CTM Tongue Image Consulting System based on Deep Learning Technology

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Abstract: - Internet is an important development step in information times. With the tide of Internet development, internet plus health will become a trend of new times. The Chinese Traditional Medicine (CTM) tongue image consulting system based on deep learning technology has created a more perfect and intelligent personal health management system by connecting smart devices to mobile platforms. The system will serve customers perfectly through health food therapy, medical consultation, etc.

Key-Words: - Chinese Traditional Medicine; tongue diagnosis; characteristic constitution; health monitoring; dietary recommendations; deep learning; health management.

1 Introduction

In more than 1000 years, CTM diagnoses by tongue image. [1], based on modern information technology, especially high-end image processing technique and machine learning methods, personalized scientific diagnosis can be made by utilizing tongue image. Thus, more ordinary people can enjoy the health services brought about by tongue image consultation. So the development of a TCM tongue health consulting system based on deep learning technology comes into being.

2 CTM Tongue Image Consulting System

2.1 The Function of the CTM Tongue Image Consulting System

The system has several functions as below. First, tongue diagnosis is a very important step in TCM observation. The doctor can understand the situation of the patient through observation of the tongue. The software of tongue diagnosis will integrate well with the information technology method. Thus, the diagnosis will be more comprehensive and objective. The health of customer will be protected effectively by setting up real-time updated profile through long time auditing; second, APP, website, Wechat, synthetic management of third-party platform and effective building of personalized health management system can truly meet the needs of modern people to use anytime, anywhere. At the same time, it has comprehensively realized scientific, information, and entertainment; Thirdly, the combination of health monitoring & dietary recommendation and effective connection with the medical institution can make the function more comprehensive and the service more personalized.

2.2 The Product and Service of CTM Tongue Image Consulting System

2.2.1 Background of the Product and Service

With the rapid popularization of mobile Internet technology and the widely used smart phone, more and more functions can be realized based on smart mobile platform such as various APPs on Wechat public platform. At the same time, due to people's attention to health and the change of lifestyle, various systems related to individual health records, testing and diagnosis based on smart mobile platform come into being. For various reasons almost all of these systems or application programs

are based on western theories and relevant concepts. The treasure TCM has not yet been carried forward on mobile platforms.

Chinese civilization has a long history. TCM has spread and developed with the process of history. It has formed a set of solid and unique TCM theory and clinical application system. Compared with western medicine, TCM emphasizes people-oriented. TCM comprehensively understands various physical features of the human body and systematically grasps the relevant information of the occurrence and development. Thus TCM can guide clinical treatment and health care. TCM forms a multilevel and multi-angle complementarity with the diagnosis and treatment system of western medicine, [2], [3].

2.2.2 Tight Relationship with the Internet

Emerging industries formed by the "Internet +" and integration and upgrading with traditional industries will be the important economic growth point of expanding consumption and promoting employment. From the perspective of industrial structure, "Internet +" drives the upgrading of industrial structure by forming a great economic vitality and wealth effect, rapid development of emerging information industry, and fusion optimization of internet technology and traditional industries. Internet can reduce the transmission cost of information to a very low level. After receiving a large amount of information, the degree of information asymmetry between consumers and producers has decreased significantly. The choice range of residents' consumption has been greatly expanded. Residents can use social mobile networks to unite. They begin to participate in all commercial links of production and consumption after solving the problems of dispersion and isolation to interconnection. They can truly become the leading force of production and consumption. [4], so the system is developed based on the Internet.

2.3 The Product Line of the CTM Tongue Image Consulting System

2.3.1 Tongue Image APP

2.3.1.1 Basic Principle

The diagnostic technology of traditional TCM is well known around the world. The four diagnostic methods including looking, listening, questioning, and feeling pulse have been widely used for thousands of years. Tongue diagnosis is an important step to look for diagnosis. It is an effective diagnosis method for the doctor to understand the pathological changes in patients by observation of the tongue. According to TCM theory, the tongue is a mirror of the body's internal physiology. The tongue can fully and flexibly reflect the internal changes of the the internal organs of human viscera. Therefore, tongue diagnosis has become one of the important tools of TCM diagnosis, [5].

Western medical research has also noticed that tongue images can reflect physical conditions. The British used a three-color colorimeter to check the tongue of the patient in the 1970s. They believe that any tongue containing blue is abnormal. However, the diagnosis of the tongue has always been analyzed and judged by subjective visual observation. And doctors use language to summarize the disease, lack of automatic and quantitative objective measurement. Tongue diagnosis is easily affected by external conditions such as light, angle, and other factors, etc. Also, the interference of doctors' human factors (such as knowledge level, clinical diagnosis experience, etc.) can affect tongue diagnosis. All these restrict the wider application and modernization of tongue diagnosis. With the continuous development and technical promotion of the modernization of TCM in recent years, people have higher requirements for the quantification and objectification of tongue diagnosis. The objective study of tongue image has started since the 1990s. Researchers have made many valuable explorations on extraction of tongue image features and tongue image analysis, [6].

With rapid development of artificial intelligence (AI) in past a few years, more and more AI technologies combine with traditional applications. Like tongue diagnosis, TCM doctors can examine diseases of patients through tongue color, shape, and texture. Many AI specialists want to simulate the process that TCM doctors' examination based on AI technologies. Currently, most methods are focused on comparison of the tongue photos themselves, [7]. These research methods propose higher requirements for taking tongue photos.

On methodology our technology achieves a breakthrough. The deep learning technology of the convolutional neural network(CNN) is applied. Through PCA Net model, tongue photos can be analyzed starting from the underlying pixels for feature purification and analysis. Because taking tongue photos comes from mobile phone, the method provides greater redundancy on different mobile brand, photo color, taking angles etc. The research method is pioneering.

The CTM tongue image consulting system innovatively applies deep learning technology to analyze and judge tongue photos. It is shown in Figure 1, [8].

The main working mode of tongue image diagnosis software is to take photos of users' tongues through smart phones. Then the health of the user can be judged through the software's analysis of photos. Users can be given corresponding suggestions on health care, lifestyle, and dietary choices by diagnosis and analysis of tongue, and preliminary judgment and screening of diseases. At the same time, users can choose to answer some questions based on the theory and practice of TCM to further improve the accuracy of disease judgment and the pertinence of the corresponding suggestions.
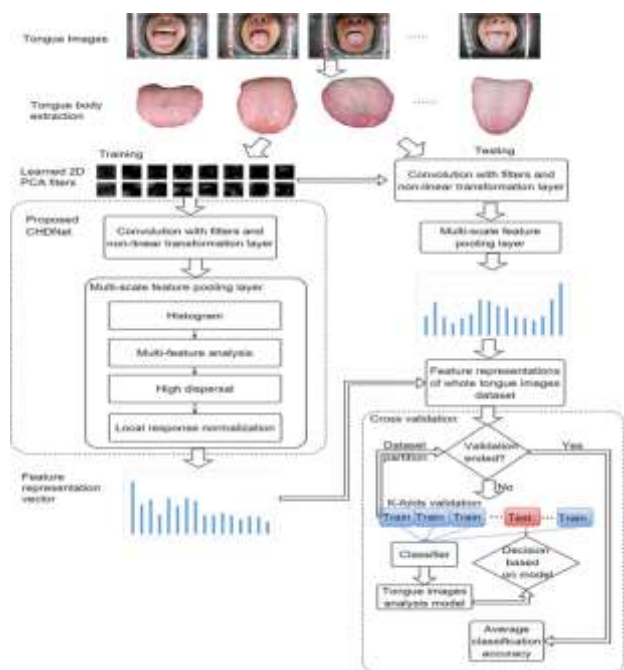

Fig. 1: Structure of the CTM tongue image consulting system

2.3.1.2 Health Monitoring and Evaluation

Dynamic assessment of health status can be obtained through recording the tongue image for a long time and comparing the objective indexes (color, texture, shape, etc.). For example, in patients with acute ischemic stroke, the tongues are often red and crooked, with greasy white moss [9]; red tongues with greasy white moss are also observed in patients with Helicobacter pylori infection [10]. Tongue shape assessment is also an important component of tongue diagnosis. Such geometrical shape information includes thickness, size, cracks, and tooth marks. In patients with primary Sjögren syndrome, the tongues are typically thin, reddish-red, nonmossy or cracked, [11]. In patients with primary insomnia, the tongues are predominantly red and fat, with yellow and white greasy moss, and tooth marks, [12] etc. The normal tongue is an ellipse tongue, but there are also six other classes of tongue shapes: square, rectangular, round, acute triangular, obtusely triangular, and hammer, [13]. The user's tongue can be better modeled through the multiple use of the tongue image diagnosis software by the same user. To find subtle but medically meaningful changes in the tongue, it is necessary to reduce the interference of various random errors. Thus, it can effectively assist in assessing changes in health status or physical recovery after treatment. The process is shown in Figure 2.
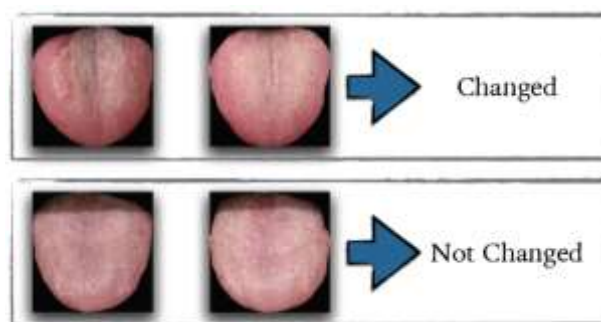

Fig. 2: The change of tongue image

Figure 2 shows a comparison of the images of the tongue of the same user at different times using the software for detecting the image of the tongue. The right side of Figure 2 is the release change of the main seven features (red is the previous feature distribution, and blue is the latter). It can be seen from the picture that there are significant changes in body state in the image above. However, there are no big changes in the image low.

At the technical level of AI, an end-to-end network called Tongue U-Net (TU-Net) can be proposed, which combines the classical U-Net structure with the squeeze-and-excitation (SE) block, the dense atrous convolution (DAC) block, and the residual multikernel pooling (RMP) block. The method can be applied to a tongue dataset with 300 images, and it performed better than other segmentation methods such asU-Net, Attention U-Net, [14].

A tongue segmentation method using a multitask, end-to-end learning model named TongueNet, for supervised deep CNN training is also presented. A feature pyramid network based on the designed context-aware residual blocks to extract multiscale tongue features is used. The region of interest (ROI) of the feature maps was also used for finer localization and segmentation. [15], in

a small-scale tongue dataset, they also applied U-Net for fast tongue segmentation, and achieved the highest accuracy of 98.45% and consumed 0.267 s per picture on average, [16].

Table 1. Different tongue images versus health characteristics

Name	Tongue Image	Corresponding Symptoms	Picture
Normal	① Light red and bright ② Moist tongue ③ Moderate in size, soft & flexible ④ The tongue coating is even, thin, white and moist	_ _ _ _ _	
Dentate tongue	① The edge of the tongue looks like a bite mark like a tooth ② The tip of the tongue has a papillary protrusion.	① Poor renal function leads to the problem of early aging of the kidney. There will be lower limb edema and obesity. ②The kidney reflects the main bone. People with this tongue image are prone to low back pain ③Beware of the risk of latent glaucoma ④Poor liver and gallbladder metabolism and easy fatigue	
Strawberry tongue	Red dots can be seen on the tongue image like strawberry	①The function of the pancreas and spleen is poor, and there are many obesity problems. ②It is easy to have bad breath, poor skin quality, and poor physical strength. ③If you do not pay attention to maintenance, be careful with diabetes	
Blood stasis tongue	There is no tongue coating and the tongue is dark red or purplish red	① There may be something wrong with the circulatory system. Blood is acidic and the metabolism is poor. Free radicals in the body are too high, increasing the risk of cancer, hypertension and stroke. ②The heart is sluggish and the thinking is not agile	
Body poison tongue	The thick coating of the tongue coating is clearly visible	①The toxin content in the body is too high and necessary to do environmental protection in the body & clean up some waste. ②People with this tongue image have physical problems, mainly the function of the lungs and intestines. There will be constipation or diarrhea	
Pressure tongue	After sticking the tongue, the uncontrollable shaking will occur on the surface of the tongue will happen	①Problem with autonomic nerves is indicated. In severe cases, the hands will shake and the body will also have the problem of shaking. ②Having the tendency to neuroticism, stress, insomnia, irritability, and depression ③The problem of overwork death should be paid attention to	
Fissured tongue	Longitudinal or transverse cracks can be clearly seen on the tongue surface	①It indicates that there is something wrong with body metabolism. There can be signs of mineral deficiency or an imbalance in hormone secretion ②Women will have trouble with monthly affairs and hair loss ③Men fear signs of kidney failure	
Sublingual varicosis	Vascular sclerosis above the neck, memory loss, migraine, stroke insomnia, Alzheimer's disease, neuroticism	①Caused by trauma ②Qi deficiency, qi depression, bad mood, anger, and pressure may lead to congestion in the body	

Additionally, using the U-Net structure, exploring to extract the ultrasound tongue contour using the U-Net, and superior performance has been obtained, [17].

The constitution and morphology related to tongue image is listed in Table 1. [18], [19], TCM 9 tongue model classification can lead to different health statuses. Through different classification, more details could be discussed. For example, tongue crack segmentation is also an essential component of computer-aided diagnosis applied. Tongue cracks refer to fissures with different depths, and [7]: Digital tongue image analyzes for health assessment 7shapes on the tongue's surface and muscle layer. In most cases, it can be seen as a changeful curve structure on the surface of the tongue, and its depth is determined by the severity of the atrophy and lesions of the tongue mucosa. Also, the quantitative value of the fissured tongue reflects the health condition of the internal organs, [20].

2.3.1.3 Dietary Recommendation System

According to the health situation reflected in the tongue image of customers, diet recipes that can improve your health can be recommended. The system needs to consider several things. Firstly, according to the results of daily health status, personalized diet recommendations (diet therapy) could be provided; Secondly, according to the principle of health preservation of TCM, geographical location, characteristics of solar terms, etc., dishes could be arranged reasonably. Personal order or comprehensive preparation of dishes will be taken into account considering the image of all diners will be took into consideration; Thirdly, regarding chronic diseases, dietary recommendations will be made based on recommended guidelines combined with theory of TCM. It focuses on cancer, hypertension, diabetes, and digestive system diseases; Fourthly, dietary recommendations will also be done base on main manifestations of sub-health, including fatigue, insomnia, tension, etc. The function of monitoring dietary calories is also developed at the same time. Automatic calorie estimation based on recipes or photos of dishes is included. According to the user's selected dietary scheme (NIH-recommended DASH guideline recommended by NIH or popular light fasting banting), the user's diet can be guided and supervised. The process is shown in Figure 3, [21].

The example shows ordering at a restaurant based on tongue image. The customer can get the hotel menu information by scanning QR code.

Depending on the situation of the tongue image, dishes or side dishes will be automatically recommended through tongue image diagnosis software.

Fig. 3: Dietary recommendation system

2.3.2 Wechat Public Platform for TCM health

Wechat has become an integral part of people's lives. Wechat has more than 1.2 billion users because of the advantages including fast speed, free expense, cross-platform, flexible, intelligent, etc. Building a Wechat platform will not only accumulate users and spread culture & information but will also become the service interface of product marketing, [22].

2.3.2.1 Release of TCM Health Information

Relevant seasonal and regional health knowledge can be published regularly based on season and region on the platform. General knowledge of health care and family diet and medication health care methods can also be introduced.

2.3.2.2 Online Classroom of TCM

The platform can regularly publish micro videos related to TCM health care including TCM diet regimen, TCM exercise regimen, TCM health preservation etc. Online small-scale micro-classroom teaching may be conducted by contacting the relevant specialist. The ways can include online real-time teaching by doctors and online real-time communication.

2.3.2.3 TCM Online Health Consultation

Users can directly upload tongue image information and send it to the background. The platform uses a tongue image analysis program to automatically analyze tongue image types and give diet suggestions. The communication ways also include user feedback questionnaire information and asking questions to doctors, etc. The users can enjoy the service of online doctor professional health assessment, disease risk assessment, diet and

exercise suggestions, etc. User questions could also be answered at the same time.

2.3.2.4 Health Micro-Store

The platform can become a platform for professionals and buyers to communicate. Local TCM clinics can not only sell relevant health care products online, including health care equipment, dietary supplement, and health books, etc. but also bring online customers offline and provide real-time diagnosis.

2.3.3 TCM Health Preservation Website

The developed tongue image APP, Wechat public platform, and portal to develop will realize unified background management and use the same database. The website focuses on the health status of individuals and families, customized private health account for users and dynamic monitoring for individual users. The main functions are shown below.

2.3.3.1 Personal Health Management System

Users can log in to their own account on the website and get relevant health information including long-term tongue image analysis, long-term health change trend of scientific system, health care feedback, prediction & guideline received regularly, and realizing the real-time update of users' health records, etc. The users can look for people with similar health and form their own circle of friends through website.

2.3.3.2 TCM health Care Course

The website regularly publishes video courses on TCM health preservation including TCM diet regimen, TCM exercise regimen and TCM physical health preservation etc. The website will realize real-time communication between doctors and users through the way of inviting experts and doctors to give lectures online in real time on a regular basis.

2.3.3.3 TCM Health Care Information

Users can utilize the website easily and quickly to obtain valuable information such as popular knowledge including common sense of TCM, diet health care of TCM and sports health care of TCM, etc. The website will provide users with the main information and communication channels of the relevant medical institution and expert physicians through an effective connection with relevant medical institution.

3 Summary

The tongue image can be handled to understand the health status of customers and give the corresponding suggestions through the CTM tongue image consulting system based on deep learning technology.

3.1 Big Data System for Health Management

The big data system of health management is to research and develop a personalized medical cloud platform information system that integrates all data. It can implement automatic health monitoring, health guidance, and medical consultation. It can provide customers with all-round health-related information (diet, exercise, medicine, etc.). It can also provide complete health detection, prevention plan, and relevant health knowledge. The system is shown in Figure 4.

The system has a functional interface that can monitor dietary calories and physical exercise, including setting and achieving fitness goals, communicating with friends and doctors, learning, etc.

3.2 Big Data System of Tongue Image

The big data system of tongue image can collect a large number of tongue images and related health information. The system searches for tongue images to high similarity with users by means of big data search. Then a more comprehensive physical condition assessment can be performed for the customers based on existing tongue images and their diagnostic information. The system is shown in Figure 5.

The customer tongue image can be searched for in database. The health situation of the customer can be evaluated using a similar tongue image. Health advice can be provided and the information can be stored in the electronic medical record.

Tongue classification tasks can be divided into two main categories. The first is a classification based on the clinical characteristics of the tongue, such as the color of the tongue coating, the distribution of the tongue coating, tooth marks, tongue cracks, and tongue shape. The second is to classify diseases that can be reflected in the clinical attributes of the tongue, such as gastritis, appendicitis, and breast cancer. In early research, machine learning methods, such as support vector machines were applied to classify tongue images. Before training these classifiers, feature extraction is an important step.
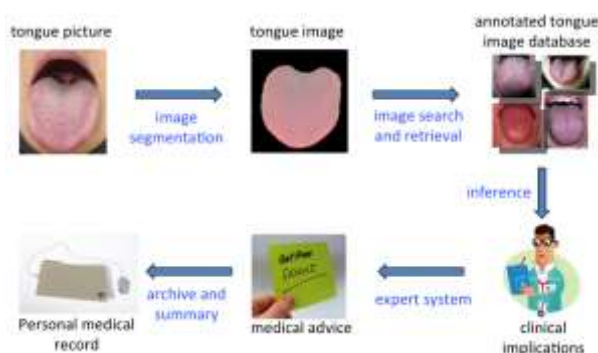
Fig. 4: Big data system for health management

Fig. 5: Big data system of tongue image

Many studies have tried to use different methods to extract features such as the color, texture, and shape to improve the accuracy of the classifier, and some studies have optimized the structure of the classifier, which greatly improves the accuracy of tongue image classification. With the introduction of deep learning, CNNs have significantly increased the number of parameters in the classifier and subsequently improved the accuracy of the classifier. After that, some [7], Digital tongue image analyses for health assessment 21 more complex networks such as VGG, Resnet, Inception were proposed, and the performance of tongue image classification was further improved. However, more research is needed to further improve the accuracy of tongue image classification. In the next few years, tongue classification also needs significant improvement for broad applications. Tongue classification and tongue diagnosis on mobile devices represent a

general trend of TCM-assisted tongue diagnosis, but the quality of the data on mobile devices is limited. It requires bigger datasets and better machine learning models to address these issues. The computerized tongue diagnosis system provides a certain level of convenience for both physicians and patients. Physicians can refer to the results of the tongue diagnostic system to aid in their diagnostic process; patients can upload their tongue pictures via their cell phones to obtain an assessment of their health status. Although many studies of computerized TCM diagnostic systems have been published, limited by hardware technologies and computational methods, almost all of these computational diagnostic systems can only simulate one of the four diagnostic methods in TCM to assist in disease detection. According to the four diagnostic theories TCM, other data (e.g., pulse, etc.) of the patient are also necessary to make a more accurate assessment of health status. Combining tongue diagnosis with other data, such as pulse diagnosis, is an inevitable trend in computerized TCM diagnosis.

In summary, with the gradual and wide application of CTM tongue image consulting system, the health level can be improved really through the gradual transformation from the mode of passive treatment to the mode of active management and health prevention.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)
The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Conflict of Interest
The authors have no conflicts of interest to declare.