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A Comparative Study of FFT, DCT, and DWT for Efficient Arrhytmia Classification in RP-RF Framework

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ABSTRACT

Computer-aided ECG classification is an important tool for timely diagnosis of abnormal heart conditions. This paper proposes a novel framework that combines the theory of compressive sensing with random forests to achieve reliable automatic cardiac arrhythmia detection. Furthermore, the paper evaluates the characterization power of FFT, DCT and DWT data transformations in order to extract significant features that will bring the additional boost to the classification performance. The experiments – carried out over MIT-BIH benchmark arrhythmia database, following the standards and recommended practices provided by AAMI – demonstrate that DWT based features exhibit better performances compared to other two feature extraction techniques for a relatively small number of random projected coefficients, i.e. after considerable (approx. 85%) dimensionality reduction of the input signal. The results are very promising, suggesting that the proposed model could be implemented for practical applications of real-time ECG monitoring, due to its low-complexity.

KEYWORDS

Compressive Sensing, DCT, DWT, ECG Classification, FFT, MIT-BIH, Random Forest, Random Projection

1. INTRODUCTION

The electrocardiogram (ECG) is a non-invasive technique that is most widely used as a primary diagnostic tool for detecting cardiovascular diseases. The ECG is an electrical signal that reflects the electrical activity passing through the heart muscle, measured by placing electrodes at the body surface. It is characterized by five peaks and valleys, labelled by successive letters of the alphabet P, Q, R, S and T. The P wave represents the excitation of the atria or the upper chambers of the heart, while the QRS wave (or complex) and T wave represent the excitation of the ventricles or the lower chambers of the heart. Figure 1 shows the schematic record of the normal heartbeat. Any deviation from the norm in a particular ECG measurement – manifesting itself in a form of an irregular heartbeat pattern, also known as cardiac arrhythmia – might be an indication of possibly serious cardiac issue

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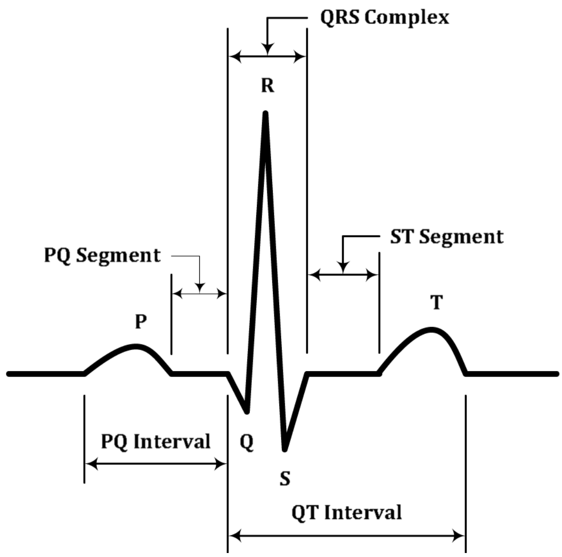
Figure 1. A typical ECG signal with P, Q, R, S and T marked



or abnormality. Timely detection and identification of cardiac arrhythmias may help save patients' lives and enhance their quality of living through more effective treatment.

Up to now, a number of methods for automatic arrhythmia classification in the ECG signals have been previously reported in the literature (Luz, Schwartz, Cámara-Chávez, & Menotti, 2016). These mainly focus on linear discriminant analysis (Sharma & Singh, 2014), artificial neural networks (Ebrahimzadeh, Ahmadi, & Safarnejad, 2016; Sarkaleh & Shahbahrami, 2012), support vector machines (Khazaee & Zadeh, 2014), mixture-of-experts algorithms (Übeyli, 2008) and statistical Markov models (Liang, Zhang, Tan, & Li, 2014). The most difficult problem faced during automated ECG classification is that there is a great variety of morphologies among the heartbeats belonging to one class, even for the same patient (Osowski & Linh, 2002). Moreover, heartbeats belonging to different classes can be morphologically similar to each other. Therefore, an effective feature extraction technique is needed to produce such representation of the original ECG signal that will suppress the differences among the ECG waveforms of the same class and, at the same time, emphasize the differences for the waveforms belonging to different types of arrhythmias. Various features have been used by other researchers to characterize arrhythmias including: morphological features and heartbeat time intervals (de Chazal & Reilly, 2006), statistical and mixture modelling features (Afkhami, Azarnia, & Tinati, 2016), temporal features (Syama Uday, Mohanalin, & Devi, 2016), frequency domain features (Gothwal, Kedawat, & Kumar, 2011; Ganesh Kumar & Kumaraswamy, 2014), hybrid features (Muthuvel, Suresh, Alexander, & Veni, 2014), Hermite polynomials (Ebrahimzadeh, Ahmadi, & Safarnejad, 2016) and wavelet transform coefficients (Sarkaleh & Shahbahrami, 2012).

Random forest, proposed by Breiman (2001), is a scheme for building a predictor ensemble with a set of decision trees that grow in randomly selected subspaces of data. In recent years, random forest classifier is hot in the machine learning community due to its excellent classification performance, its efficiency in training and testing and its uncanny ability to handle a very large number of input variables without overfitting. As highlighted by various empirical studies, random forest has emerged as a strong contender to state-of-the-art methods, such as neural networks and support vector machines. In fact, it is considered to be one of the most accurate general-purpose learning algorithms available. Nevertheless, there have only been a few studies utilizing random forest algorithm for classification of ECG heartbeat patterns (Emanet, 2009; Ganesh Kumar & Kumaraswamy, 2012; Marasović & Papić,

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