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Hybrid classification engine for cardiac arrhythmia cloud service in elderly healthcare management ☆

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ABSTRACT

The self-regulation ability of the elderly is largely degenerated with the age increases, and the elderly often expose to great potential hazards of heart disorders. In practice, the electrocardiography (ECG) is one of the well-known non-invasive procedures used as records of heart rhythms and diagnosis of unusual heart diseases. In this paper, we propose a healthcare management system, named CardiaGuard, which is specialized in monitoring and analysis the heart disorder events for the elderly. The CardiaGuard cloud service is an expert system designed based on the hybrid classifier implemented using support vector machine (SVM) and random tree (RT) classification algorithm. We conduct a comprehensive performance evaluation which shows the proposed hybrid classification engine are able to detect six types of cardiac disorders with higher accuracy rate than the SVM-based classifier alone. CardiaGuard poses a great solution to enhance the quality of good clinical practice on the healthcare management for the elderly in cardiology.

1. Introduction

Heart disease is the major cause of death for countries. In today's complex life, it is easy to find physical and emotional disorders on every citizen. Sleep disorders is a common problem in the elderly, which causes even more severe physical conditions such as heart disorders. For more comfortable and complete healthcare service, a lot of healthcare system models have been proposed to help diagnose, monitor and provide services to heart disease patients in recent years [1,2]. For clinical observation, there exists an inextricable connection between the disorders and the autonomic nervous system.

Although the advance in medical technology extends the lifespan of human beings, it is still a challenging task to meet the requirements of quality clinical practices under limited available medical resources and healthcare resource. Moreover, the patient's family wants the necessary and appropriate action taken at any time when a patient is in need of care or when an unusual emergency situation is occurring. With the rapid development of information and communication technology, more ehealth services are introduced in order to improve access, efficiency and quality of health care services. There is an urgent need for the home care system to send real-time monitoring of physical information to a central health management system, which would serve as a platform where the doctor could communicate with patients who need helps.

To mitigate the potential impact of the limited medical resource, home telecare and remote healthcare services emerge to offer monitoring, alerting services or providing medical information or healthcare tutorial remotely in

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recent years. And to provide quality telecare services, a good healthcare management system (HMS) is critical since all services are carried on the platform. An effective HMS would benefit not only patients, but also benefit to the patient's family with enough information and suggestion, as a result taking correct actions when taking care of patients.

The degradation of the ability to adapt and respond to changing health situations and environments causes a lot of potential hazards on the health of the elderly. Among all potential threats, heart disorders are more critical that may cause sudden death. Electrocardiography (ECG), one of well-known non-invasive procedures, is commonly used to detect abnormal heart rhythms and a powerful tool in diagnosing heart disorders, which is evolved from a long history references to and correlation with known cardiac disorders. Further, each individual has his own unique ECG signal which may also be influenced by his mood, illness and also his environment. Conventional analysis tools (e.g., rule-based analysis) do not have a personalized learning heart disorder capability. Therefore, the clinical experts still need to get involved and carefully identify the symptom. There are many studies on ECG signal processing such as baseline correction, noise removal, R-wave detection, QRS algorithm and disease diagnosis [3–6]. With medical knowledge and techniques, hence, electrocardiography (ECG) can be used as an important cue for diagnosis of heart disease and trace of treatment.

On the other hand, real-time heart rate variability (HRV) analysis, measured based on QRS detection and beat-to-beat intervals, is essential to emotional recognition. One of the most important parameters is RRI that is the interval between two successive *R* points, the peak of the QRS complex in electrocardiography (ECG) wave. Recent studies also show that RRI is very useful to identify premature ventricular contraction (PVC), a common type of heart arrhythmias [7]. What we are interested in is how to build a reliable cloud ehealth service to recognize the disease detection and arrhythmia classification through HRV and RRI analysis. In this paper, we propose a healthcare management system, named CardiaGuard, built on the top of cloud computing platform. Taking advantages of the cloud computing platform (such as flexibility, cost reduction, reliability, security gains), CardiaGuard is able to provide reliable and safe real-time surveillance of the heart disorder events for the elderly.

In the near future, the Android systems [8,9] are expected to be more popular. From the perspective of health care applications, the Android system with wireless transmission in smart home also provides a feasible solution for the development of a portable ECG monitoring system. So, in this paper, we present the healthcare system model and application function, and make analysis of Arrhythmia classification based on RRI. For the experiments, MIT-BIH database [10] is adopted as the benchmark to test and verify our proposed method. The rest of this paper is organized as follows. In Section 2, the background information is about the ECG and classification algorithms. The personal healthcare system is introduced in Section 3. Then, the analysis of arrhythmia classification is shown in Section 4. Finally, Section 5 concludes with a short summary of the research contributions.

2. Background

Heart rate variability (HRV) [11,12] is the variation of time interval between heartbeats that represents a physiological phenomenon. Generally speaking, HRV analysis can be divided into two categories: time domain and frequency domain measurements. For time domain analysis of HRV, it uses the simplest parameters to be calculated, such as the RR intervals (RRI), mean NN intervals (MNN, RR_m), the standard deviations of all NN intervals (SDNN), the square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD) and the proportion derived by dividing the number of interval differences of NN intervals greater than 50 ms by the total number of NN intervals (PNN50). On the other hand, the frequency domain analysis can help discriminate between sympathetic and parasympathetic contents of RR intervals, such as the spectral power in the high frequency band 0.15–0.4 Hz (HF) of the RR intervals, that in the low frequency band 0.04–0.15 Hz (LF), that in the very low frequency band 0.0033–0.04 Hz (VLF), and the ratio of LF and HF bands power (LF/HF). Basically, HF is related with parasympathetic activation, LF is related with sympathetic activation, and LF/HF is related with autonomic nervous activation. Usually, frequency domain analysis is performed by means of Fast Fourier Transformation (FFT) for the same parameters with the time domain measurement. Using FFT is simple in calculation to get power spectral density (PSD).

Especially, fast arrhythmia classification by automatic computer procession can help save time for physicians to diagnose. However, physicians have to check the arrhythmias again, and then make professional judgment. We know that using the current R–R interval (RRI_{-1}) and the previous R–R interval (RRI_{-2}) as attributes could performs very well for PVC identification. At the meantime, LF, HF and VLFP are critical parameters for PVC detection. There are many methods for classification proposed in literature, as shown in Table 1, including K-nearest neighbors (KNN) [13,14], decision tree (DT) [15], classification and regression tree (CART) [16], principal components analysis (PCA) [17], Fisher linear discriminant analysis (LDA) [18–20], genetic programming (GP) [21], hidden Markov models (HMM) [22], artificial neural network (ANN) [23,24], support vector machine (SVM) [25,26], multinomial logistic regression (also called Softmax Regression, SR) [27], Bayesian classifiers [28], Rule/knowledge-based algorithms [29] and random tree (RT) [30–32]. About the decision tree based algorithms, random forests (RF) classifier takes the majority among random trees, which is developed from former DT and CART with higher classification accuracy.

Several popular algorithms are used for disease identification and classification of cardiac arrhythmias. For reducing system complexity and improving accuracy, one kind of methods has a step for feature reduction. For example, GP can be used to select effective features to distinguish between different types of arrhythmias.

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