Mobile Cloud-Based Framework for Health Monitoring with Real-Time Analysis Using Machine Learning Algorithms

Suman Mohanty, Ravi Anand, Ambarish Dutta, Venktesh Kumar, Utsav Kumar, and Md. Ruhul Islam

Abstract Cloud computing in the field medical sciences has made remarkable progress and has been a boon for medical firms. The motive being to provide health consultancy remotely as well as quickly. It mostly emphasizes on proper diagnosis of the patient as and when required. In contrast to the existing system which is at times prone to errors leading to many deaths due to faulty diagnosis and monitoring. Cloud-based system provides much fluidity by providing quick assistance for patient irrespective of their location. Cloud infrastructure has greater computational power and can analyze patient's data remotely helping the medical practitioner to provide diagnosis rapidly, and greater precision is achieved by deploying machine learning algorithms. To make this system accessible from anywhere, in our paper, we propose the use of mobile cloud computing-based architecture for health monitoring. Mobile cloud computing relies on cloud computing to deliver applications to monitoring devices. Real-time monitoring is possible where data can be fetched with the use of mobile cloud applications. Mobile computing provides a platform for making the use of high-end cloud infrastructure to use powerful computation ability to deploy forecast models. Mobile cloud computing plays a vital role since it extracts the advantages of integrating both cloud and mobile computing to provide healthcare assistance. The proposed architecture is scalable as data storage can be increased/decreased by health institutions, reliable as it implements MCC and affordable as it works as a subscription model.

Keywords Mobile cloud · Gene · Machine learning techniques · Time-series analysis · Artificial neural networks · Support vector (SVM)

1 Introduction

The widespread of medical devices along with the Internet has revolutionized patient monitoring and medical assistance systems. Different acquired information such as

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blood sugar level, heart rate, and other signals which are transmitted to the doctor's end through cellular networks and wireless media automated medical forecasting and analytical tools enable remote diagnosis [1]. Cloud computing is an efficient platform for monitoring and managing services. It provides secure transmission, and retrieving medical information using private cloud, secure storage, sharing, and medical information exchanges is achieved through private cloud. The use of machine learning algorithms and deep learning models for clinical applications is capable of transforming the delivery traditional health monitoring services.

2 Literature Review and Existing System

Extensive work on health monitoring, diagnosis, and detection is being carried by many researchers. Computer scientists and researchers tried to blend health monitoring along with remote diagnosis. A work by Bhosale et al. [2], Patient Management System For Doctors Using Cloud Computing, helped us to understand how management systems can be deployed in the cloud and can be recursively used for future reference of patients health.

Another good literature was by Mamun [3], and his Cloud-Based Framework for and Monitoring System for Remote Healthcare Applications idea is on how the cloud technology can be used in a similar viewpoint and how it can improve the detection and monitoring method. This is a literature that helped us to build a solid foundation.

This literature research on [4] Mobile Cloud Computing: Review, Trend and Perspectives by Mr Han Qi and his team of Malaysia University helped us to understand the importance of Mobile Cloud Computing.

One of the other notable work we used for our reference was by Qayyum et al. [5] Secure and Robust Machine Learning for Healthcare: A Survey. It helped us to how data processing is important as a strategic resource and how mobile cloud is an extension of cloud computing with high mobility and scalability

3 Cloud Computing Services

Cloud computing is a hardware–software package, which is the storage and computing power and also the software required to utilize the hardware very efficiently. Cloud computing looks after the weighted tasks involved in computation and processing data away from devices we use. It migrates all computation to greater block of computer in the Web. The Internet tends to be the cloud, the information, applications, and work which is accessed through any device irrespective of geographical location. [6]. Cloud computing can both be private and public. Public cloud devices charge some fee for rendering service. Private cloud services are confined to a group of people and provide services to a specific organization which is confined to the people associated. These are framed networks which supply hosted

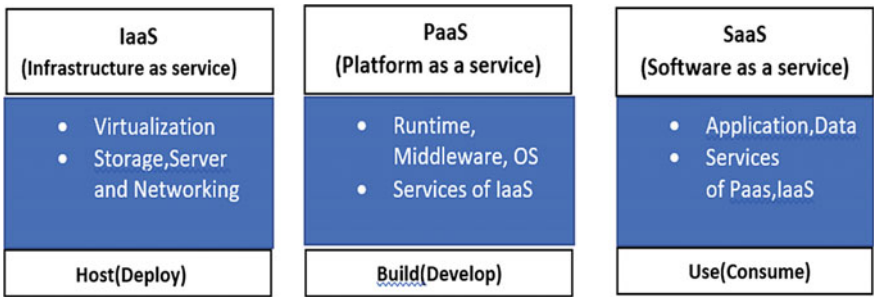

Fig. 1 Cloud services

services. Hybrid cloud is a technology that incorporates one or more public cloud services with a private cloud, with customized software that allows for communication within each separate service. When demands and costs vary wildly, a hybrid cloud approach provides organizations with greater versatility by shifting workloads across cloud solutions (Fig. 1).

4 Mobile Cloud Computing

We can say that mobile cloud computing is a mixture of mobile computing and the expansion of the cloud computing. It is somewhat similar to cloud computing. With the help of mobile cloud computation, users of the mobile can run applications on their mobile without completely relying on the mobile operating system and the computing or the memory capacity of the smartphone [7]. Mobile cloud computing is complete mixture of mobile development and cloud computing. With the help of mobile cloud computing, the mobile user can use applications with many options and functional capabilities delivered over the Internet and powered by infrastructure of cloud backend.

Architecture

In mobile cloud computing, the mobile devices and the mobile networks are connected with the help of satellite and access point. The main part of this satellite or access point is to establish the connections and control functional interfaces between the networks and mobile devices. The requests of the mobile users and their information such as their ID and location are transmitted to the central processor. These central processors are connected to the servers; the server provides the mobile network services. The mobile device users who are connected in the mobile cloud network can access services such as authorization and authentication based on the user or subscriber's data stored in the databases. Then, the subscriber's data and the subscriber's request are transferred to cloud through the Internet. In the cloud, there is cloud controllers, and this cloud controller is responsible to process the subscriber's

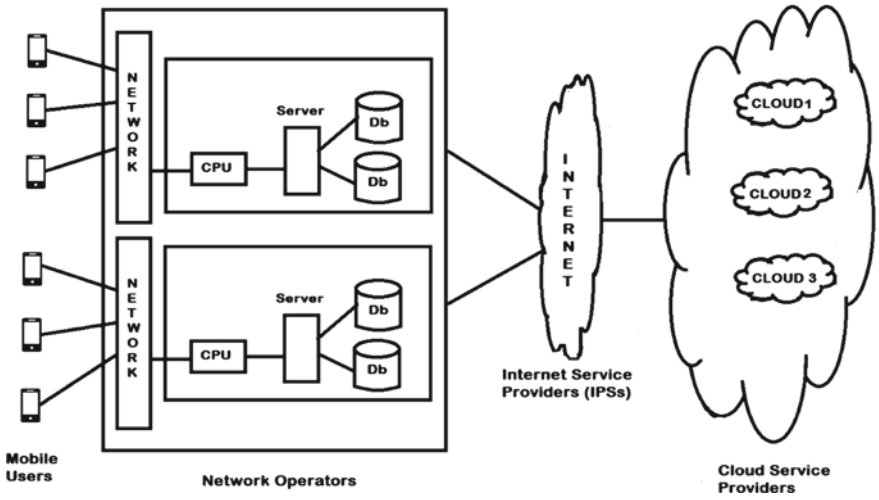

Fig. 2 Mobile cloud architecture health monitoring systems

request and provide the subscriber the corresponding cloud services. Figure 2 shows the architecture of the mobile cloud computing.

5 Health Monitoring System and Sensors

The patients end comprises of IoT module. The module consists of multiple biomedical sensors which enable the measurement of vital health data such as heart rate, saturation of oxygen in blood, and body temperature. The considered sensors include electromyography sensors which measure response of muscles and reads electrical activity due to simulation of muscle nerves. It helps to detect muscle and nerve problems. It also includes electrooculography which is a method for measuring the potential difference between the retina and cornea which is the front and back of human eye. The signal generated due to this is termed as electrooculogram. It mainly focuses on diagnosis of eye and other ophthalmological treatment. It does not take in account the response to individual visual stimulus.

An embedded blood sugar is to measure the glucose concentrated in the blood. It also exists in form of strips of glucose paper which is dipped to some substance and measured with respect to standard glucose chart for monitoring patients with hypoglycaemia/diabetes mellitus. We have taken in account electroencephalography (EEG), which measures electrical activity in the brain, as cells in brain communicate through electrical impulses. It helps to detect brain disorders such as seizures, stroke, dementia, and disorder in sleep. One of the most vital sensors used is the heart rate monitor which is a common sensor module used to monitor heart rate during various physical activities.

- This enables close monitoring of patient's health at real time using mobile cloud architecture.
- The data triggered after being read through sensors helps the doctor to remotely diagnose the patient as well as maintaining a health record in the proposed system

6 Machine Learning Algorithms for Deployment in Cloud

6.1 Support Vector Machine

SVM is one of the most used algorithms that are being deployed for classification and regression problems. Not only that, its extensive use is also found in the problems, specially the classifications were dataset that needs to be divided into two different classes using a hyperplane. For the new data to be classified correctly, the selection of hyperplane should be in such a way that the distance between any point within the training set and the hyperplane should be maximum [8]. Support vectors are the most essential and most difficult data points that need to be classified. These are the one that is nearest to the decision surface or the hyperplane and hence should be attended carefully (Fig. 3).

$$\text{the function of line, } y = mx + c$$
$$mx + c - y = 0, \text{Let vector } X = (x, y) \text{ where } x, y \tag{1}$$

$$w = (m, -1), \text{Now hyperplane is } w.X + b = 0$$
$$\text{the hypotheshis function } h = \begin{cases} +1, \text{ if } w.X + b \geq 0 \\ -1, \text{ if } w.X + b < 0 \end{cases} \tag{2}$$

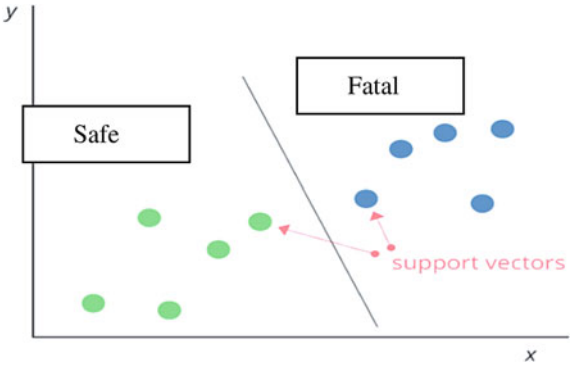

Fig. 3 2D support vector graphs

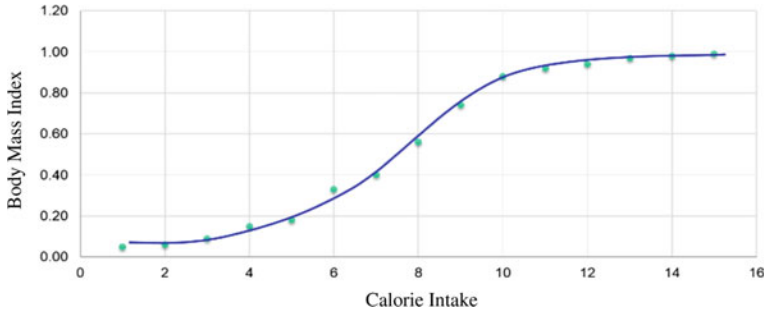

Fig. 4 Logistic function

6.2 Logistic Regression

Another supervised learning algorithm is logistic regression which is grouped under classification algorithms and are mainly deployed for predicting the probability of an output variable. Multiple linear regression is also akin to this, having an exception that response variable is binomial. In case of healthcare, where logistic regression is broadly deployed for predicting the risk of a disease and to further ameliorate in making decisions, predicting the probability of output variable and classification problems is important [8]. It forecasts the likelihood of a given case, making it a valuable method for determining disease risk and enhance clinical choices (Fig. 4).

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$

the weighted sum of inputs, $x = \Theta.\text{weight} + b$

Logistic equation i.e., Obese Probablity

$$= \frac{1}{1 + e^{-x}} = \frac{1}{1 + e^{-\Theta.\text{weight}+b}} \tag{3}$$

6.3 Natural Language Processing

Taking healthcare into consideration, substantial fraction of data is unstructured and indecipherable like discharge summaries, patient's health reports, operational procedure, etc., thereby making it difficult to understand by computers without special programs or methods [9]. The collections of enriched and well-structured data that are available from the previously encountered disease-related keywords help in identifying different unseen words from the clinical notes and hence overcoming this problem.

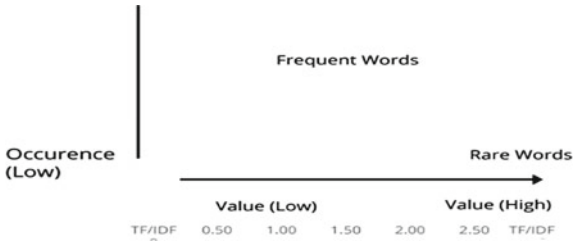

Fig. 5 Automated health report data mining

TF-IDF Term frequency-inverse document frequency measures the importance of a word under a document in the collection or corpus. Term frequency is the frequency measure of words in the document, and inverse document frequency is the measure of commonness in the words among the different text corpus. The frequency count of the words helps in understanding the most significant words and the least significant words as well [9]. TF-IDF is also important in situations where disease correlation between patients are high as well as in searching of databases for sequential patterns (Fig. 5).

7 Architecture and Working

7.1 Cloud Services

Why Azure over alternative Cloud services?

Microsoft has produced a number of the industry's leading advanced security technologies, so you can be guaranteed that your information is securely protected [10]. Microsoft has taken significant measures to ensure high standards of protection around the cloud space. With tools consisting of threat intelligence, threat analytics, Azure Info Security, and two-factor authentication, your Azure environment is secure. These methods help you assess, create, and re-establish threats in real time and respond to suspicious activity of the server and the user on your network and have the best protection levels. With Azure, the collection, use, and distribution of your client data are owned and managed by yourself. Microsoft has provided detailed information about their expertise to handle your knowledge

Azure Virtual Machine

Virtual machine allows you to produce and manage a gaggle of similar, scalable, and load-balanced VMs. It is a computer file usually referred to as an image that functions like an actual computer. It is one of the files holding it all. It operates on Windows, Linux, and so on. This gives you the ability to run multiple computers on a physical machine. You can have a different operating system on each system. It solves the following purposes

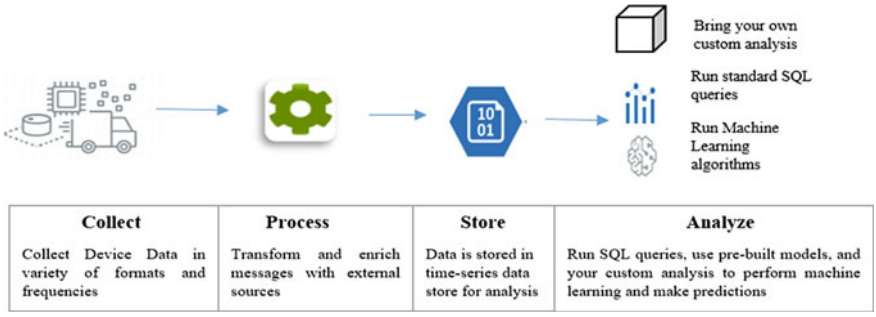

Fig. 6 Cloud services working diagram

- Development and testing
- Applications within the cloud
- Augmented data/knowledge center.

Azure Cosmos DB

It is a completely NoSQL information management service for parallel app development Microsoft's internationally distributed, multi-structured database service which is Azure Cosmos DB. Cosmos DB helps you to scale throughput and storage elastically. Using your chosen API, including: SQL, MongoDB, you can elastically scale and take advantage of quick, millisecond data access.

Azure Time Series Insights

End-to-end IoT analytics platform observes, analyzes, and visualizes your industrial IoT knowledge at scale. Turn IoT knowledge into unjust insights. Improve operations and decision making with decades of IoT knowledge delivered with made image and a jailer expertise. Use period of time information insights and interactive analytics accelerates IoT information (Fig. 6).

7.2 Working of Time-Series Forecasting Using Trained Model

Time-series analysis is a mode which helps in recognizing patterns in historical data, to detect occurrence of sequences and forecasting or predicting future values on the basis of past trends [11]. In this paper, our motive was to visualize assumed patient's data who is a prolonged hypertension patient using various machine learning algorithms such as support vector machines (SVMs) and artificial neural networks (ANNs). We were interested to explore the established time-series forecasting methodologies to have insight on health data trends and discover early signs and symptoms of deteriorating health conditions on the basis stored sets of health

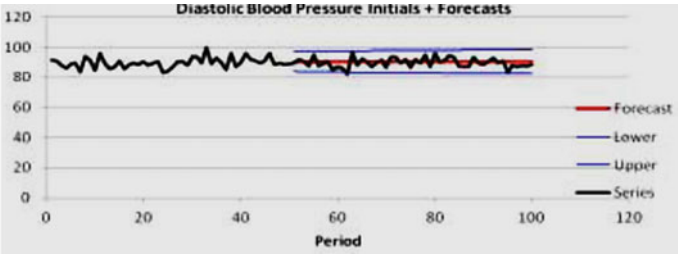

Fig. 7 Forecast range versus actual values [11]

data and events. The autoregressive integrated moving average (ARIMA) model is established for its detailed statistical features and as an effective process for linear modeling [11]. In case of nonlinear modeling, SVM and ANN models can help in capturing historical info by nonlinear function and hence be proved to be robust time-series forecasting methods due to their flexibility in nonlinear mapping ability and are tolerant to twisted forecasting data (Fig. 7).

8 Proposed Architecture of Cloud-Based Framework for Health Monitoring System

The proposed system works in the following manner. Sensor at the patient's end fetches necessary data through the services available via mobile network to the cloud which acts as a federal point of entry enabling full access to capabilities inherent in the mobile network platform. APIs are used to transfer data TO Microsoft VM and then to the Cosmo DB. After storing the data, it is sent to the monitoring system for detecting any fatalities or alarming condition. Real-time data is used for time-series forecasting and is stored as historic data. In case of any abnormalities based on the monitoring and time-series forecasting, doctor is notified in order to provide assistance and diagnose. Doctors can view patient records using API.

A model is built using ML approaches mentioned above; once the model is trained, real-time data along with recorded data is transferred to Azure Time Series insights for prediction. It can be visualized as an infrastructure, providing centralized and powerful platforms in the cloud via base stations of mobile network (Fig. 8).

The proposed architecture in the given figure above can be deployed, and it is an add-on to the existing system as stated in Table 1 for comparison.

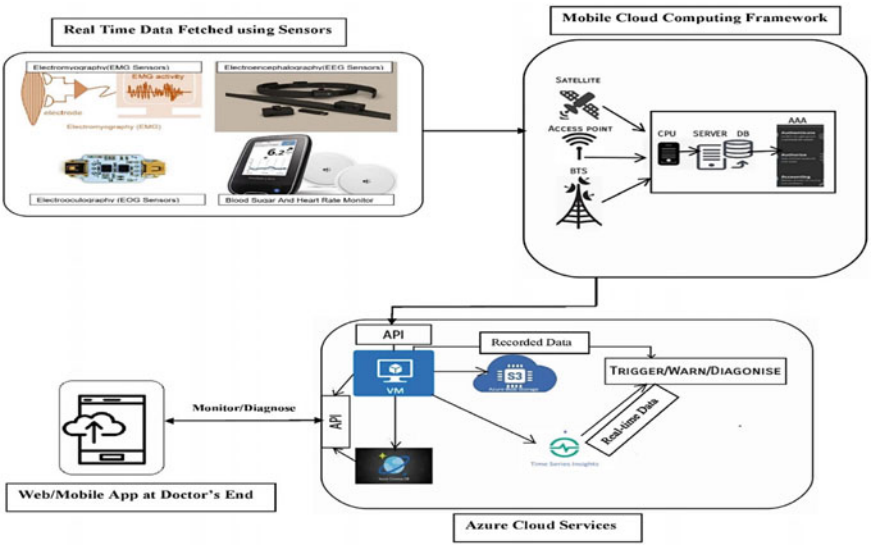

Fig. 8 Proposed architecture with MCC framework and cloud services

Table 1 Proposed architecture with MCC framework and cloud services

	Existing system	Proposed system
Architecture	Cloud based with Internet connectivity	Mobile cloud-based framework using base stations
Algorithms	Support vector machines, neural networks	SVM, logistic regression, natural language processing
Reliability and accuracy	Lower reliability, average accuracy	Enhanced reliability with greater accuracy
Monitoring	Monitoring using forecasting models	Real-time monitoring using time-series insights

9 Conclusion

The above-stated work is a theoretical approach, the architectural framework is a robust model for practical application in health monitoring systems, and it aims to efficiently use mobile cloud and machine learning approach for remote monitoring and real-time analysis. It will be very useful in areas with less resources and connectivity issues, when immediate assistance is not available or with patients who need constant monitoring. For future scope, this architectural framework can be developed further to make software which can integrate with the framework to facilitate real-time application

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