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Mobile cloud computing for ECG telemonitoring and real-time coronary heart disease risk detection

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ABSTRACT

Advancement in healthcare technologies and biomedical equipment leads to accurate diagnosis of heart related diseases. The major challenges associated with telehealthcare technologies are complex computational requirement and large amount of data processing in continuous monitoring. Mobile cloud computing approach is presented in this work to overcome the issues involved in ECG telemonitoring. Mobile cloud approach is superior to telehealth monitoring techniques due to the access to centralized cloud data and report delivery to mobile phones. In this work, ECG telemonitoring and coronary heart disease (CHD) risk assessment are combined using mobile cloud computing approach. CHD risk is identified using feature extraction and adaptive neuro fuzzy inference system (ANFIS) based classification. In feature extraction process, R-peaks are detected using wavelet transform to find heart rate variability (HRV) of the ECG signal. Various HRV parameters are extracted and applied to ANFIS classifier which employs adaptive feature selection to evaluate CHD risk. Since the mobile cloud approach deals with large amount of data, 160 files of MIT–BIH arrhythmia database has been used in this work for the assessment of CHD risk. ECG signal data are classified into two categories (normal and CHD risky) using ANFIS classifier. The classifier performance is evaluated and comparison is established with other similar classifiers.

1. Introduction

In recent years, there are lot of advancements in healthcare technologies and biomedical equipment to fulfil the demands of modern healthcare diagnosis and treatment. Though the advanced medical equipment in healthcare centers provides rapid and accurate analysis, there is a requirement of continuous real time monitoring of patients and elderly people especially for chronic diseases [1]. Mobile based monitoring devices play a major role in the monitoring and computing of the acquired physiological signals. Real time monitoring systems receive the health feedback of individuals continuously to analyze the risk related to critical health conditions [2]. Recently, Internet of Things (IoT) based remote monitoring gained huge popularity in personalized healthcare systems due to the connectivity of sensing devices and cloud server [3]. IoT driven monitoring generates large amount of data and it is a huge challenge to make affordable, power efficient and high quality portable devices for real time monitoring [4].

Mobile cloud computing (MCC) approach has evolved as a major computing paradigm in the new era, where there is a possibility of utilizing large data storage and abundant computing power [5]. Fig. 1 shows the telemedicine based medical diagnosis and treatment with cloud computing technique. In MCC, mobile devices acquire the physiological signals in daily clinical practices from various sensors and recording devices and enable the storage of huge volume of medical records using cloud services. The stored cloud data can be accessed through internet connection by hospital server system, physicians and users using desktop and mobile devices [6].

In MCC approach, mobile devices capture the data and perform the simple processing tasks to conserve the battery power. The cloud computing power is utilized while applying exhaustive computational tasks and algorithms such as machine learning algorithms and soft computing techniques [7]. Various machine learning algorithms are utilized to process the physiological signals for feature extraction and analysis. Shen et al. used a cloud computing power for electroencephalograph (EEG) signal analysis, where feature selection and support vector machine (SVM) classification are performed to identify brain related diseases [8]. A

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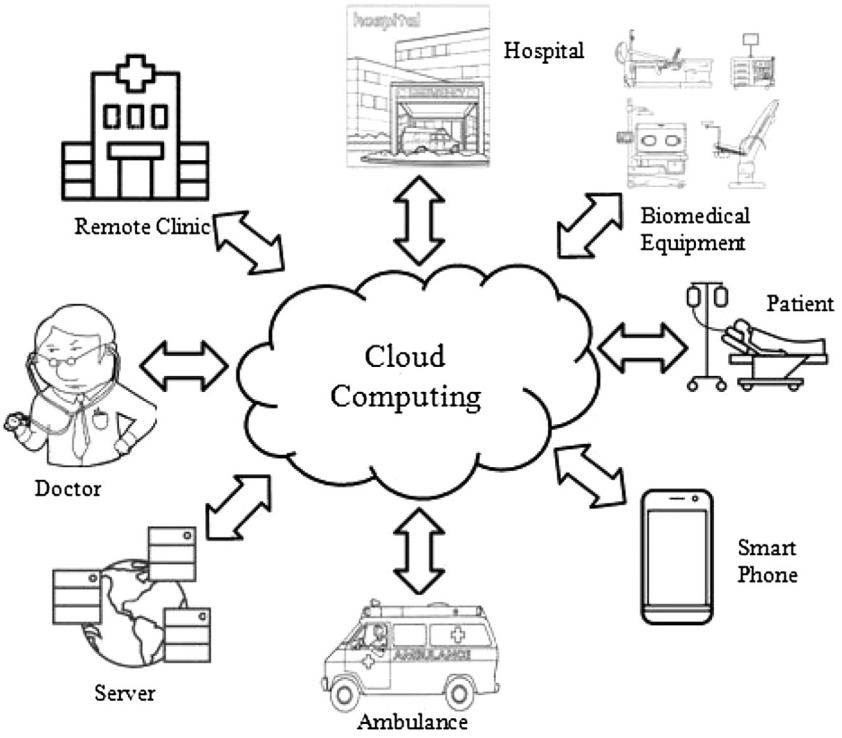

Fig. 1. Cloud computing paradigm for telemedicine.

personal electrocardiogram monitor has been developed for storing personal health record of the patients, performing artificial intelligence based ECG analysis and transmitting data to the remote locations through cloud services [9].Cloud based coronary heart disease (CHD) risk detection techniques have become popular and effective in recent years to monitor the people with cardiac diseases [10]. In this work, mobile cloud computing frame work is presented for CHD risk assessment using post processing of ECG signals.

CHD occurs in human beings due to the inadequate blood supply to heart muscles by the coronary arteries. The coronary arteries get narrowed in CHD patients due to arteriosclerosis that is an arterial disease in which cholesterol deposit plaques occupy a significant portion of the arteries. These cholesterol deposit plaques obstruct blood flow that leads to many heart related problems [11]. Whenever there is a shortage of blood flow to the heart, required amount of oxygen and nutrition are not delivered to the heart for the proper operation. The oxygen and nutrients shortage leads to chest pain and myocardial infarction (MI) in most of the elderly people [12]. Since CHD is mainly responsible for MI, CHD risk assessment methods are necessary for the identification of cardiovascular diseases [13]. Few medical indicators for performing CHD risk assessment are cholesterol level, blood pressure, age, diabetes and smoking habits. Though lot of diagnostic methods have been developed using various tools for the CHD prediction, identifying cardiovascular problems in early stage remains a huge challenge for physicians. Therefore, early identification of cardiovascular events with higher specificity is required for accurate CHD prediction. Age, blood pressure, total cholesterol and smoking habits were considered for the prediction of arterial disorders and CHD risk [11]. In that study, authors elucidated the need for machine learning techniques for the early stage prediction of CHD. In this work HRV features and smoking habits have been considered for the assessment of CHD using adaptive neuro fuzzy inference system (ANFIS).

Electrocardiogram (ECG) morphological analysis has been used for the assessment of heart related problems based on the shape of the signal, but complex computations are needed to classify different arrhythmias. Heart rate variability (HRV) has attracted huge interest among researchers which is the study of variations in the beat to beat timing of the heart. HRV is a measure of variability in inter-beat interval (IBI) or R-R interval, which is defined as the time in milliseconds between consecutive R waves of an electrocardiogram. The R-R interval of normal person should be relatively constant from beat to beat. If any changes observed in R-R interval that indicates irregular heart rate. The RR intervals can be analyzed in frequency domain using transform techniques such as fast Fourier transform (FFT), short time Fourier transform (STFT) and wavelet transform [14].

Time domain and frequency domain parameters of HRV provide vital information which are crucial in the detection of sympathetic and parasympathetic activities [15]. The frequency domain HRV analysis provides more information about cardiovascular activities while comparing with time domain parameters [16]. There are three important frequency regions in human HRV: below 0.04 Hz is very low frequency (VLF), between 0.04 and 0.15 Hz is low frequency (LF), and between 0.15 and 0.5 Hz is high frequency (HF). The LF spectrum is mainly affected by both sympathetic and parasympathetic activities, and the HF is mostly found in parasympathetic activity. The VLF spectrum may be affected by factors such as temperature, hormones, etc. The LF to HF ratio is responsible for finding sympathovagal balance [17]. The extracted time domain and frequency domain features are applied to ANFIS classifier to classify the ECG signal.

Discrete wavelet transform (DWT) has gained more attention in recent years due to its capability of extracting time-frequency domain information retrieval from the non-stationary signals. Though DWT is widely popular for information extraction, the mother wavelet selection is crucial in most of the feature extraction processes. Since the all wavelets are produced from mother wavelet through translation and scaling, mother wavelet needs to be carefully selected [18]. Machine learning techniques evolve from artificial intelligence concepts that can be used in computational tasks where the conventional algorithms are infeasible.