An Integrated and Intelligent Dental Healthcare System with Mobile Services

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Abstract. Medical informatization takes a key role in medical and healthcare industries, which is a necessary way of improving service quality and treatment experience in a hospital. In this paper, we design and implement an integrated and intelligent healthcare system with mobile services, specific to dental healthcare. The developed system contains four components, including WeChat official account, intelligent question and answering (Q&A) system, mobile follow-up care mini program and AI speech assistant. The developed WeChat official account and intelligent Q&A system provide a large amount of professional knowledge on dental health, which can help narrow the knowledge gap between doctors and patients. The two components facilitate patients to follow up our applications without downloading any extra softwares, as the developed functions (e.g., voice service) are provided through mobile services. These two components also facilitate follow-up management, decreasing manpower and resource usage in hospital. Our system is developed to serve patients as well as dentists, and provides a group of interactive healthcare services in a low cost. In this paper, we elaborate the whole system architecture and implementation detail of each component. We also report the performance test result and training process of the classifier.

Keywords: Dental healthcare · Intelligent information system · Mobile service · Neural network · Voice service

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1 Introduction

The need for dental healthcare or oral healthcare is common nowadays. With the improvement of medical level, an increasing number of people begin to pay attention to their dental health. At the same time, dental healthcare has a great demand for medical informatization. For ordinary people, there is a need for professional knowledge to evaluate their dental problems and seek potential treatment that they intend to receive. The key reasons for the need of medical informatization in dental healthcare are as follows. First, the process of dental medical treatment is complicated. The cycle of treatment is long, usually lasting for several weeks. During the treatment, a patient needs to be treated many times. Second, dental diseases are usually highly professional and most people lack the way to acquire such professional knowledge of dental healthcare. Third, follow-up care is required after dental operation. Patients need a stable and effective way to give feedbacks about their dental problems along with each treatment.

However, the existing dental healthcare information systems have three major defects. First, the existing systems are not intelligent enough, which cannot intelligently answer patients' professional questions related to dental healthcare. Meanwhile, the existing systems cannot provide voice service or information retrieval service. Second, the existing systems are not comprehensive enough, which only provides a small part of necessary services. For example. Some existing dental healthcare systems only provide follow-up care service, and some other systems only provide knowledge retrieval service. Third, there are few existing systems that provide dental healthcare with mobile services. Lacking mobile applications, patients cannot keep sustained attention to their dental conditions in mobile phone platform anytime or anywhere, and are hard to complete the follow-up care to give feedback of their subsequent dental problems.

To solve the problem of the lack of a comprehensive dental healthcare information system, we developed an integrated and intelligent dental healthcare platform providing mobile services. The developed system is based on the tool and framework provided by WeChat and Web service platform, and contains four components, including WeChat official account, question and answering (Q&A) system, the follow-up care mini program and AI speech assistant. WeChat official account provides dental knowledge for patients by retrieval portal. The Q&A system can answer questions raised by patients related to dental health. The follow-up care mini program and AI speech assistant are developed for patients' subsequent dental problems after medical treatment. Patients can give feedbacks on their dental health conditions anytime and anywhere, which also help hospitals improve service quality. We built such a comprehensive system containing the above four modules, and the developed system has been deployed in a high-level dental hospital, i.e., *the affiliated Stomatological Hospital of Xi'an Jiaotong University*[1]. Besides the provided services, the developed system is also used to collect real data generated during the process of dental healthcare, and further analyze and visualize the data, and then guide the hospital to improve treatment quality.

[1] http://www.dentalxjtu.com/index_en.php.

The remaining sections of this paper are organized as follows. Section 2 summarizes the work related to dental information systems and mobile medical applications. Section 3 presents the whole framework of our mobile-oriented dental healthcare system. Section 4 elaborates the four developed components of the system. Section 5 describes the system configuration, deployment and application. Section 6 concludes the whole paper.

2 Related Work

With the development of computer technology, dental healthcare information systems have developed rapidly and undergone several phases. With the popularity of electronic medical records, HIS (hospital information system) has gradually involves intelligent elements. In recent years, the emergence of mobile medical care has become a new direction. Nowadays, various mobile medical applications have emerged and are expected to have a promising future. Here we focus on two types of related systems, including dental healthcare information system and mobile medical application.

Dental Information System. Medical information systems have developed for more than 20 years, and have already achieved some progress [16]. However, the existing medical information systems are still in the early stage of development, and most existing systems are in low informatization level, insufficient management and defective function [7]. Most of existing medical information systems only have desktop terminals, and do not support mobile services [10]. The staff operation mode is usually rigid, and medical records are hard to be obtained anytime or anywhere. The intelligent development of existing medical information systems is not enough, although some hospital information systems have also introduced several intelligent techniques. For example. The affiliated hospital of Zhejiang University employs data mining technique to achieve real-time integration and classification of hospital information. Medical staff can understand medical status of a patient in a real-time manner [17]. But the system in the affiliated hospital of Zhejiang University is not fully intelligent. In contrast, our developed system provides voice service and information retrieval service, further improving the efficiency of medical staff.

Mobile Medical Application. Mobile medical healthcare refers to the use of wireless computers or communication devices (e.g., smart phone and tablet computer) that can be carried around to meet the healthcare needs of hospital staff and patients [11]. In [11], the author analyzed and evaluated the function and development of mobile medical applications in China. In [5], the author takes Chunyu healthcare system [1] as an example to study the sustainable development of mobile health network. Let us further take the Good doctor healthcare system [3] and Chunyu healthcare system as two examples. An investigation showed that doctors commented that Good doctor healthcare system and Chunyu healthcare system specialized in online doctor-patient interaction. The existing mobile medical applications do not provide professional dental medical services, and the resources and materials on dental healthcare are limited. Our dental information system combines the advantages of existing healthcare systems and develops a group of mobile medical services for dentists and patients. Our system also provides a humanistic pre-diagnosis mobile counseling service platform to enhance the patient's service depth.

3 The Architecture of the Developed System

Figure 1 presents the whole architecture of the built dental healthcare system with mobile services, which contains four components and each component is given a brief explanation as follows.

1. **WeChat official account.** The developed WeChat official account is an mobile assistant and extension of the intelligent medical system. For the developed mini program, the WeChat official account can send instant follow-up reminding message to patients, and popularize the mini programs to patients. WeChat official account provides access to the intelligent dental healthcare Q&A system, which takes a role of an interface to users. The developed WeChat official account also provides patients a variety of dental healthcare articles and procedures of dental treatment.
2. **Follow-up care mini program.** The main service of the developed mini program is post-diagnosis follow-up care. The follow-up care is conducted according to different types of patients and different time intervals, such as 24 h, 72 h, one week, one month and one year. The developed mini program matches different follow-up problems database, presenting to patients in a user-friendly way. Such a design can save patient's time, and send follow-up message instantly. Patients' feedbacks are sent to the doctor through WeChat official account. After receiving the message, doctors will make a phone call to the patient to improve the medical diagnosis. After all follow-up care feedbacks are stored in the database, the system will generate a follow-up care report in .pdf (portable document format) format, which can be exported for analysis at any time.
3. **AI smart speech assistant.** In order to cover patients of all ages in follow-up care, in the case that some patients do not use the mini program for follow-up care, our intelligent medical care system is capable of automatically dialing the AI smart voice phone, generating professional words requiring to ask for follow-up care. This component is capable of automatically recording and identifying the conversation, and asking the next question based on the patient's answer. Similar to the mini program, the AI smart speech assistant records the information for follow-up care and automatically generates a follow-up care report.
4. **Doctor-patient question and answering (Q&A) system.** The developed Q&A system can scientifically answer the medical questions raised by a patient, as the Q&A system undergoes sufficient training on a large doctor-patient dialogue corpus. After a patient asks a question to our system, a

classifier will first make a decision on whether the patient's question is a problem in dental healthcare field or not. The part-of-speech tagging and dependency parsing can extract the key phrases from the question. We build an answer retrieval engine, and can find the most suitable answers with the highest scores. The answers with the top scores will return to the patient. The developed doctor-patient Q&A system can improve the patient's knowledge level in dental healthcare, and help patients better understand the doctor's treatment.

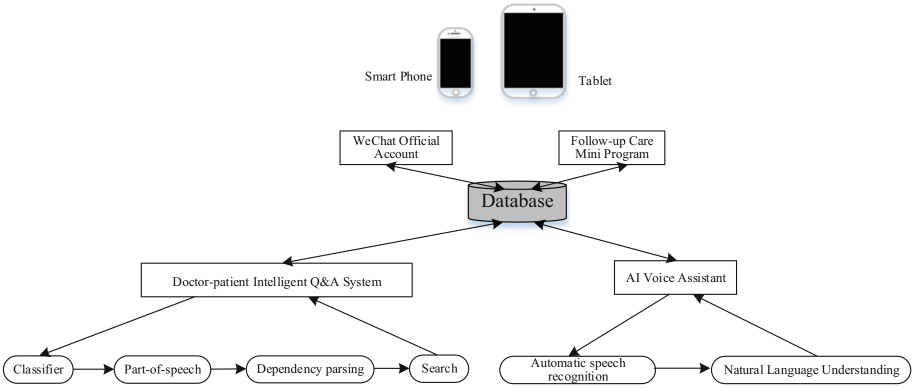

Fig. 1. The architecture of the developed dental healthcare system

4 The Developed Four Components

4.1 The Developed WeChat Official Account

The WeChat official account platform[2] is a platform for operators to provide information and services to WeChat users. The official platform development interface is the basis for providing services [4]. Developers can create WeChat official accounts and obtain administrator right in official platform websites.

The Web framework selected by WeChat is the Flask micro-framework [2], and the recommended programming language is Python. Typically developers will use Flask to build a WSGI application (Web server gateway interface, WSGI for short). The simplest version is to verify the server URL configured in WeChat official platform. The Flask micro-framework is easy to extend, and we can use Flask to build a complete WeChat back-end service. We use the recommended server Waitress[3] that is designed to be stable and secure to run the WSGI application. The server URL configured on WeChat official platform must be *http://* or *https://*, supporting ports 80 and 443 [4]. With the reverse proxy function of Nginx[4], we appoint a proxy *http://URL:80* to the server's local

2 https://mp.weixin.qq.com/?lang=en_US.
3 https://pypi.org/project/waitress/.
4 http://nginx.org/en/.

http://localhost:port. Such a strategy prevents the WeChat back-end from being suspended when the common ports 80 and 443 are occupied.

When a user interacts with the WeChat official account, the server address is configured on WeChat official platform website. For example. If a user sends a message to WeChat official account and clicks on the menu, the WeChat official platform will push a message or an event to the server. Then the WeChat back-end can respond according to its own business logic, such as replying messages. The *access_token* is the globally unique interface credential of the WeChat official account [4]. The WeChat official account developer needs to use *access_token* for invoking each interface. A WeChat back-end uses the central control server to uniformly obtain and refresh the *access_token*, which needs to be refreshed periodically. The WeChat back-end uses database Redis[5] to store the value of *access_token*.

When a user sends a message to the WeChat official account or when an event is triggered by certain user actions, the WeChat official platform will send an XML packet of POST message or event to the WeChat back-end. The WeChat back-end needs to parse the received XML packet to receive the value of the corresponding tag and return a specific XML structure in the response packet. Note that, sending a passive response message is not through an interface, but is a reply to the message sent by the WeChat server. In addition, within 12 h, the customer service interface can also be invoked to send a message to ordinary users through posting a JSON (Javascript Object Notation) data packet. The WeChat official account encryption and decryption are a new mechanism provided by the official platform to further strengthen the security of WeChat official account. After the encryption and decryption are enabled, the invocation interface will not be affected. Message encryption and decryption are required only when there is a passive reply to the user's message. Template messages can only be used in service scenarios that meet their requirements. A user will trigger a template message after performing a specific action on the developed WeChat official account. From the above process, it can be seen that the template message is a way of passive reply.

4.2 The Developed Intelligent Dental Healthcare Q&A Sub-system

The intelligent dental healthcare Q&A sub-system is a key component of our developed system. The main function of Q&A system is to answer the patient's questions. The developed Q&A component contains several modules, including a classifier, sentence parsing module and search engine. The proposed classifier classifies the questions raised by users. In the developed dental healthcare Q&A system, we classify all questions into two categories, i.e., ordinary chatting questions and professional dental related questions. After classifying, the Q&A system will pass the question to the sentence parsing module for parsing. The parsed sentences will be further filtered, and be passed to the search engine to return the correct answer.

[5] https://redis.io/.

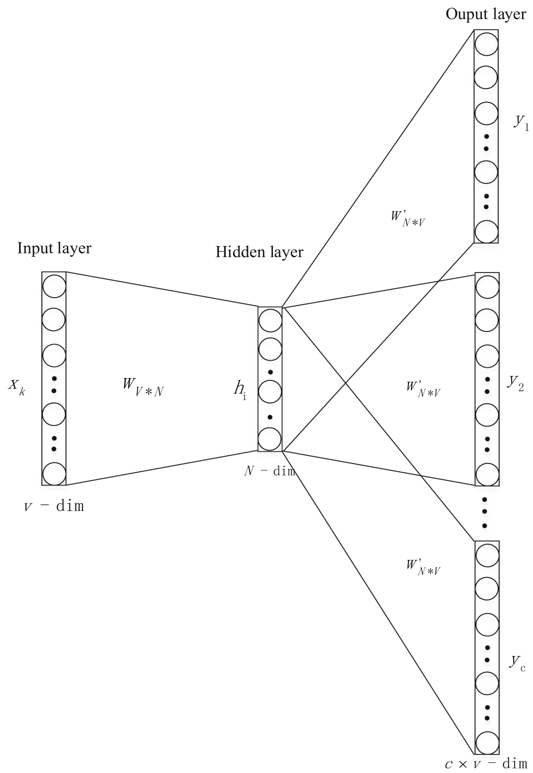

Fig. 2. The network structure of the implemented skip-gram model

The Built Neural Network-Based Classifier. Word2vec contains a collection of models that are capable of generating distributed representation of words or word vectors. The word2vec models are typically neural network-based models that can learn contexts of words in a corpus [14]. Word2vec takes a corpus of texts as input and generates distributed representation of words. The produced vectors typically contain several hundred dimensions, and each word in the corpus is learned to be assigned to a vector. Skip-gram and CBOW (continuous bag-of-words) are two typical models in word2vec. The input of CBOW is the context words around the central word. The idea of skip-gram is opposite to that of CBOW, that is, the input is a central word, and then the task is to generate the vectors of the context words around the central word. In the developed Q&A system, we choose the skip-gram model as it works well for uncommon words when the computing power is sufficient. The developed system implements the skip-gram model that is trained with a 200-dimensional vector on Chinese Wikipedia corpus. Figure 2 shows the network architecture of the implemented skip-gram model.

In Fig. 2, x is the one-hot embedding of a word, v is the vocabulary size, and N is the dimension of word vector. c is twice of the size of the word vector window,

w is the central word vector matrix, and w' is the matrix formed by context words' vectors. The vectors of words are trained first, and the next task is to design the classifier. We adopt recurrent neural network (RNN) as the basic classifier. As the traditional RNN has been verified to suffer from gradient vanishing and gradient explosion [15], in the developed system, we adopt a variant of RNN, i.e., LSTM (long-short term memory) network [6]. LSTM is a neural network configured with three gates, including input gate, forgotten gate and output gate. Figure 3 shows the network structure of the implemented LSTM.

The calculation involved in Fig. 3 are as follows.

$$
\begin{aligned}
i^{(t)} &= \sigma(w^{(i)}x^{(t)} + U^{(i)}h^{(t-1)}) && \text{(input gate)} \\
f^{(t)} &= \sigma(w^{(f)}x^{(t)} + U^{(f)}h^{(t-1)}) && \text{(forget gate)} \\
o^{(t)} &= \sigma(w^{(o)}x^{(t)} + U^{(o)}h^{(t-1)}) && \text{(output gate)} \\
\tilde{c}^{(t)} &= \sigma(w^{(c)}x^{(t)} + U^{(c)}h^{(t-1)}) && \text{(new memory cell)} \\
c^{(t)} &= i^{(t)} \circ \tilde{c}^{(t)} + f^{(t)}c^{(t-1)} && \text{(final memory cell)} \\
h^{(t)} &= o^{(t)} \circ tanh(c^{(t)})
\end{aligned} \tag{1}
$$

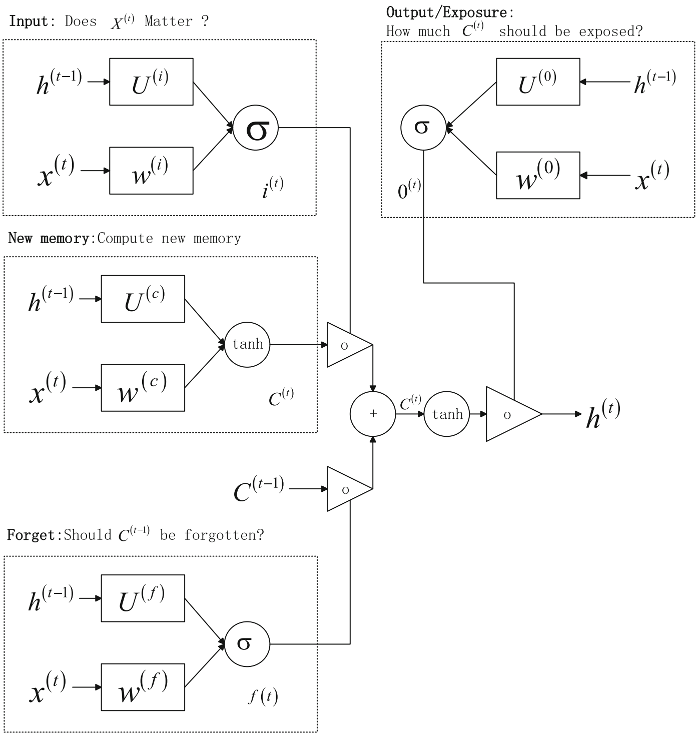

Fig. 3. *Input* denotes the input gate, and *New memory* denotes the new memory cell. *Forget* denotes the forget gate, and *Output* denotes the output gate. t denotes the current moment, $t-1$ represents the last moment, x denotes input, and h denotes the output of the hidden state.

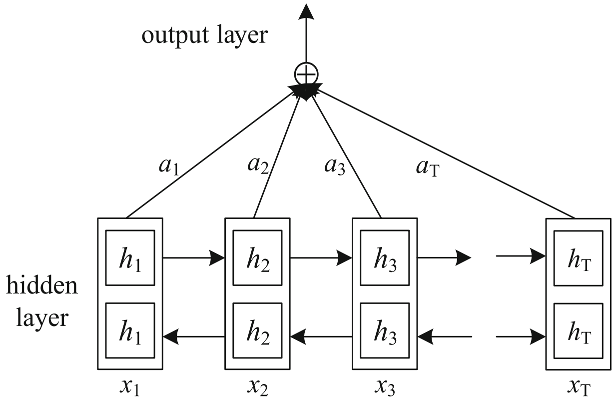

Fig. 4. "hidden layer" is the network structure of bi-directional LSTM. $a_1, a_2, a_3, \ldots, a_T$ are parameters in attention mechanism.

The calculation process of LSTM is as follows. The new memory cell uses $x^{(t)}$ and $h^{(t-1)}$ to generate $c^{(t)}$. So the new memory contains the attributes of the current word. The input gate uses $x^{(t)}$ and $h^{(t-1)}$ to determine how much the attribute of the word at the current moment should be kept, and this amount is represented by $i^{(t)}$. The forget gate uses $x^{(t)}$ and $h^{(t-1)}$ to determine how much the past memory should be forgotten, and this amount is represented by $f^{(t)}$. The final memory cell adds up the new memory retained by input gate and the past memory forgotten by forgotten gate to generate the final memory $c^{(t)}$. The output gate uses $x^{(t)}$ and $h^{(t-1)}$ to determine how much new memory $tanh(c^{(t)})$ should be output, and the output amount is represented by $o^{(t)}$.

In order to improve the accuracy of developed classifier, we build bi-directional LSTM network in the developed system, and the network structure is shown in Fig. 4. In the built bi-directional LSTM, the jth hidden state $h_j \rightarrow$ carries the jth word itself and a part of information in previous words. If the input is in reverse, the jth hidden state $h_j \leftarrow$ carries the jth word and a part of information in posterior words. So combining $h_j \rightarrow$ and $h_j \leftarrow$, $h_j[h_j \rightarrow, h_j \leftarrow]$ can contain the information before and after the jth word. The built classifier aims to classify the questions raised by users, most of which are short sentences, so our system adds the attention mechanism to the basic LSTM network. The attention mechanism is to assign different weights to different words in a sentence, which is likely to improve the accuracy of the classifier, especially in the case of short sentences. In detail, a layer of parameters after hidden layer are added, and are continually trained to be optimized. Figure 4 shows the bi-directional LSTM network with attention mechanism.

Sentences Parsing Module. After classifying the raised questions, if the question is classified into the professional dental healthcare category, we build a sentence parsing module that is used to finish a series of NLP tasks, including segmenting, POS (part-of-speech), and dependency parsing. The final results are generated by filtering the results of dependency parsing. Dependency parsing is to determine the dependencies between words in a sentence. Table 1 shows the result of dependency parsing built in our system for an example of user's question. The original question is in Chinese "戴活动假牙会戴坏其他牙吗？", and the corresponding English question with the same meaning is "Will wearing removable dentures impair other normal teeth?"

Table 1. The column below "dependency parsing" is the result of a question after dependency parsing. The column below "selected_dep" is the result after this system filters the original results of dependency parsing.

The result of dependency parsing
(root, ?#PU,戴#VV) (compound:nn,假牙#NN, 活动#NN) (dobj,戴#VV, 假牙#NN) (aux:modal,坏#VA, 会#VV) (aux:ba,坏#VA,把#BA) (det,牙#NN, 其他#DT) (dep,坏#VA, 牙#NN) (xcomp,坏#VA,戴#VV) (conj,戴#VV,坏#VA) (discourse, 戴#VV,吗#SP) (discourse, ?#PU, 吗#SP)

The result of selected_dep
(dobj, 戴#VV,假牙#NN) (compound:nn, 假牙#NN, 活动#NN) (det,牙#NN, 其他#DT) (dep, 坏#VA, 牙#NN)

In our system, only eight types of dependencies are remained, including *amod* (adjective modified noun), *compound:nn* (noun modified noun), *advmod* (adverb modified adjective), *nsubj* (noun subject), *dobj* (direct modified object), *det* (qualified modification), *parataxis* (parallel relationship) and *assmod* (association modification). For the complete list of the abbreviation in dependency parsing, please refer to paper [9]. Our system does not completely use all these eight dependencies, but adds some constraints to each dependency. For example. For the dependency *advmod*, two constraints are added. We only keep the lengths of the modifier and the modified word are both longer than 1, because in *advmod*, the valuable information contained by the object and the adjective with the length less than 1 is quite limited. Table 2 gives an example of the result of a sentence that is segmented, parsed and filtered.

Table 2. "keywords_filtering" refers to the result with sentence parsing and filtering

The result of keywords_filtering
戴 活动 假牙 其他 牙 坏

Query Module. The query module is built on the basis of an open-source text retrieval engine, i.e., Lucene[6], which provides a complete query engine and index engine. First, we build a Web crawler that is used to collect questions and answers related to dental healthcare from Internet. The collected questions and answers are checked, reviewed and corrected by professional dentists in *the affiliated Stomatological Hospital of Xi'an Jiaotong University*. Then we build indexes with Lucene's index engine for the checked questions and answers. We use Lucene's query engine to return the answer to the question raised by a user. In the search process, our system also adds extra resources, such as synonym dictionary. If a keyword of the question is in the synonym dictionary, the related synonym will also be searched together.

4.3 The Developed WeChat Follow-Up Care Mini Program

The WeChat follow-up care mini program adopts the B2C (business-to-customer) architecture, and the development adopts the architecture mode of server, client, and data management. The server uses Node.js[7] to build the RESTful API. The client uses the WeChat mini program to obtain data by sending an HTTP communication request to the server API. The data management module is the data management back-end for administrators to log in. This subsection introduces the key techniques used by WeChat mini program, including the MINA framework, Node.js framework, construction of RESTful API and MongoDB database.

The MINA framework[8] consists of three parts, including logical layer, view layer, and system layer. The MINA framework provides a set of JavaScript API for the upper layer by encapsulating the basic functions of file system and network communication provided by WeChat mini program. The MINA framework provides a set of language WXML (WeiXin Markup Language) similar to HTML tags and basic components at the view layer [8]. The view layer is a collection of .wxml and .wxss files. For users, the view layer is an interface that directly interacts with each user.

There are nine pages in the mini program, which are the dental classification page, doctor page, home page, patient information page, patient landing page, patient satisfaction survey page, patient message page, tooth type page, and end page. Each page has a life-cycle corresponding to its business logic, which is implemented by *page()* function in page's logical layer. The logical layer of the WeChat mini program development framework is implemented by JavaScript. On the basis of JavaScript, the *app()* and *page()* methods are added to register the program and the page. As the mini program does not run in a browser, some JavaScript's capabilities specific to Web development cannot be used, such as *document()* and *window()* [18]. The system layer contains temporary data, file storage, and network storage.

6 http://lucene.apache.org/.
7 https://nodejs.org/en/.
8 https://developers.weixin.qq.com/miniprogram/dev/framework/MINA.html.

Representational state transfer (REST) refers to a constraint and paradigm in communication. REST defines all entities on the Internet as resources, and each resource corresponds to at least one URL. Each URL represents a type of operation, so REST makes Web resources and services addressable. The interaction between a client and a server accessing network resources through standard HTTP requests, such as GET, POST, PUT and DELETE. The following Fig. 5 shows an example of a part of POST code.

For database, we employ a NoSQL database MongoDB[9]. The MongoDB database system is a type of transitional database, between the typical NoSQL database and traditional relational database [13]. The MongoDB database system uses BSON (Binary JSON) format to store data, which is similar to JSON format. Based on BSON format, the database system can store more complex data types and implement complex key-value nesting operation [12]. For WeChat mini program, the database structure follows the standard structure of MongoDB. The advantages of high-speed reading and writing, big data processing, and distributed scalability of MongoDB database meet the needs of mini program.

4.4 The Developed AI Speech Assistant

The developed AI speech assistant is used for patients who do not participate in the follow-up care of WeChat mini program. The AI speech assistant is built as a robot system based on RASA[10] and a speech recognition conversion layer based on hierarchical attention network. The service flow of the AI speech assistant is to convert the text into a speech call for follow-up care, then convert the patient's speech follow-up results into text and store the results in database. First, the raised questions are carefully designed. These designed questions are applied to the robot assistant system with RASA as the core part. The whole text follow-up care process is realized by training the RASA core module and NLU (natural language understanding) module. We develop a hierarchical attention network to convert text into speech, and make phone calls to patients. Second, the system automatically records and uploads the records of the conversation to server. Finally, the hierarchical attention network can convert the speech into text in the back-end and output the details of each phone call.

[9] www.mongodb.org/.
[10] https://www.rasa.com/.

```
infoPost: {
        method: 'POST',
        path: '/api/info',
        handler: async (request, h) => {
            let appId = config.wxappid
            let encryptedData = request.payload.foruid.encryptedData
            let sessionKey = request.payload.foruid.sessionKey
            let iv = request.payload.foruid.iv
            let pc = new WXBizDataCrypt(appId, sessionKey)
            let Encrydata = pc.decryptData(encryptedData , iv)
            request.payload.unionid = Encrydata.unionId
            delete request.payload.foruid
            let entity = new inforModel(request.payload)
            let existModle = await inforModel.findByOpenId(request.payload.openId)
            if (existModle.length == 0) {
                let crOne = await inforModel.create(entity)
                if (crOne) {
                    return {
                        status: 201 //Created successfully
                    }
                }
                else {
                    return {
                        status: 400
                    }
                }
            }
            else {
                let upOne = await inforModel.updateOne({ openId:
                            request.payload.openId }, { $set: request.payload })
                return {
                    status: 200 //update completed
                }
            }
        },
        config: {
            tags: ['api', 'info'],
            description: 'update'
        },
    }
```

Fig. 5. An example of POST code

5 System Configuration, Deployment and Test

5.1 System Running Environment

The front-end of the integrated and intelligent dental healthcare system is mobile devices, such as smart phones and tablets. Three of the developed modules, including WeChat official account, follow-up mini program and AI speech assistant, are all based on mobile WeChat platform.

The system back-end is built on Tencent cloud server, running Ubuntu Server 16.04.1 64-bit system with four CPUs, 8G memory and 5 Mbps bandwidth. We applied Nginx server[11], a high-performance HTTP and reverse proxy service. The Flask framework, a lightweight Web application framework is also adopted. MongoDB and Redis are employed as databases. We deployed and applied the developed dental healthcare system in a real dental hospital, that is, *the affiliated Stomatological Hospital of Xi'an Jiaotong University*.

5.2 System Implementation

WeChat Official Account. As shown in Fig. 6, the "post-diagnosis reminder" is a template message.

Fig. 6. The developed WeChat official account

After the user completes the teeth repair, the WeChat back-end triggers a follow-up care template message to the user. The "introduction to the department of prosthodontics" is a passive reply message. When the user clicks on the menu of WeChat official account menu, the WeChat official platform sends a click event to the WeChat back-end, and the WeChat back-end responds to the message "introduction to the dental restoration section". After the user sends a text message to WeChat official account, the WeChat back-end invokes the customer service message interface to reply to the user within 12 h.

[11] http://nginx.org/en.

Intelligent Dental Healthcare Q&A System. There is a classifier module in our dental healthcare Q&A system, which was introduced in Sect. 4.2. The training process and classification accuracy of the built classifier are shown in Table 3. The classification accuracy of our classifier can achieve 87.73%.

Table 3. The training process of the built classifier

Iter:0, Training Loss: 0.72, Training Acc: 49.00%, Val Loss: 0.76, Val Acc: 36.36%
Iter: 50, Training Loss: 0.3, Training Acc: 91.00%, Val Loss: 0.43, Val Acc: 79.55%
Iter: 100, Training Loss: 0.23, Training Acc: 92.00%, Val Loss: 0.32, Val Acc: 86.82%
Iter: 150, Training Loss: 0.22, Training Acc: 91.00%, Val Loss: 0.31, Val Acc: 87.73%
Iter: 200, Training Loss: 0.2, Training Acc: 95.00%, Val Loss: 0.29, Val Acc: 88.64%
Iter: 250, Training Loss: 0.14, Training Acc: 95.00%, Val Loss: 0.33, Val Acc: 88.64%
Iter: 300, Training Loss: 0.12, Training Acc: 98.00%, Val Loss: 0.36, Val Acc: 87.73%
Iter: 350, Training Loss: 0.29, Training Acc: 87.00%, Val Loss: 0.34, Val Acc: 89.09%
Iter: 400, Training Loss: 0.13, Training Acc: 96.00%, Val Loss: 0.37, Val Acc: 87.73%
Iter: 450, Training Loss: 0.18, Training Acc: 93.00%, Val Loss: 0.38, Val Acc: 87.73%
Iter: 500, Training Loss: 0.22, Training Acc: 93.00%, Val Loss: 0.43, Val Acc: 87.73%
Iter: 550, Training Loss: 0.18, Training Acc: 93.00%, Val Loss: 0.42, Val Acc: 87.73%
Iter: 600, Training Loss: 0.21, Training Acc: 90.00%, Val Loss: 0.43, Val Acc: 87.73%
Iter: 650, Training Loss: 0.19, Training Acc: 90.00%, Val Loss: 0.43, Val Acc: 87.73%

In Table 3, "Iter" is the number of iterations, "Training loss" is the value of the loss function on training set, and "Training Acc" is the accuracy on training set. "Val Loss" is the value of the loss function on validation set, and "Val Acc" is the accuracy on validation set. The built classifier stops training when the accuracy of the validation set is not updated for more than five times. The intelligent doctor-patient Q&A system provides a RESTful API for other authorized access. We evaluated the response time for sentences with different lengths. The sentences of different lengths refer to the contained different numbers of Chinese characters. The interval in the horizontal axis is five words. The results are shown in Fig. 7. From Fig. 7, it can be seen that along with the sentences' lengths increasing, the response time becomes larger smoothly.

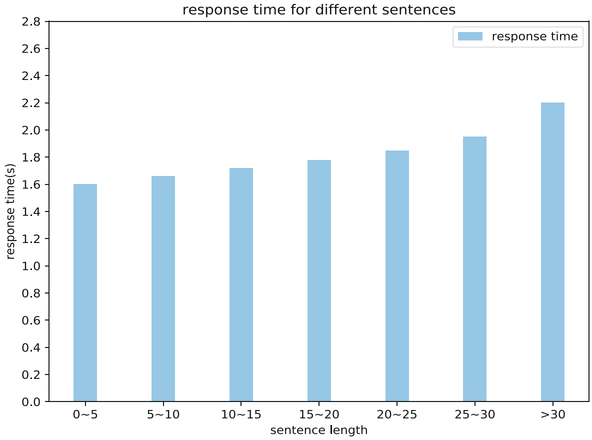

Fig. 7. Response time for sentences with different lengths

The Developed AI Speech Assistant and WeChat Mini Program. Fig. 8 shows the developed AI speech assistant, and Fig. 9 shows the developed WeChat mini program.

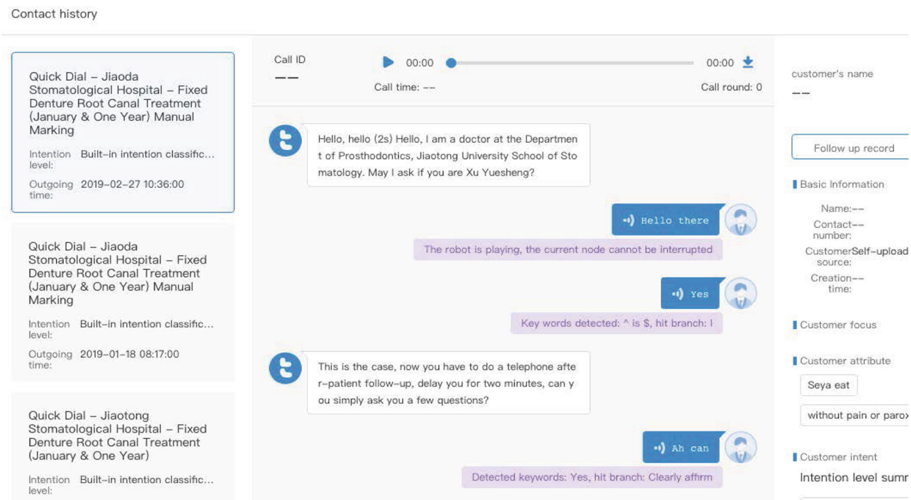

Fig. 8. The developed AI speech assistant

(a) Example page 1 in WeChat mini program

(b) Example page 2 in WeChat mini program

Fig. 9. The developed WeChat mini program

6 Conclusion and Future Work

In this paper, we present four developed components to form a complete intelligent dental medical system with mobile services. The developed system consists of four modules, including WeChat official account, intelligent Q&A system, follow-up care mini program and AI speech assistant. The key function of our system is to provide follow-up care service for patients. Also, the system makes a lot of efforts to provide service in both sides of patients and dentists, reducing the manpower of traditional follow-up care services. Our system provides an interactive healthcare service for patients, also easing dentists' burden. Our system has been deployed and applied in a real dental hospital. We are continuously monitoring the status of system running and are improving system functionality, performance and robustness according to the feedbacks collected from patients and dentists.

The built system also gives several future directions for exploration. In the future, we will continue to collect users' comments and use text mining techniques to analyze those comments. We also plan to expand the dental knowledge database enlarging the resources of our system.

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