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Heart Anomaly Detection using Deep Learning Approach based on PCG Signal Analysis

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Abstract -Phonocardiography is one of the effective techniques for recording of heart sound during a cardiac cycle which helps in identification and further diagnosis of diseases related to human heart. Contraction of heart muscles and closure of heart valve produces heart sound, which can be analysed by an experienced cardiologist. The objective of this study is to generate an automatic classification method using one dimensional convolution neural network based on phonocardiogram data for anomaly detection in heart sound.

The proposed system consists of three stages namely 1) Data Acquisition 2) Pre-processing 3) Feature Extraction and Classification.

We proposed an intelligent neural network approach for classification of PCG data. Heart sound recording (PCG data) which is nothing but an audio file is converted into its time domain representation. This converted PCG data is fed as input to convolution neural network. Emphasis was also given on noisy heart sound recording. Noise can reduce the efficiency of classification as it can disturb the values of neural network. The Accuracy of the proposed system is 91.5% with sensitivity of 0.92 and specificity of 0.91.

Keywords -Convolution neural network, PCG data, phonocardiogram, heart sound.

1. Introduction

According to World Health Organization (WHO), cardiovascular diseases (CVD) are the main reason of most of the deaths globally. CVD kill more people than any other disease in the world. More than 17.5 million deaths across the globe are due to the cardiovascular diseases. About 610,000 people die of heart disease in the United States every year– that's 1 in every 4 deaths. More than 29% of the total deaths in 2004 are due to cardiovascular diseases and the number is increasing every day. Coronary heart disease (CHD) is the most common type of heart disease, killing over 370,000 people annually. The current methods of detecting the primary signs of abnormalities in heart are very costly. They may not be affordable in underdeveloped and developing countries where the economic condition of the country is not so good. So, there is a need for a feasible and reliable system for early detection of heart abnormalities. Any method which can help to detect signs of heart disease could therefore have a significant impact on world health.

The stethoscope is an acoustic medical device for auscultation, or listening to the internal sounds of human body. It is a primary device to listen to heart sound. The advantage of using electronic stethoscope over acoustic stethoscope is that its properties like amplified sound output, enhanced frequency range, ambient noise reduction, etc. It consists of an amplifier to amplify the low intensity heart sound. Electronic Stethoscope transmitted sound electronically, so, it can be a wireless device, or can be a recording device. It can also provide visual display of the recorded heart sound.

The PCG recording consists of four heart sound signals namely S1, S2, S3, S4. The first two are normal heart sounds generated by opening of normal heart valves. There is abnormal heart sound along with S1 and S2 additional like S3 and S4. These abnormal sounds are called murmurs. The present medical testing techniques which can detect the abnormality in heart sound is very costly. It is not affordable for an average human being. So, the main challenge is to develop such a technique which is precise, reliable and affordable.

The heart sound is still the primary tool for detecting and analysing the condition of human heart. The correct interpretation of heart condition mostly depends on the experience of the cardiologists. It can be error prone. A more reliable computer-based technique needs to be developed.

Several methods are being proposed for medical system development for heart disease diagnosis. The objective our study is to propose an intelligent algorithm to determine the presence of abnormalities in heart sound of patient's data. Also, along with this we wanted to build a feasible and affordable solution.

2. METHODOLOGY

The methodology [1] proposed in this study is a basic three steps architecture data acquisition, pre-processing, classification, the dropout layer.

2.1. Data Acquisition

The data set used for supervised machine learning purpose is the PASCAL data set which contains the heart sound recordings labelled by three categories namely Artefact, Normal heart sound and abnormal heart sound. Around 400 HS files are there in PASCAL data set.

In the processing step, we made two same copies of the data set. In the first copy of the data set, the labels Normal and Abnormal is replaced by Non-Artefact label. This is done for signal quality assessment. The analogue HS is then converted into its time domain representation [2]. The advantage of converting analogue data into time domain is that the analogue data is converted into numeric equivalent representation which is a machine understandable format and also it is effortless for analysis purpose. Various mathematical functions can be applied on the numeric data which can be used for analysis and therefore the time domain representation is very important.

The input size of CNN is already fixed. So, the recordings have to be converted to some fixed length prior to training [3]. We converted the signal into fixed sized data of 8-11 sec.

If it is longer than specified time, we truncate the data into fixed size. If it is shorter, we extend it by repeating the original signal to make it into specified length. Down sampling is applied to discard the ineffective data. Down sampling improves the generalization on the data set. There is some really low frequency sound recorded by the electronic stethoscope, especially murmur which are passed through a low pass filter which allows low frequency sound to pass and eventually rejects the noise from the data. So, this is the first step towards filtering noisy data.

2.2. Signal Pre-processing

Signal pre-processing is done for the assessment of quality of the heart sound files. Artefacts are the sound files containing noise along with data which are poor in quality. These HS signals are not fit for classification. The Signal Quality Assessment block [4] ensures that these files should be discarded. Now the data set is remained with only good quality audio files which are potentially fit for classification.

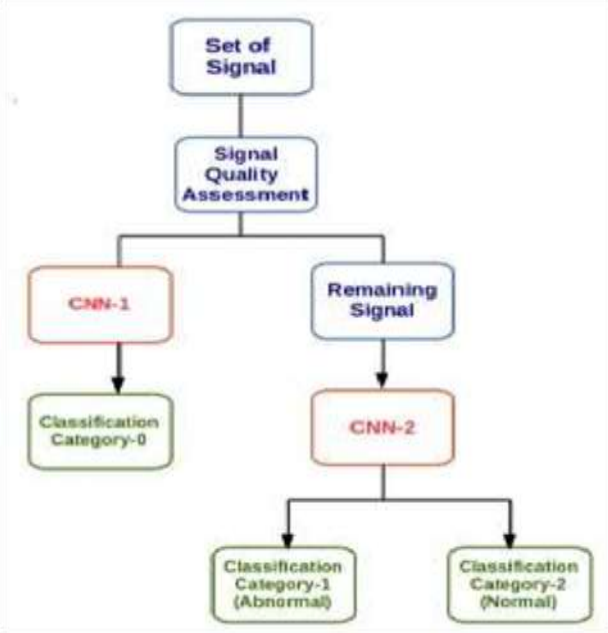

Fig -1: Proposed block diagram

A CNN can be useful for classification and can be as Good or Bad Quality classifier [5].So, here the advantages of neural network is exploited for signal quality assessment classifier of heart and sound files into good quality files which free from noise and poor quality files contain the heart sound data set is feed to a convolution neural network which classifies the data into two namely artefact and non-artefact. The main reason of doing this is to the value of neurons from getting distorted. While the training neural network, in every epoch the values of neurons in CNN gets closer and closer to the actual value feature presented to the neural network and hence the efficiency increases gradually. So, if we discard the recordings containing artefacts, we can increase the efficiency of classification of the neural network. So, the CNN-1 also known as good or bad quality signal classifier can also be viewed as the first step towards increasing the accuracy of the system. Greater the accuracy of CNN-1 of filtering the bad quality signal better will be the performance of CNN-2 for classifying normal and abnormal heart sound and hence better will be the performance of the system.

2.3. Feature Extraction and Classification

Convolution neural network is mainly composed of two parts, feature extraction and classification. The section of feature extraction is responsible for extracting effective features from the PCG signals automatically. The classification part makes use of those extracted feature. In short, these two sections complete the main work of this paper cooperatively.

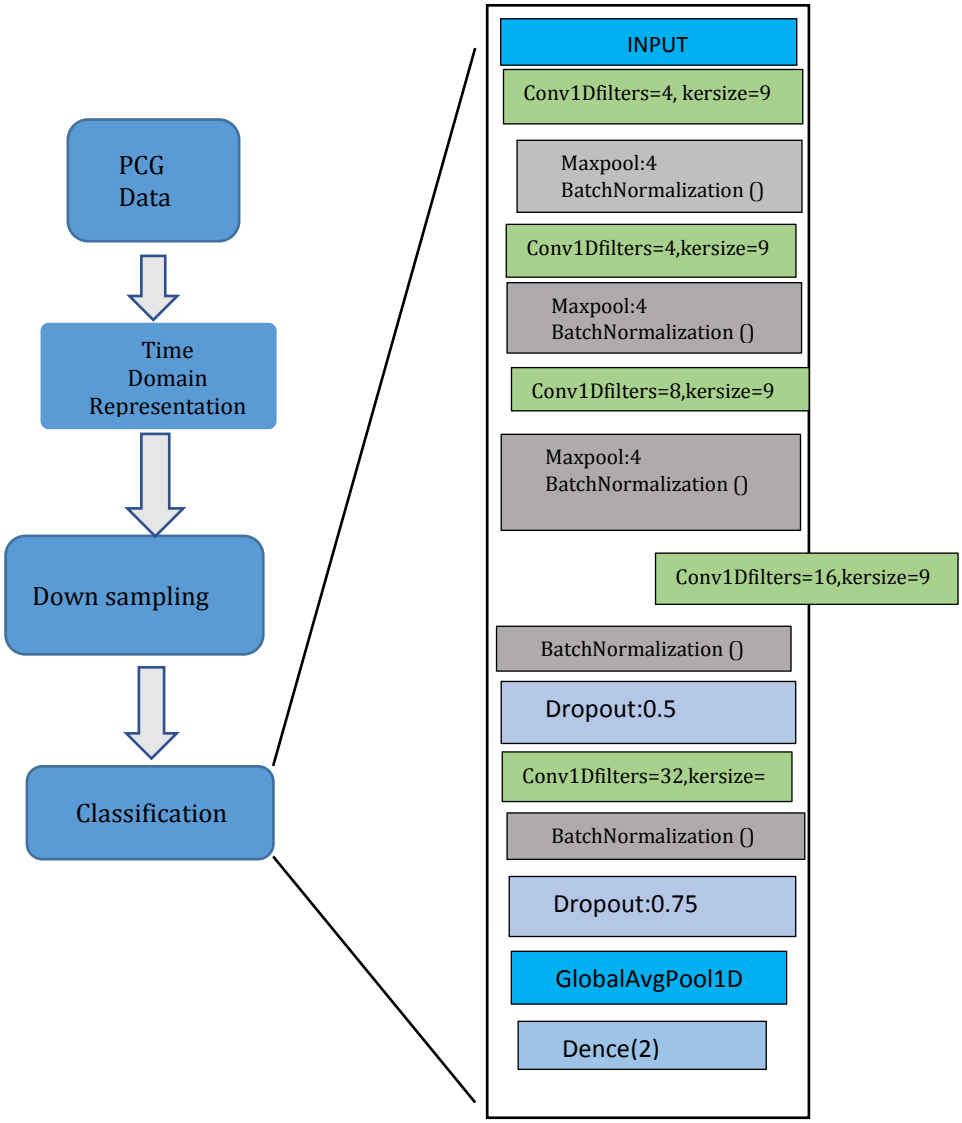

Fig -2: Proposed processing methodology

Purpose of above implementation of neural network:

For binary classification, the last layer has 2 neurons as shown. It can also be done using 1 neuron but just for better representation and understanding we have opted for 2 neurons instead of 1.

Left: PCG data (.wav file) is converted into binary data of fixed length using time domain representation which is then fed to CNN model. Right: CNN architecture includes several convolution and max pooling layers, Batch Normalization layer followed by fully connected or dense layers.

2.4 The dropout layer [6]

The term "dropout" refers to dropping out units (both hidden and visible) in a neural network. It is a very efficient way of performing model averaging with neural networks. Model averaging is a natural response to model uncertainty. The dropout layer allows for regularization by randomly setting some neurons in previous layers to zero during training.

a) Max Pooling [6]

The objective of Max pooling is to down-sample an input representation. It helps in reducing the dimensionality and alleviate feature extraction. It reduces the computational cost by reducing the number of parameters to learned. Batch Normalization allow each layer of neural network to learn by itself a little bit more, independently of other layer. It reduces over-fitting and increases the stability of neural network.

b) Batch Normalization

Batch Normalization allow each layer of neural network to learn by itself a little bit more, independently of other layer. It reduces over-fitting and increases the stability of neural network.

3. CONCLUSION

This study attempts to solve a very complex and critical problem of medical sector. It strives to classify the heart sound captured by PCG into normal and abnormal heart sound. This will significantly help the health care industry as the greatest number of deaths across the world is due to the heart related problems. The methodology adopted for classification is a technique in computer science known as neural network. Use of one-dimensional neural network is demonstrated. The model proposed in this study demonstrates a novel approach for classification of noisy data containing artefact. First step is Quality assessment. The advantage of this step that the noisy data does not disturb the original neural network which is used for classification of good quality heart sound file into normal and abnormal heart sound. Instead, a separate neural network is used for the same purpose of classification of noisy data from good quality heart sound data.

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