction.
  Table I and Table II show the detailed module descriptions in client and server programs.

TABLE I
MODULE DESCRIPTION OF CLIENT PROGRAM

Client-Side	Description
User Register	Support register with assist of server
User Login	Support login via checking from server
Data Manipulation	Measured data analysis, storage and view
Feedback Check	Show feedbacks from doctor with assist of server
Alarm Setting	Set alarm to add some reminding

TABLE II
MODULE DESCRIPTION OF SERVER PROGRAM

Server-Side Module	Description
Register Confirmation	Check and insert the account information into database
Login Certification	Check the login information from database
Data Storage	Save the measured data and analysis result in database
Feedback Extraction	Extraction feedbacks from doctor server database

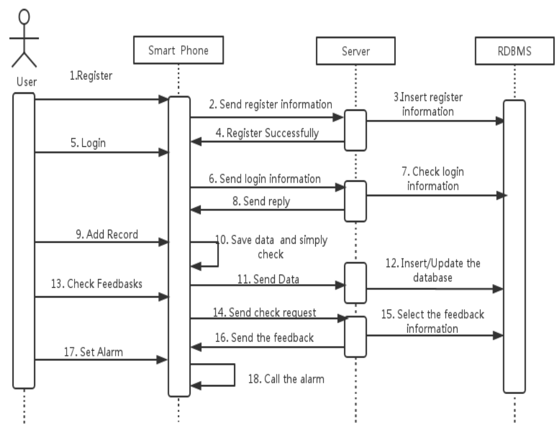

Fig. 4. Sequence Diagram

- The sequence diagram shown in Figure 4 illustrates how the client program communicates with the server program. In short, the client sends request to the server. Then the servlet executes some operation with the database server. Next, the servlet returns the results to the client.

C. Detailed Design

- *Client Side Design* The client side program is an Android application. The class diagram is illustrated in Figure 5. In addition, the interface HttpClient is consistent with the interface design in server side to support the communication between client and server.

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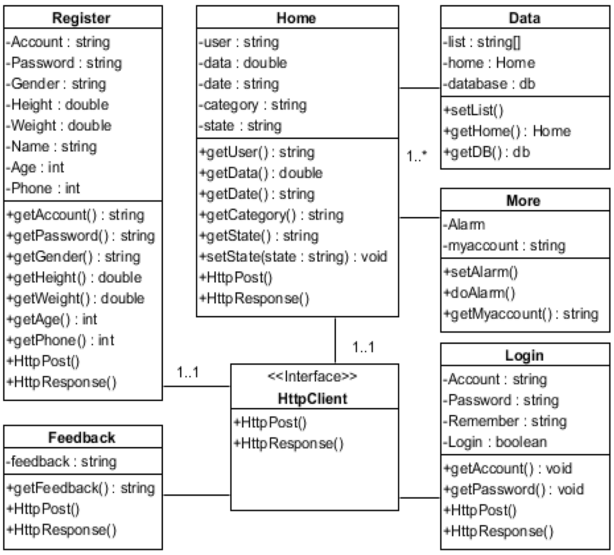


Fig. 5. The Class Diagram for the Client program

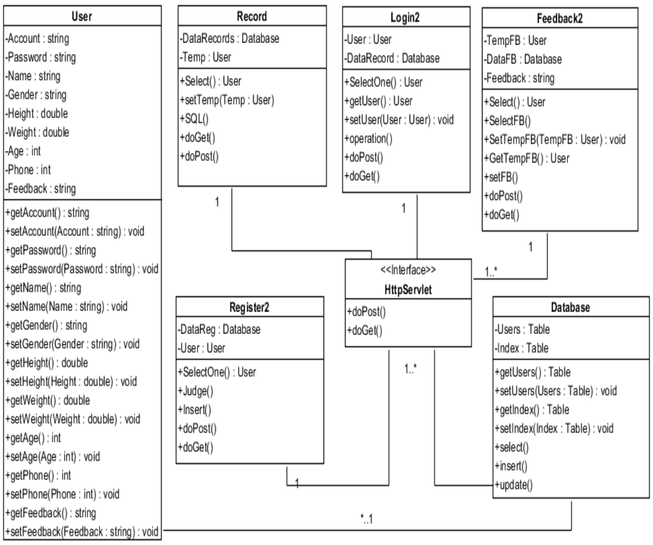
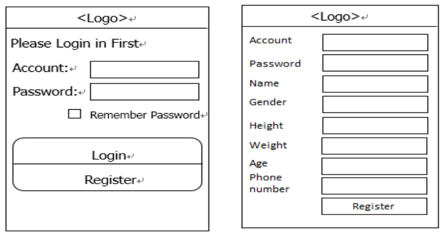


Fig. 6. The Class Diagram for the Server program

- *Server program* is a dynamic web application. The class diagram for the server program is shown in Figure 6. Six classes are designed, including Record, Register2, Login2, Feedback2, Database, and User. The first four classes are used to support the communication with the client side program. Thus, these four classes extend HttpServlet interface to support the inter-linkage between the client side and the server side. In addition, the ”Database” class is used to connect the server side with the database server, and the ”User” class is the entity to store the information extracted from the database.
- *Database Design* In this project, two databases are created. One database is in the android application to store the measured data, and another database is in the server side to store the account information and measured data. In addition, the database in android application is designed to reduce the unnecessary waste of data size. Thus, users do not need to download the information of measured data. The database in client side is a SQLite database [37], which stores the measured data for users. The database in server side stores users personal information and measured data, including account, password, name, gender, height, weight, age, feedback, phone number and the measured data in different date and time.
- *User Interface* In this application server program is mainly used for querying and storing the user information, such as the account information and measured data. Thus, the interface for server can be replaced by any Graphic-User-Interface tool for MySQL. One of the user interface design for the client side is shown in Figure 7.



(a) User Interface Design for Login Page (b) User Interface Design for Register Page

Fig. 7. Login and Register User Interface

IV. Development and Testing

- *Experimental Environment* In this project, the android application and its server side are developed. The server installs the MySQL Server, Tomcat, Eclipse, Android Software Development kit Java Development kit (SDK), Android ADT, Java Runtime Environment, and corresponding Java Development kit (JDK). In addition, an Android smart phone is required to run the developed client application .
- *Client Side Program* Five functionalities are implemented, i.e., login, register, data manipulation, feedback check and alarm setting. Data manipulation supports data analysis and storage, and data view function.
- *Server Side Program* The server program mainly consists of four servlets which respond to the corresponding requests from the client application. In addition, the server supports the data query and modification to the database.
- *Project Deploy and Network Setting* The server program is developed as a dynamic web application and deployed on the web server Tomcat. Oray Peanut Hull is used to build a static host for the developers personal computer and thus enables the access from client in different areas. The basic network configuration consists of three steps:
  1) Create an account in the official website of this software
  2) Download and install the software
  3) Login in the software and then open the Network Mapping
- *TESTING* The decision table based testing [39] has been applied to test the above functionalities.
  In order to test the capacity of the server, a load testing [35] was used to test the scripts and ensure that

the server can handle multiple requests from a number of clients simultaneously. The load testing software SoapUI [38] was used and the simple strategy was chosen to test the program. The strategy runs the specified number of threads with the specified delay between each run to simulate a "breathing space" for the server. In this test, the thread, which was represented the client number, was increased from 0 to 1000 with the step of 200. In addition, the delay was set to a fix number, which was 1 second, and random was set to amount of delay. Figure 8 shows one testing result when the client number is increased to 1000. The load testing results illustrate that the performance of the server is acceptable since the response time is less than 0.5 second, though the response time increases as the client number increases.

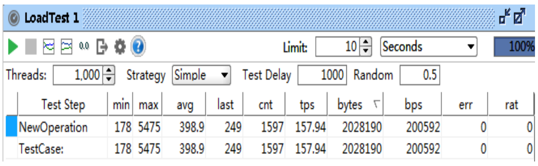


Fig. 8. Load Testing Diagram

V. Conclusion

In this paper, a software system for diabetes diagnosis based on Chinese Health Information Platform(CHIP) is designed and developed. This is our first attempt and some improvements can be conducted. For example, the network mapped by the software Oray Peanut Hull sometimes is not stable. Therefore clients may not successfully access to the server all the time. In order to achieve a stable network, it is possible to deploy the server side into a cloud host instead of a personal computer. In addition, the user interface can be more intuitive and user friendly. For example, the measured data can be shown in a table or a pie chart. To make the system complete, another important program should be developed, i.e., the program for doctor side. The system should support doctors to access patients' medical history and give proper treatment. Due to the deficiency of doctors, the system should support dynamic and intelligent allocation for doctors. Due to the confidentiality of patients, the system should also provide certain security mechanism.

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