Classification of Arrhythmia by Using Deep Learning with 2-D ECG Spectral Image Representation

Done by:

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Introduction:

Overview of title and project

Introduction Cardiovascular diseases (CVDs) are the leading cause of human death, with over 17 million people known to lose their lives annually due to CVDs]. According to the World Heart Federation, three-fourths of the total CVD deaths are among the middle and low-income segments of the society]. A classification model to identify CVDs at their early stage could effectively reduce the mortality rate by providing a timely treatment]. One of the common sources of CVDs is cardiac arrhythmia, where heartbeats are known to deviate from their regular beating pattern. A normal heartbeat varies with age, body size, activity, and emotions. In cases where the heartbeat feels too fast or slow, the condition is known as palpitations. An arrhythmia does not necessarily mean that the heart is beating too fast or slow, it indicates that the heart is following an irregular beating pattern. It could mean that the heart is beating too fast—tachycardia (more than 100 beats per minute (bpm)), or slow bradycardia (less than 60 bpm), skipping a beat, or in extreme cases, cardiac arrest. Some other common types of abnormal heart rhythms include atrial fibrillation, atrial flutter, and ventricular fibrillation.

These deviations could be classified into various subclasses and represent different types of cardiac arrhythmia. An accurate classification of these types could help in diagnosing and treatment of heart disease patients. Arrhythmia could either mean a slow or fast beating of heart, or patterns that are not attributed to a normal heartbeat. An automated detection of such patterns is of great significance in clinical practice. There are certain known characteristics of cardiac arrhythmia, where the detection requires expert clinical knowledge. The electrocardiogram (ECG) recordings are widely used for diagnosing and predicting cardiac arrhythmia for diagnosing heart diseases. Towards this end, clinical experts might need to look at ECG recordings over a longer period of time for detecting cardiac arrhythmia. The ECG is a one-dimensional (1-D) signal representing a time series, which can be analyzed using machine learning techniques for automated detection of certain abnormalities. Recently, deep learning techniques have been developed, which provide significant performance in radiological image analysis . Convolutional neural networks (CNNs) have recently been shown to work for multi-dimensional (1-D, 2-D, and in certain cases, 3-D) inputs but were initially developed for problems dealing with images represented as two-dimensional inputs . For time series data, 1-D CNNs are proposed but are less versatile when compared to 2-D CNNs. Hence, representing the time series data in a 2-D format could benefit certain machine learning tasks . Hence, for ECG signals, a 2-D transformation has to be applied to make the time series suitable for deep learning methods that require 2-D images as input. The short-time Fourier transform (STFT) can convert a 1-D signal into a 2-D spectrogram and encapsulate the time and frequency information within a single matrix. The 2-D spectrogram is similar to hyper-spectral and multi-spectral images (MSI), which have diverse applications in remote sensing and clinical diagnosis, including spectral un-mixing, ground cover classification and matching, mineral exploration, medical image classification, change detection, synthetic material identification, target detection, activity recognition, and surveillance. The 2-D matrix of spectrogram coefficients could be useful for extracting robust features for representation of a cardiac ECG signal . This representation could allow the application of CNN architectures (designed to operate on 2-D inputs) for development of automated systems related to CVDs.

Literature survey:

The ECG signal detects abnormal conditions and malfunctions by recording the potential bio-electric variation of the human heart. Accurately detecting the clinical condition presented by an ECG signal is a challenging task . Therefore, cardiologists need to accurately predict and identify the right kind of abnormal heartbeat ECG wave before recommending a particular treatment. This might require observing and analyzing ECG recordings that might continue for hours (patients in critical care). To overcome this challenge for the visual and physical explanation of the ECG signal, computer-aided diagnostic systems have been developed to automatically identify such signals automatically. Most of the research in this field has been conducted by incorporating different approaches of machine learning (ML) techniques for the efficient identification and accurate examination of ECG signals. ECG signal classification based on different approaches has been presented in the literature including frequency analysis, artificial neural networks (ANNs), heuristic-based methods, statistical methods, support vector machines (SVMs), wavelet transform, filter banks, hidden Markov models, and mixture-of-expert methods. An artificial neural network based method obtained an average accuracy of 90.6% for the classification of ECG wave into six classes. Meanwhile, a feed-forward neural network was used as a classifier for the detection of four types of arrhythmia classes and achieved an average accuracy of 96.95%. Machine learning is a subset of artificial intelligence used with high-end diagnostic tools for the prediction and diagnosis of different types of illnesses. Deep learning, as a subset of ML, has many applications in the prediction and prevention of fatal sicknesses, particularly CVDs. Different Remote Sens. 2020, 12, 1685 3 of 14 techniques of deep learning used for the analysis of bioinformatics signals have been presented in . A recurrent neural network (RNN) was used for feature extraction and achieved an average accuracy of 98.06% for detecting four types of arrhythmia. For the classification and extraction of features from a 1-D ECG signal, a 1-D convolutional neural network model was proposed and yielded a classification accuracy of 96.72%. Another deeper 1-D CNN model was proposed for the classification of the ECG dataset and obtained an average accuracy of 97.03%. In both instances, a large ECG dataset was used, but the ECG signals were represented as a 1-D time series. A nine-layer 2-D CNN model was applied for an automatic classification of five different heartbeat arrhythmia types achieving an accuracy of 94.03% .