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Cardiac arrhythmia detection using deep learning

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Abstract

An electrocardiogram (ECG) is an important diagnostic tool for the assessment of cardiac arrhythmias in clinical routine. In this study, a deep learning framework previously trained on a general image data set is transferred to carry out automatic ECG arrhythmia diagnostics by classifying patient ECG's into corresponding cardiac conditions. Transferred deep convolutional neural network (namely AlexNet) is used as a feature extractor and the extracted features are fed into a simple back propagation neural network to carry out the final classification. Three different conditions of ECG waveform are selected from MIT-BIH arrhythmia database to evaluate the proposed framework. Main focus of this study is to implement a simple, reliable and easily applicable deep learning technique for the classification of the selected three different cardiac conditions. Obtained results demonstrated that the transferred deep learning feature extractor cascaded with a conventional back propagation neural network were able to obtain very high performance rates. Highest obtained correct recognition rate is 98.51% while obtaining testing accuracy around 92%. Based on these results, transferred deep learning proved to be an efficient automatic cardiac arrhythmia detection method while eliminating the burden of training a deep convolutional neural network from scratch providing an easily applicable technique.

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Keywords: biomedical signal processing; deep learning; ECG classification; convolutional neural networks; cardiac arrhythmia; tranfer learning

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1. Introduction

The Electrocardiogram (ECG) is an established technique in cardiology for the analysis of cardiac condition of the patients. In its basic definition, ECG is the electrical representation of the contractile activity of the heart, and can be recorded fairly easily by using surface electrodes on the limbs or chest of the patient. The ECG is one of the most recognized and used biomedical signal in the field of medicine. The rhythm of the heart in terms of beats per minute (bpm) can be easily calculated by counting the R peaks of the ECG wave during one minute of recording (see Fig.1 for a single ECG waveform). More importantly, rhythm and the morphology of the ECG waveform is altered by cardiovascular diseases and abnormalities such as the cardiac arrhythmias (Rangayyan, 1999), which their automatic detection and classification is the main focus of this paper.

In current medical routine, careful study of the ECG by expert cardiologists is necessary for the diagnosis of life threatening cardiac arrhythmias. However, automatic classification of cardiac arrhythmias can both provide objective diagnostic results and save time for the cardiologists. These advantages have provided considerable commercial interests in the computer aided classification and diagnosis of the ECG signals in hospital and health community. The interpretation of the ECG signal is an application of pattern recognition. The purpose of pattern recognition is to automatically categorize a system into one of a number of different classes. An expert cardiologist can easily diagnose various cardiac arrhythmias just by looking at the ECG waveforms printout. In some specific cases, sophisticated ECG analysers can achieve a higher degree of accuracy than that of cardiologist, but at present there remains a group of ECG waveforms that are difficult to identify by computers. However, the use of computerized analysis of easily obtainable ECG waveforms can considerably reduce the cardiologist's workload. Some analysers can assist the cardiologist by producing a ready diagnosis while others can provide a limited number of parameters by which the cardiologist can make his own diagnosis.

The aim of this paper is to develop such a computer aided diagnostic system which assists expert cardiologists by providing intelligent, cost effective and time saving ECG arrhythmia diagnostics. To achieve this goal, conventional ECG signal processing techniques along with the state of the art deep learning methods are implemented to the task of ECG arrhythmia pattern recognition. At its current state, the proposed system can specifically distinguish and classify cardiac arrhythmias known as Right Bundle Branch Blocks (RBBB) from Paced Beats and Normal (Healthy) Beats. Where, Normal beats are healthy adult human ECG waveform; Paced beats are artificial beats from the device called pacemaker; and RBBB is an arrhythmia that is frequently associated with ischemic, hypertensive, rheumatic and pulmonary heart disease, right ventricular hypertrophy and some drug intoxication which has a ECG waveform with QRS duration between 0.10 and 0.11 sec (incomplete RBBB) or 0.12sec or more (complete RBBB), prolonged ventricular activation time or QR interval (0.03sec or more) and right axis deviation (Milliken, 1971) (see Fig 2 for sample waveforms). However, apart from these the system can also be easily adapted to further classify other various similar cardiac arrhythmias.

The rest of the paper is organized as follows: First, recent related deep learning based methods for ECG arrhythmia detection are briefly reviewed in section 2. Then, in section 3, proposed method is explained in detail and in section 4, experiments and results are discussed. Finally, in conclusions, the current state of the proposed method is assessed and future directions for development are provided.

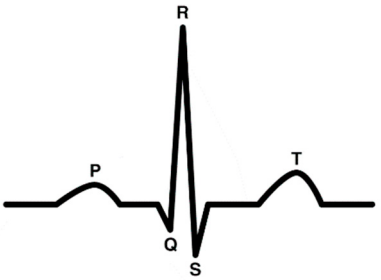

Fig. 1. Normal/healthy ECG waveform. Where, P-wave, QRS-complex and T-wave represent the contraction/depolarization of atria, contraction/depolarization of ventricles and repolarization of ventricles respectively.