Sensor Diagnosis System for Sleep

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Abstract. The cloud-computing-dirven and fog-computing-dirven mode have further inspired the studies of preventive medicine. If the database of physicians’ recorded clinical cognitive diagnosis can be smartly utilized in the Internet of Things (IoT) technologies for AI monitoring of sleep quality and disease risks prediction, then the preliminary diagnostic data provided by such terminal sleeping diagnosis device might be used for prevention of diseases at early-stage and, therefore, to greatly reduce medical cost, to increase accessibility of reliable medical services and to further reduce medical risk. However, the diagnostic big data is almost missing in current e-medical system. Therefore, a wearable smart sensor diagnosis system for sleeping patients is proposed in this article. Within the diagnosis system, smart devices for brain, nose, heart, lung and legs are included. All detected data is uploaded to the user's mobile APP for preliminary comprehensive diagnosis calculation, which is called fog calculation. The refined data provided by the APP of sleeping sensor system can cover a large proportion of physicians’ cognition of each patients’ real conditions. Refined data, which has been removed redundant data by fog calculation, is uploaded to big data cloud for accurate diagnosis and treatment. The sleeping diagnosis big data, uploaded by sensor system perhaps reflected the values of the well-linked text information produced by a combined database of online and offline medical records.

1. Introduction
In recent years, to meet the emergency demands of real-time or latency-sensitive applications in e-medical system, a novel computing paradigm that expands Cloud Computing (CC) approach, called Fog Computing (FC), which extending the Cloud Computing to the new edge of smart devices of the network. The up-to-date fog computing mainly focus on the reduction of response time of big data and the data analysis. With the vigorous development of Internet of Things (IoT), billions of smart wearable devices equipped with huge capacity for sensing, collecting and uploading data intelligently will be Integrated in IoT in the next decade. [1-3] The purpose of this paper is to identify the core data from the data uploaded by the sleep monitoring data collection system and eliminate the redundant data. It is well noted that Fog Computing paradigm contributed a lot to e-healthcare, much less latency and power consumption highlighting the advantages of such Fog Computing paradigm.

2. Main Points of this Research
This study mainly researches the remote monitoring of sleep quality and smart diagnosis technologies. In other words, this article devotes to IoT-based sleep preliminary diagnosis. The following key points are summarized:
After thoroughly surveying recent intellectual technologies, this research designed the overall frame for fog computation of sleep diagnosis system. In a word, this article is devoted for the expansion and refinement of IoT terminals.

First, to increase comfort a whole set of modified smart wearable sleep devices are displayed here and most of them are of good viscosity but are not tighten up as much as the traditional sleep diagnosis devices.

Second, this research discusses the combination of head, nose, hands, chest, feet data acquisition and the related supportive technologies for preliminary diagnosis and data mining.

Third, here introduced a simplified fog computation model for smart sleep diagnosis. This proposed model is aimed to achieve a low-latency and higher accuracy rate.

Finally, the potential crisis, the possible barriers and challenges must be systematically discussed, to prevent any hindrance that may hinder the improvement of fog computation for preliminary intelligence sleep diagnosis.

2.1. Smart Devices for Data Acquisition

The set of wearable devices, as shown in Figure 1, are including: 21-points electroencephalogram, airflow measurement of nose, heart and breath rhythm, electromyogram, and the saturation of blood oxygen. Since each independent wearable device can send data to the app interface of the smartphone, users can choose to buy or wear only one or several of a set of devices.

- Electroencephalogram (blue circles indicated by blue arrows and marked with blue words): the detection of brain functions by recording the bioelectrical waveform impulses of the brain. Electroencephalogram is used for identifying the disease stages of sleeping patients. The diseases monitored by the equipment mainly include: epilepsy, hysteria, paroxysmal syncope, cranioencephalic trauma and encephalitis.

- Airflow measurement of nose (dark gray curves indicated by dark gray arrows and marked by dark gray words): temperature of alternating hot and cold airflow is measured by sensitive air pressure sensor and thermistor, respectively. This part of smart devices can monitor breathing hover and other more dangerous conditions during sleep.

- Heart and breath rhythm (two dark green semicircles equipped with rectangular, pointed by dark green arrows and marked with dark green words): electrocardiogram is acquired by detecting the bioelectrical activity of users' heart during chest contraction and expansion. All of the Chest and abdominal wall movements are measured by belts tided to users' thoracic and abdominal. These might be utilized for the detection of early-stages heart diseases.

- Electromyogram (the six red semicircle rings indicated by red arrows and marked with red words): by recording of bioelectrical impulses during deep sleeping to detect muscle state of the legs and chest. Through the data collected above, symptoms of muscular dystrophy, muscular atrophy and nerve injury can be preliminarily diagnosed.
The saturation of blood oxygen (six long, dark yellow rectangles pointed by dark yellow arrows and marked with dark yellow words): oximetry detected from finger and toe blood flow pulse. Low oxygen might specify the appearance of severe nasal polyp or thrombus.

2.2. Advantages of Preliminary Diagnosis by Smart Devices in Sleeping
This study designed a set of detachable intelligent wearable devices for preliminary diagnosis that users can wear comfortably in sleep. The purpose of the design is to realize the collection of primary diagnosis and treatment data at home with the help of cloud computing and fog computing, and predict the early symptoms of emergency and early detection and treatment of early chronic diseases. In short, using the fog computing link in the Internet of things, we can realize the popularization of e-medicine, save the time and economic cost of users, save the medical resources of hospitals, and eliminate the potential danger of users' health as much as possible.

2.3. Data Reserve and Emergency Handling
Since each user's smartphone APP can accurately store historical data and form the user's own database, the normal base value of each function parameter can be calculated by referring to the basic parameters such as age, weight, gender, height entered by the user. The database values of various functions of independent users might be used as the diagnosis basis for outpatient doctors. When a large number of independent users' data base databases of various functions are uploaded to the cloud data terminal, they can be used as a powerful county, city, province and country targeted medical and pharmaceutical policies or commercial reference.

For individual users, the base value of each function data of independent users is a dynamic array of diagnostic thresholds, which is used to filter key data and dangerous data urgently needed to be processed from a large number of function data and upload them to the cloud data terminal as a reference for subsequent diagnosis and treatment and clinical intervention.

If the cloud data terminal determines that a user is indeed in a critical moment after comprehensive diagnosis, it will feed back the data to the user's smartphone APP, dial out the emergency call of the nearest hospital through address location and topology calculation, and send relevant information to the user's relatives and friends at the same time.

3. Framework of Multilayer Internet of Things
The data attributes and specific functions of key layers of multilayer Internet of Things should be described as the following Table 1:

| Data                        | Smart devices APP of smartphone | Cloud data process |
|-----------------------------|---------------------------------|--------------------|
| Real time data Historical data record, from multiple devices, threshold data synthesis, dangerous data upload | According to the threshold data and other parameters, identify the authenticity of the dangerous data and the emergency level of the user's situation, and make corresponding response |
| Communication mode          | Bluetooth[4] Wifi[4]            | Wifi               |
| Calculation operation       | of Nil                          | Fog computing      | Cloud computing |
| Handling dangerous situations | off Flashing light Notify the patient's relatives and friends, and emergency filing shall be made to the relevant departments of the hospital nearest to the patient, and emergency response signals shall be fed back through communication with "smart devices" and "app of smartphone" |

![Table 1. Functions of different layers in the Internet of things.](image-url)
For the calculation part, the following three points need to be stated in detail:

- "App of smartphone" must include two basic functions of filtering and noise reduction in fog computing.
- "Cloud data process" is only possible to provide accurate processing results in the cloud computing phase when users have complete real-time data. Therefore, it is strongly recommended that users purchase and wear a full set of sleep collection equipment when they need accurate cloud computing results.
- In the "cloud data process" segment, there should be an authoritative database such as "national health big data" as a key reference.[5]

4. Emergency Data Handling

Each single user has its own set of normal data values. It includes the fluctuation range of normal value and the risk threshold data. When approaching 95% of the threshold value, the kinescope of corresponding smart device will flash. When the threshold value is reached, the key data will be uploaded to the smartphone as the emergency data to be diagnosed and then uploaded to the cloud data processing system.

4.1. Calculation of Diagnostic Accuracy

As an evaluation, the accuracy of the system $\eta$ can be calculated as follows:

$$\eta = \frac{N_{\text{real-patient}} + N_{\text{real-healthy}}}{N_{\text{real-patient}} + N_{\text{real-healthy}} + N_{\text{Misdiagnosis-patient}} + N_{\text{Misdiagnosis-healthy}}} \times 100\%$$

In Equation 1, each variable has the following meaning: $N_{\text{real-patient}}$ indicates the total number of times the patient was accurately diagnosed as a patient, $N_{\text{real-healthy}}$ indicates the total number of times a healthy user is accurately diagnosed as a healthy person, $N_{\text{Misdiagnosis-patient}}$ indicates the total number of times the user was misdiagnosed as a patient, $N_{\text{Misdiagnosis-healthy}}$ indicates the total number of times a user with a disease is misdiagnosed as a healthy person.

5. Conclusion

This paper provides a set of self diagnosis equipment for users to use during sleep time by using fog computing and cloud computing. The specific summary is as follows:

- The whole set of devices can be used separately, because each independent device has Bluetooth communication to connect to the smartphone.
- Run fog calculation in smartphone APP: integrate basic data such as user's age, gender, weight and height to synthesize health value range and risk threshold value. This step is a preliminary diagnosis.
- After receiving the emergency diagnosis data, the cloud processor carries out comprehensive analysis and judgment with the large sample database, draws the diagnosis conclusion and disposal measures, and feeds back to the user. This step is accurate diagnosis, so it is highly recommended that users with accuracy requirements purchase and wear a complete set of equipment.
- Compared with the traditional terminal, this system has the advantages of fog computing, cutting redundant data, greatly reducing the amount of uploaded data, greatly improving the data accuracy and calculation efficiency of the upper structure, and greatly saving the storage space of the upper structure.

Acknowledgement

The author sincerely thanks for funding: the exploration of the "Internet plus" in the process control technology course (No. EJY1902).
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