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A new automated CNN deep learning approach for identification of ECG congestive heart failure and arrhythmia using constant-Q non-stationary Gabor transform

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ABSTRACT

Electrocardiogram (ECG) is an important noninvasive diagnostic method for interpretation and identification of various kinds of heart diseases. In this work, a new Deep Learning (DL) approach is proposed for automated identification of Congestive Heart Failure (CHF) and Arrhythmia (ARR) with high accuracy and low computational requirements. This study introduces, for the first time, a new ECG diagnosis algorithm that combines Convolutional Neural Network (CNN) with the Constant-Q Non-Stationary Gabor Transform (CQ-NSGT). The CQ-NSGT algorithm is investigated to transform the 1-D ECG signal into 2-D time-frequency representation that will be fed to a pre-trained CNN model, called AlexNet. Extracted features with the AlexNet architecture are used as relevant features to be discriminated by a Multi-Layer Perceptron (MLP) technique into three different cases, namely CHF, ARR, and Normal Sinus Rhythm (NSR). The performance of the proposed CNN with CQ-NSGT is compared versus CNN with Continuous Wavelet Transform (CWT), revealing the effectiveness of the CQ-NSGT algorithm. The proposed approach is examined with real ECG records, and the experimental results show the superior performance of the proposed approach over other existing techniques in terms of accuracy 98.82%, sensitivity 98.87%, specificity 99.21%, and precision 99.20%. This demonstrates the effectiveness of the proposed system in enhancing the ECG diagnosis accuracy.

1. Introduction

The Electrocardiogram (ECG) is a diagnostic method that measures and records the electrical activity of the heart muscles. ECG is widely used in several medical studies for interpretation and identification of heart disorders. One of these disorders is Congestive Heart Failure (CHF), which is a serious cardiac condition associated with high mortality and morbidity rates. In CHF, the heart cannot pump blood efficiently to supply organs with oxygen and nutrients, causing easy fatigue, breathlessness, and generalized swelling. According to the European Society of Cardiology (ESC), at least 26 million adults are diagnosed with CHF worldwide, while 3.6 million are newly diagnosed every year [1]. 17–45% of patients diagnosed with CHF die within the first year and the rest within 5 years [1]. However, successful early diagnosis of CHF can enhance the treatment options and reduce the death rates. Another serious disorder caused by irregular heart rate is Arrhythmia (ARR), which is most often responsible for sudden deaths. ARRs can be classified into two main classes: ventricular and supraventricular. Ventricular ARRs occur in the lower chambers of the heart, called ventricles, while supraventricular ARRs originate from above the ventricles, usually in the top chambers of the heart, called the atria. Both classes are investigated in the current study.

ECG Diagnosis of ARR and CHF requires accurate and uniform evaluation by experienced cardiologists, which is tedious and time consuming. Therefore, it is very important to develop new efficient Computed Aided Diagnosis (CAD) systems that can enhance the diagnostic reliability of ECG recordings. With the advances of signal processing and Machine Learning (ML) techniques, several CAD systems were developed over the last decades for automated identification of heart diseases [2–4]. Deep learning (DL) represents the most modern and effective branch of ML in biomedical engineering applications which utilizes a hierarchical level of Neural Network (NN) [5,6]. There are several DL architectures such as Stacked Auto-Encoder (SAE), Deep Belief Networks (DBNs), and Convolutional Neural Networks (CNNs) [7, 8]. One of the most effective architectures in image processing applications is the deep CNN, the focus point of this work.

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