Design and Implementation of An Intelligent Health Management System for Nursing Homes

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***Abstract*—The ageing population has led to a dramatic increase in the demand for analysis and assessment of the health of older persons in public health services. Due to medical conditions and other reasons, most of the elderly in some urban nursing homes will only detect and analyze their own physiological indicators when they are sick. From the perspective of health management, we should continuously monitor the physiological indicators of each elderly individual, and through the analysis and evaluation of their daily physiological indicators data, and then predict and timely intervene in their health. This can not only effectively improve the health of the elderly, but also effectively reduce the pressure on public health services. In order to allow more elderly people in nursing homes to enjoy effective health monitoring and early warning and timely intervention, we have designed an intelligent health management system based on technologies such as cloud computing, Internet of Things, knowledge graph, and deep learning. The system consists of three parts: the Internet of Things platform, the intelligent analysis platform, and the SAAS management platform. The IoT platform is mainly responsible for collecting data such as daily physiological indicators, sleep data, air indicators, and service demands of elderly people in nursing homes. The intelligent analysis platform is mainly responsible for analyzing and evaluating the data collected by the IoT platform based on the disease knowledge map and related deep learning frameworks. The SAAS management platform is mainly responsible for background management and health data visualization on the nursing terminal, service terminal, and health monitoring terminal. The system realizes continuous monitoring, analysis, assessment, prediction and early intervention of the health of each elderly person in the nursing home, which effectively improves the health of the elderly and effectively reduces the pressure on public health services.**

Keywords—Cloud Computing, Internet of Things, Health Analysis , Health Assessment, Big Health, Health Management

I. INTRODUCTION

There are many applications of disease prediction research and health management. For example, Edward Choi [1], a researcher at the Georgia Institute of Technology in the United States, can use the recurrent neural network model to detect the early clinical manifestations of heart failure before half a year to a year and a half. Professor Eric R.Gamazon and Lea K. Davis of Vanderbilt University Medical Center constructed a complex disease risk assessment method, namely Polygenic Risk Score [2], based on the distribution of susceptibility genes on people's DNA. Baidu has built a system by combining medical knowledge graphs, structured medical records, AI-assisted decision-making systems, and multidisciplinary collaboration platforms. This system can provide users with functions such as disease screening, diagnosis, treatment, hospital management, pharmaceutical services, and chronic disease management. Apple has launched secure sharing and new health analytics in iOS 15, designed to help users improve personal health management. The system adds trend analysis of more than 20 types of data including heart rate, sleep, and exercise, and provides communication with third-party device data to obtain health trend analysis information. "Shanghai Health Cloud Platform" has uploaded more than 20 million electronic data of physical signs, and through early detection and complication screening, 45,200 patients with prediabetes and 159,600 patients with complications have been screened. However, the current research on disease prediction and the application of health management do not have periodic real-time physiological monitoring, sleep monitoring, and living environment monitoring of living individuals. And no relevant analysis and evaluation of the collected data, no relevant health warnings, and no effective intervention and supervision.

According to our research findings, at present, there are many applications of physiological testing, sleep testing, and living environment testing for the elderly in nursing homes. Such as sphygmomanometer, oximeter, thermometer, sleep pad, sleep pillow, formaldehyde detector, etc. However, these devices are actually not very popular. Even after buying these devices, they are not used frequently, and these devices are more used to cope with inspections. There are three main reasons. First, most nursing homes do not have a health record information system; second, the blood pressure, blood oxygen, heart rate, and body temperature detection equipment cannot communicate directly with the existing information system, and the staff needs to manually enter it after testing; Third, blood pressure, blood oxygen, heart rate, body temperature detection equipment, sleep pads, sleep pillows, formaldehyde detectors and other equipment data are independent of each other and cannot be effectively aggregated. According to our research, health management is the detection, monitoring, analysis and evaluation, intervention and supervision of the health of individuals and groups. Health management is the detection, monitoring, analysis and evaluation of individual health. Intervene on risk factors that endanger health, give personalized health improvement guidance, and supervise people to actively improve and maintain health. Its application scenario is shown in Figure 1.

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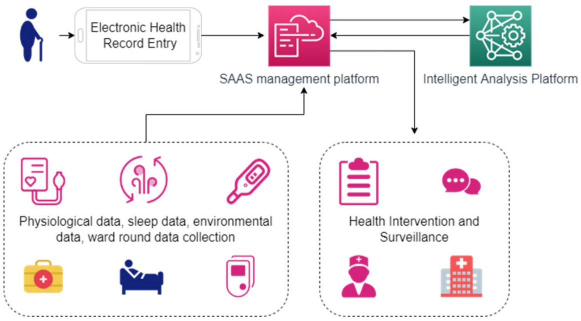

Figure 1 Smart Health Management Application Scenario

According to our research, if we want to realize the popularization of intelligent health management for the elderly in nursing homes. First, it is necessary to build a SAAS management platform for nursing home health management. Then, an IoT communication platform needs to be developed based on the TCP protocol. This platform is mainly used to collect physiological data, sleep data, environmental data and daily ward round data. Secondly, it is necessary to build an intelligent analysis platform based on disease knowledge graph and deep learning framework. Finally, the SAAS management platform outputs the relevant health reports, health intervention opinions, supervision reports, recommended hospitals and departments, etc. after the intelligent analysis platform analyzes and evaluates the data uploaded by the IoT platform.

There are two main types of existing nursing home management platforms. One is for the daily data visualization and call service access of the elderly at the district level; the other is customized development, mainly for the daily OA management, check-in, settlement, and logistics of the nursing home. , institutional affairs, etc. Therefore, we need to build a general-purpose SAAS management platform for nursing homes according to the application scenario requirements of intelligent health management. We need to build a public cloud management platform that includes electronic health records, data monitoring and communication, service management and monitoring, service feedback and health staff management. Existing sphygmomanometers, oximeters, thermometers, sleep pads, sleep pillows, formaldehyde detectors and other testing equipment. Because the manufacturers are different, they all have their own small programs, APP, Web and other platforms. At present, there is no IoT communication platform that can integrate different manufacturers and different devices.

The goal of this research is that in the application scenario of nursing homes, the intelligent health management system can collect the user's physiological data, sleep data, environmental data and daily ward round data in real time through the Internet of Things platform; Clinical symptoms, medical history information, and the user's data on the IoT platform are analyzed and evaluated, and finally health warnings and health intervention plans are output.

This paper has five chapters in total. The first chapter is introduction, which mainly describes the research background and current situation of the application of an intelligent health management system applied to nursing homes, as well as an overall overview of the main content of this paper. The second chapter SAAS management platform design and implementation, mainly describes the construction process and implementation of SAAS management platform. The third chapter is the design and implementation of the IoT platform, which mainly describes the construction process and implementation method of the IoT platform. The fourth chapter is the design and implementation of the intelligent analysis platform, which mainly describes the construction of the knowledge map of common diseases of the intelligent analysis platform, the construction of the prediction model of common diseases, and the realization of the intelligent analysis platform. The fifth chapter is the conclusion, which mainly expresses the research results of this paper and the prospect for the future.

II. SAAS MANAGEMENT PLATFORM DESIGN AND IMPLEMENTATION

A. *Overview of Intelligent Health Management System*

According to the usage scenario of the intelligent health management system of the nursing home, the overall system implementation framework is shown in Figure 2.

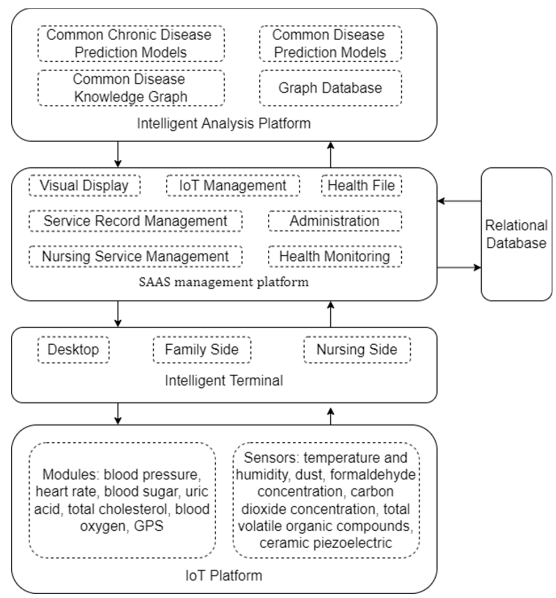

Figure 2 System implementation framework

The intelligent analysis platform consists of a common chronic disease prediction model, a common disease prediction model, a common disease knowledge graph, and a graph database. The IoT platform consists of blood pressure module, heart rate module, blood sugar module, GPS module and other modules, as well as temperature and humidity sensors, carbon dioxide concentration sensors, total volatile organic compounds sensors. It consists of sensors such as ceramic piezoelectric sensors. The intelligent terminal consists of a family terminal, a desktop terminal, and a nursing terminal. The SAAS management platform consists of data visualization, health records, health monitoring, nursing service management, service record management, IoT management, and administrative management.

B. *SAAS management platform design*

According to our research, the functions of the SAAS management platform of the intelligent health management system for nursing homes include data visualization, health records, health monitoring, nursing service management, service record management, IoT management, and administrative management.

Data visualization mainly realizes abnormal risk display of 8 types of indicators including smart mattress, smart urine pad, service call, physiological monitoring, ward rounds, electronic fence, air monitoring, and health management. Health records mainly realize the functions of adding, deleting, modifying and querying the electronic information related to the elderly in nursing homes. Health monitoring mainly realizes physiological monitoring, air monitoring, daily ward rounds, service monitoring, and electronic fence related information query. Nursing service management mainly realizes the functions of ward round content management, class content management, ward unit management, ward management, class management, shift management, shift list, drug management, and shift management.

Service record management mainly realizes service detailed records, SOS service, call service, diaper service, service video, service evaluation, and query of catering management related information. IoT management is mainly responsible for the addition, deletion, modification and query of related information of smart watches, smart mattresses and smart diapers. Administrative management mainly realizes the addition, deletion, modification and inquiry of information related to notification management, personnel management and financial management.

TABLE I. HEALTH MONITORING

Physiological Monitoring	***Sleep Monitoring***	***Air Monitoring***
Blood Pressure	Sleep Duration	PM2.5
Heart Rate	Number of Physical Movements	PM10
Blood Sugar	Number of Getting Out of Bed	Carbon Dioxide
Uric Acid	Snoring	Formaldehyde
Cholesterol	Breathing Rate	Total Volatile Organic Compounds
Blood Oxygen	Sleep Heart Rate	Temperature
High Density Lipoprotein		
Low-density Lipoprotein		
Triglycerides		
Body Temperature		

The physiological monitoring in Table 1 mainly realizes the data display of blood pressure, heart rate, blood sugar, uric acid, cholesterol, blood oxygen, high-density lipoprotein, low-density lipoprotein, triglyceride, and body temperature. Sleep monitoring mainly realizes the data display of sleep duration, number of physical movements, number of getting out of bed, number of snoring, breathing frequency, and sleep heart rate. Air monitoring mainly realizes data display of PM2.5, PM10, carbon dioxide, formaldehyde, total volatile organic compounds, temperature and humidity.

The establishment of health files takes the individual as the basic unit, and is entered manually. The health file information of each elderly person in the nursing home includes name, gender, ID number, occupation, ethnicity, permanent area, marital status, female menstrual history/marriage history, allergy history (yes, specify/none), chronic disease history (diabetes, hypertension, viral hepatitis, etc.), family medical history, living habits (smoking history, drinking history, staying up late, etc.), medical records, physical examination records, and medication records.

C. *Implementation of SAAS management platform*

The SAAS management platform consists of three parts: database, server, and front-end management interface. The database uses a relational database for data storage. The server is developed using the Web application framework of the MTV (model M, template T, view V) framework mode. The front-end management interface is developed based on Twitter's Bootstrap framework and the jQuery framework released by John Resig. The visualization part is developed based on html5 Canvas, and the data is entered in the form of forms. Use Ajax for front-end and server-side data interaction. After the nursing home staff uses the browser to enter the user's individual health information on the form, Ajax transfers the data entered in the front end to the server, and uses the user's ID number as the unique identifier to create the user's electronic health record table, and finally uses the database to store the information.

In order to allow third-party organizations to monitor user health and manage user health. The server shares the user's electronic health file with the user's hospital or sports club through an API interface.

III. IOT PLATFORM DESIGN AND IMPLEMENTATION

According to our research, the IoT platform of the intelligent health management system in the nursing home consists of three parts: the signal acquisition unit, the central control unit, and the human-computer interaction unit.

A. *signal acquisition unit*

The signal acquisition unit is composed of blood pressure module, heart rate module, blood sugar module, uric acid module, total cholesterol module, blood oxygen module, temperature and humidity sensor, dust sensor, formaldehyde concentration sensor, carbon dioxide concentration sensor, total volatile organic compound sensor, ceramic piezoelectric sensor, etc. composition. The blood pressure module consists of a brancher, a rubber tube, a cuff, a solenoid valve, an air pump, a pressure sensor, and a drive circuit.

B. *central control unit*

The central control unit inflates and deflates the air pump and the solenoid valve switch through the drive circuit, [3] the pressure sensor collects pulse data and cuff pressure data, and uses signal conditioning to separate the two data, and finally obtains the blood pressure after calculation by the central control unit chip value. The heart rate module and the blood oxygen module are composed of light-emitting diodes and photoelectric sensors. The light-emitting diode is responsible for sending visible light to the neck, fingers, wrist, and earlobe, and the photoelectric sensor is responsible for receiving and processing the reflected light. Finally, the central control unit chip calculates the heart rate and blood oxygen values [4].

The blood sugar module consists of blood sugar test strips (electrodes printed with glucose oxidase), blood sugar detection circuits, etc. The central control unit chip outputs the measured voltage for the blood sugar test strip, and uses an analog switch to control the time of the measured voltage on the blood sugar test strip. After the enzyme on the blood glucose test strip reacts with the glucose in the blood sample, the electrons generated will form a linear relationship between the glucose concentration and the current change. Finally, the blood glucose value is calculated according to this linear relationship.

The central control unit consists of T618 chip, USART serial communication interface, ADC analog-to-digital converter, GPS module, Wi-Fi module, GPRS module, power supply module, etc. The central control unit controls the blood pressure module, heart rate module, blood sugar module, uric acid module, total cholesterol module, blood oxygen module, temperature and humidity sensor, dust sensor, formaldehyde concentration sensor, carbon dioxide concentration through USART serial communication interface and ADC analog-to-digital converter respectively. Sensors, total volatile organic compounds sensors, ceramic piezoelectric sensors, GPS modules, etc. These sensors send the collected signals to the central control unit using the corresponding I/O. These signals are processed and analyzed by the central control unit. Finally, the detection results are sent to the SAAS management platform of the intelligent health management system through the Wi-Fi module or the GPRS module. At the same time, the Android ROOM is used locally to store application data persistently and display it in the corresponding UI on the display [5].

C. Human-computer interaction unit

The human-computer interaction unit consists of three parts: the desktop terminal, the nursing terminal, and the family terminal. The desktop side consists of login/logout, home page, blood pressure/heart rate measurement, body temperature measurement, blood oxygen measurement, blood lipid measurement, blood sugar measurement, uric acid measurement, environmental index monitoring, life care section, health care section, leisure and entertainment section, health education section composition. The nursing side consists of login/logout, home page, ward rounds, service processing, and service personnel list. The family terminal consists of login/logout, home page, service video list, and service evaluation [6-8].

The IoT platform will collect physiological data (i.e. blood pressure, heart rate, blood sugar, uric acid, total cholesterol, blood oxygen, body temperature, high-density lipoprotein, low-density lipoprotein, triglycerides), sleep data (i.e. sleep duration, body temperature, etc.) Movement times, snoring times, breathing frequency, time out of bed, heart rate), air data (i.e. carbon dioxide, total volatile organic compounds, temperature, humidity, PM2.5, PM10), ward round data (i.e. clinical manifestations, meals, mood , two stools, taking medicine) are uploaded to the intelligent health management system [9-11]. The intelligent analysis platform is responsible for intelligent analysis of these data.

IV. Design and Implementation of Intelligent Analysis Platform

According to our research, the intelligent analysis platform of the intelligent health management system in the nursing home is composed of two parts: the knowledge graph of common diseases and the prediction model of common diseases.

A. Common disease knowledge graph construction

The construction process of common disease knowledge graph is as follows: First, entities and corresponding relationships are extracted from "Diagnostics", "Internal Medicine" and related common disease guidelines and structured. Then, store this structured data in a relational database. Then, the semantic relationship of this knowledge graph is constructed based on the two types of medical semantic relationship, the Unified Medical Language System (UMLS) and the International Systematic Medical Terminology (SNOMED). Finally, the graph database is used for node creation and relationship creation in the knowledge store. The knowledge map of common diseases constructed in this study has a total of 19,369 entities and 181,203 associations.

When the intelligent analysis platform analyzes the data uploaded by the IoT platform or the common disease prediction model initiates a query request, the semantic recognition module will first identify the entities in the data and their corresponding relationships for semantic understanding. Finally, a syntax tree in JSON format is generated based on the predicted query content. The Match query statement construction module parses the entity nodes, Where nodes, With nodes, and union nodes in the syntax tree, and returns the query results.

B. Common disease prediction model construction

The common disease prediction model consists of a feature extraction layer, a feature update layer, and a feature decision layer. The feature extraction layer is trained based on the BERT Chinese pre-training model to obtain the vector features corresponding to the training set. The feature update layer initiates the interaction again according to the output result of the feature extraction layer, and finally updates the new intent to the feature extraction layer. If the feature update layer does not receive new intentions after initiating the interaction, the feature decision layer calculates the loss of text semantic similarity through the hinge loss function and updates the relevant parameters.

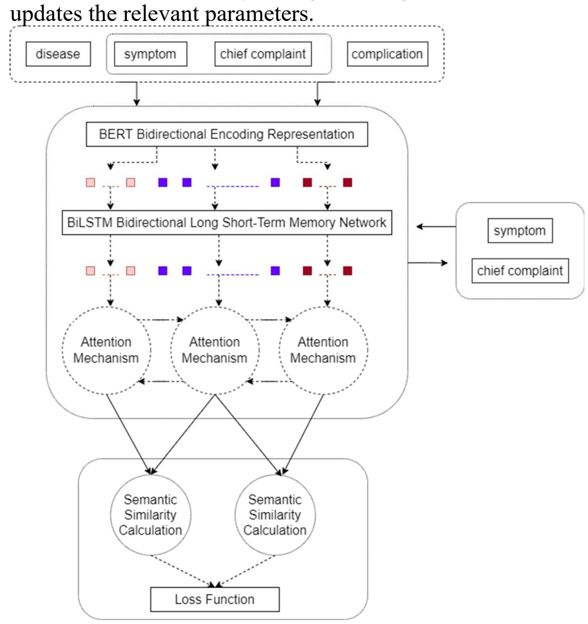

Figure 3 Overall framework of common disease prediction models

The symptom and main complaint vector matrix STCC output by BERT bidirectional encoding representation and BiLSTM bidirectional long short-term memory network interact with disease D and complication CD respectively using attention mechanism for feature interaction. For example, the interaction process between symptoms and main complaints and diseases is: the text vector matrix of symptoms and main complaints is $\mathrm{STCC} = [S_1 \cdots S_i \cdots S_n]$, and the text vector matrix of diseases is $\mathrm{D} = [D_1 \cdots D_j \cdots D_n]$, n represents the maximum length of the text, S_i represents the vector corresponding to a certain position in the symptoms and main complaints, and D_j represents the vector corresponding to a certain position in the disease.

The degree of correlation between S_i and D_j is calculated by formula (1).

$$\text{Similarity } (S_i, D_j) = S_i {D_j}^T \quad (1)$$

By formula (2), the correlation degree calculated by formula (1) is scaled between [0, 1] to obtain the attention weight of D_j.

$$\text{Attention } (S_i, D_j) = \text{softmax } (S_i {D_j}^T) \quad (2)$$

By formula (3), each vector in disease D is weighted and summed with attention weight S_i to represent the final vector representation, and the weighted vector D^d of the mutual attention mechanism updates the features of text semantics.

$$\mathrm{E}\ (S_i, D^T) = \sum_{j=1}^{n} softmax(S_i {D_j}^T) V_j \quad (3)$$

The common chronic disease prediction model belongs to the multi-label classification task, which is to judge coronary heart disease, hypertension, myocardial disease, rheumatoid arthritis, One or more labels such as diabetes.

Common multi-label classification algorithms include ML-KNN, Ranks-SVM, ML-DT, etc.ML-KNN is based on the KNN algorithm to extract K similar samples. It uses Bayesian conditional probability to calculate the probability that the sample labels are 0 and 1, and defines the label of the sample as a label with a high probability. the Ranks-SVM algorithm process is to first convert the ranking problem into a classification problem, and finally use the SVM classification algorithm to solve it.ML-DT is a binary classification prediction based on the DT decision tree algorithm [13].

The obvious features of this task are: first, the result may be one label or multiple labels. second, there is a certain correlation between each label [15]. For example, after the endothelial cells of the arterial vessel wall of a hypertensive individual are damaged due to high pressure, the smooth cells of the arterial wall are easily stimulated by the incoming low-density lipoprotein. And hyperplasia, causing atherosclerosis, and then coronary heart disease. Therefore, there is a certain correlation between the label of hypertension and the label of coronary heart disease.

In order to preserve the relationship between each label, a two-layer neural network with 500 and 500 neurons in each layer was used for feature extraction when building the model, and the batch_size was set to 32. since the probability that the value of each node that needs to be output is 1, the activation function of the output layer uses the sigmoid function. In order to reduce the cross entropy between the output and the label, the loss function uses the binary_crossentropy function, which is to move the output value of the node with the label 1 to 1, and the output value of the node with the label 0 to move to 0.

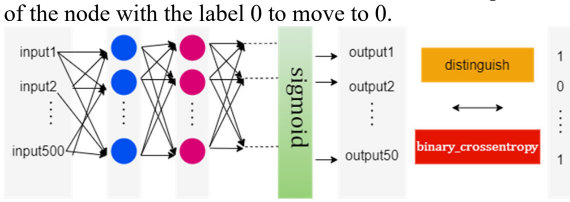

Figure 4 Overall framework of common chronic disease prediction models

The common chronic disease prediction model is a multi-label classification task based on a deep neural network. The input of the model is a comprehensive report of an individual's physiological data, sleep data and ward round data. Through this comprehensive report, determine whether the individual to which this report belongs has the following chronic diseases [coronary heart disease, hypertension, myocardial disease, rheumatoid arthritis, diabetes, gout, liver cirrhosis, chronic lymphocytic thyroiditis, chronic obstructive thyroiditis Emphysema, chronic nephritis].If the output of the model is [0, 0, 0, 1, 0, 1, 0, 0, 0, 0], 1 represents the disease at the position of the ordered sequence, and 0 represents the disease at the position of the ordered sequence. disease. the meaning of this output is that the individual suffers from rheumatoid arthritis and gout.

C. *Intelligent Analysis Platform Implementation*

First, knowledge extraction is performed from unstructured data such as "Diagnostics", "Internal Medicine" and related common disease guidelines. It is to extract the name of the disease, the cause, the first-level department, the second-level department, the disease site, the mode of infection, the susceptible population, the symptoms, the examination, the identification, the prevention, the treatment method, the nursing, the complications, the commonly used drugs, and the physiological index value. the relationships and related attributes between these entities are extracted and stored in the database. After going through the processes of knowledge representation, entity alignment, ontology construction, knowledge update, quality assessment, attribute correction, and knowledge reasoning, the knowledge graph of common diseases is finally constructed based on the graph database.

Second, use the name, etiology, disease site, susceptible population, and symptoms of the disease to construct a training set of common disease prediction models. Construct common chronic diseases (including coronary heart disease, hypertension, myocardial disease, rheumatoid arthritis, diabetes, gout, liver cirrhosis, chronic lymphocytic thyroiditis, chronic Obstructive pulmonary emphysema, chronic nephritis) multi-label classification task prediction model training set.

Google BERT [16] is a pre-trained language representatio n model that uses MLM (masked language model) to pre-trai n bidirectional Transformers to generate deep bidirectional la nguage representations. After pre-training, as long as an addi tional output layer is added for fine-tune, the state-of-the-art performance can be regained in training tasks in various scen arios. Therefore, Google keras is used to build a common dis ease prediction model and a common chronic disease predicti on model, and it is trained based on BERT.

Finally, we encapsulate the constructed common disease knowledge map and common disease prediction model into the form of API interface, which can be used by other application modules of the intelligent health management system.

Intelligent analysis is mainly divided into two steps. First, the common disease knowledge graph will provide relevant early warnings to the data uploaded from the Internet of Things according to relevant entities such as physiological index values, disease names, complications, and symptoms. Secondly, the common disease prediction model and the common chronic disease prediction model comprehensively analyze the data uploaded by the IoT [17] platform, and output health status assessment, disease risk assessment and disease risk assessment.

The intelligent intervention and supervision stage is based on the output results of the intelligent analysis and evaluation stage, using corresponding methods for individuals with different health states [18-20]. Intelligent intervention and supervision of the individual's living habits, dietary patterns and disease risk factors, so as to achieve the process of improving the individual's health status. The whole process is mainly divided into health education and disease consultation, exercise and nutrition intervention, disease risk control and real-time monitoring, and medical guidance.

The intelligent terminal of the IoT platform of the intelligent health management system pushes personalized health knowledge according to the status of electronic health records and physiological indicators [21]. The common disease prediction model in the intelligent analysis platform provides users with disease consultation services based on the clinical complaints and symptom information collected during the interaction with the user and the user's electronic health record information.

The intelligent health management system customizes exercise programs and diet plans according to the results of health status assessment, and uses accumulated points to ensure completion of exercise and nutritional intake, so as to achieve the purpose of improving health status.

The Internet of Things platform of the intelligent health management system provides an analysis of individual physiological data, sleep data, air data are uploaded in real time. The intelligent analysis platform monitors in real time. For example, once the indicators are abnormal, the system will notify the nurse station or community service station in real time.

The intelligent health management system stores information on hospitals, [22] departments and specialties, and the intelligent analysis platform recommends hospitals and departments for medical treatment according to the type of disease and the degree of risk and the specialties of nearby hospitals.

V. CONCLUSION

In this paper, we design and build a set of intelligent health management system for nursing homes based on cloud computing, Internet of Things, knowledge graph, and deep learning framework. This system realizes the real-time upload of the daily physiological data, sleep data, air data, and ward round data of the elderly in the nursing home. This system can intelligently analyze and evaluate the health of the elderly in nursing homes, and output relevant health advice and intelligent intervention programs. The physiological numerical indicators collected by the intelligent health management system designed and implemented in this paper are not comprehensive enough. Therefore, it is planned to build a health big data collection standard system in the future to improve the quality of collected data. Expand the collection scope of health big data and improve the comprehensiveness of health data. In addition, in data collection, transmission, storage, training and analysis, the security of transmission protocols and data interfaces should be strengthened to prevent health data leakage.

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