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Application of deep convolutional neural network for automated detection of myocardial infarction using ECG signals

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ABSTRACT

The electrocardiogram (ECG) is a useful diagnostic tool to diagnose various cardiovascular diseases (CVDs) such as myocardial infarction (MI). The ECG records the heart's electrical activity and these signals are able to reflect the abnormal activity of the heart. However, it is challenging to visually interpret the ECG signals due to its small amplitude and duration. Therefore, we propose a novel approach to automatically detect the MI using ECG signals. In this study, we implemented a convolutional neural network (CNN) algorithm for the automated detection of a normal and MI ECG beats (with noise and without noise). We achieved an average accuracy of 93.53% and 95.22% using ECG beats with noise and without noise removal respectively. Further, no feature extraction or selection is performed in this work. Hence, our proposed algorithm can accurately detect the unknown ECG signals even with noise. So, this system can be introduced in clinical settings to aid the clinicians in the diagnosis of MI.

1. Introduction

Myocardial infarction (MI) is caused when the blood flow to a segment of the myocardium is disrupted [4,27]. Coronary arteries are the arteries that supply oxygen-rich blood to the heart muscle. However, if there is a blockage of the coronary artery due to the buildup of plaques, it reduces the blood flow to the heart muscle. That segment of the heart muscle will start to die if blood flow is not restored in time [27]. Fig. 1 illustrates the myocardial infarction due to the blockage of a coronary artery. This artery gets blocked with blood clots also known as a thrombus. These blood clots are formed due to the plaque build-up in the artery. The complete blockage of blood flow results in a heart attack as a part of the heart muscle is damaged [21].

Furthermore, MI is also often referred to as the silent heart attack. It is because patients are not aware that they are suffering from MI until a heart attack occurs. According to the American Health Association, it is estimated that *750,000* Americans have a heart attack every year. Out of these 750,000 Americans, 210,000 of them have a recurrent heart at-

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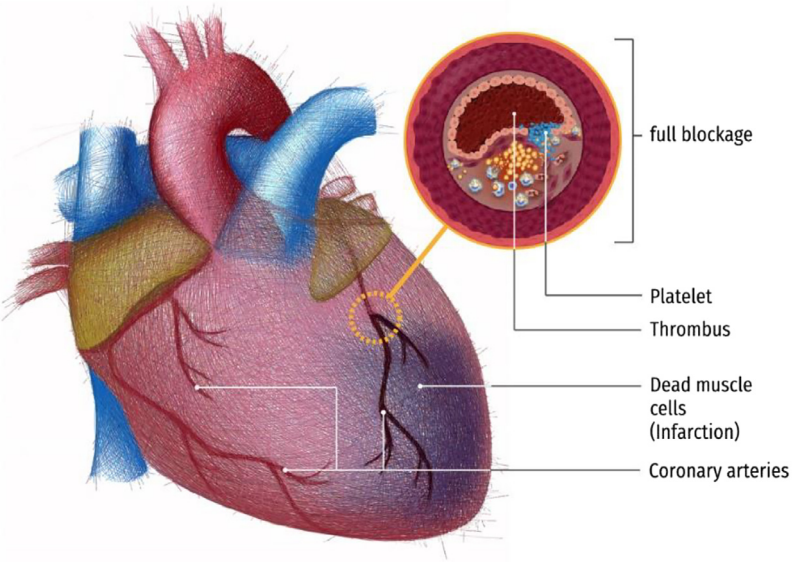

Fig. 1. An illustration of myocardial infarction.

tack [26]. Hence, approximately 72% of the heart attacks are silent. In other words, 72% of the patients' heart muscles are damaged but they are not aware of it. As a result, the mortality rate of MI is very high.

Therefore, an early diagnosis of MI will help patients to get timely treatment, and hence decreasing the prevalence of mortality [2]. The death of the heart muscles is irreversible hence, it is essential to get diagnosed early. The early diagnosis of MI can be conducted with an electrocardiogram (ECG). The ECG is the noninvasive economical primary tool which can be used to diagnose the cardiac abnormalities [4]. Fig. 2 shows the samples of normal and MI ECG signals with and without the removal of noise.

However, the ECG signals are having a very small amplitude (mV) and small duration (sec). Hence, the interpretation of these long duration of signals may lead to inter and intra-observer variabilities [25]. Moreover, it is time-consuming and strenuous to analyze the ECG signals.

The limitation of manual inspection of ECG signals can be overcome by using computer-aided diagnosis system [9]. A computer-aided diagnosis (CAD) system is preferred due to its fast, objective, and reliable analysis [9]. Many works have been conducted on the development of CAD for MI [1,18].

The studies presented in Table 6 have denoised their ECG signals before performing any feature extraction [2,5,6,22,24,31,33,35]. Nevertheless, denoising is not required in our proposed algorithm. Our algorithm can detect MI ECG signal without filtering any noise present in the ECG signal. Various features extraction techniques have been proposed to automatically detect MI using ECG signals. However, the process of choosing a set of optimal features to classify normal and MI ECG signals is very difficult [10].

Therefore, deep learning technique is introduced in this work to overcome the challenges faced by conventional automated systems. Recently, deep learning techniques have been used by many companies namely Adobe, Apple, Baidu, Facebook, Google, IBM, Microsoft, NEC, Netflix, and NVIDIA [12]. In our work, we have used an eleven layer deep CNN for the classification.

Deep learning is a representation based learning which consists of an input layer, hidden layers, and an output layer [23]. A representation based learning is a set of systematic procedures that provides a network to be fed with raw data and automatically learns the necessary representations for classification. The term deep describes the multiple stages in the learning process of the network structure [23]. The deep learning neural network is trained using the backpropagation algorithm. The CNN is one of the most popular neural network techniques [13].

CNN has been successfully utilized in computer vision since the early 21st century [23]. It performed well in recognizing handwritten digits, detecting objects, and speech recognition [23]. It has been used in the medical research field such as analyzing health informatics [30], and medical images [36] using computed tomography (CT) images [32], fundus images [14,15,37], histopathological images [16], magnetic resonance (MR) images [29], and X-ray images [19] as well. It is also noted that researchers in the medical analysis field are moving into CNN and obtaining desirable results [13]. Furthermore, we applied CNN in our previous work [3]. Our proposed system achieved the highest accuracy of *92.50%* and *94.90%* in the detection of arrhythmias with *two* and *five* seconds ECG signal [3]. Hence, the CNN has performed well in the biomedical signal and image processing domain. So, in this work, we employed it for the automated diagnosis of MI using ECG signals with and without noise.