Identification of Premature Ventricular Contraction (PVC) Based on ECG Using Convolutional Neural Network

Akanksha Kothari, Sankeit Dighe, Kedar Kale, Shubhangi Kale

Abstract- Premature Ventricular Contraction (PVC) arrhythmia patients are subjected to dangerous heart rhythms that can be chaotic, and possibly result in abrupt death. Therefore, early detection of arrhythmia with high accuracy is extremely important to detect cardiovascular diseases. The classification of heartbeats based on ECG signals plays a vital role it the field of cardiac sciences to identify arrhythmias. The use of Artificial Neural Networks (ANN) has proven to be the most effective technique for sole agenda of classification. The use of CNN is simple and more noise immune method in comparison to various other techniques. In this paper, a survey of numerous algorithms and classification techniques along with their performance measures are presented. This paper proposes the identification of PVC on the basis of heart beats by using CNN and the results obtained are compared to other traditional approaches.

Keywords- ECG, CNN, ANN, PVC.

I. INTRODUCTION

One of the most prevalent causes of deaths is Cardiovascular Diseases. A patient suspected of heart abnormality undergoes the test of heart's electrical activity. ECG beat recognition can be accomplished by ANN. If the ECG signals are clean and distinguishable, then the health information can be understood properly. The primitive stages of heart abnormalities, if detected sudden cardiac deaths and other repercussions of heart disease can be avoided. The researchers have reported such results by analysing the ECG signals and detecting the abnormalities.

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To inform on such abnormalities, an uninterrupted EGC signal monitoring is needed for each casualty. Generally, EGC signal is the graph drawn between voltage versus time. The graph is produced due to heart's electrical activities. The signal is made up of various distinguishable such as P wave, QRS complex and T wave. With the features identified in the ECG signal, it is possible to classify PVC arrhythmia against the normal beats. The purpose of this project is intended for the identification of PVC arrhythmia based on ECG signal using CNN.

This paper presents a system that monitors patient's ECG. Through this system, a doctor can supervise whether the patient is suffering from Premature Ventricular Contraction by interpreting the results given by this project.

The paper has been organized as follows: Following the Introduction, Theory And Relevance is produced in section number II. Literature Survey is discussed in section number III. Proposed Architecture is discussed in section number IV. Proposed Methodology is explained in section number V. Result is presented in section number VI. Conclusion is presented in section VII. Last section states all the references.

II. THEORY AND RELEVANCE

The human heart is stated as the most crucial organ in a body that facilitates the working of other organs by pumping blood via the circulatory system that consists of veins and capillaries that bring oxygen and other essential nutrients. The four chambers in the heart comprises of two ventricles and atriums respectively, each occupying the upper and lower chamber. The lungs receive the impure deoxygenated blood through pulmonary artery from right ventricle and oxygen rich blood is supplies through the pulmonary vein into the left atrium. Heart being a muscle itself needs oxygen for working which is accomplished by the working of two sets of arteries. Thus, blockages in any part of it can lead to a cardiac arrest. Hence, a need of a system that can predict in advance the chances of having it by analysing the heart's electrical activity, can be extremely helpful. Most common heart diseases encountered by general population are|| Acute coronary syndrome (Blood supply to heart is obstructed), Coronary artery disease (Blood supplying arteries are obstructed), Rheumatic heart diseases (Rheumatic fever) and Premature Ventricular Contraction (Purkinje fibres in the ventricles).

III. LITERATURE SURVEY

Different methods for the classification of arrhythmias using deep learning and machine learning have been proposed. The following study discusses briefly the proposed methodologies.

Zhang et al. [1] detected different type of arrhythmias from ECG classification using deep learning approach by using MIT-BIH arrhythmias dataset. A 12 layer CNN algorithm was applied and wavelet transform was used for the denoising. The operation was done on data from a single lead. The classification accuracy was of 98.67%. Tanoy Debnath et al. [2] used back propagation approach to identify different type of arrhythmias from ECG classification. The algorithm was applied and Pan Tompkins algorithm was used for the denoising. Each disease was identified with a good accuracy, Bradycardia being at 87.20% and Tachycardia at 99.97%.The dataset used was MIT-BIH dataset.

Ming Liu and Younghoon Kim [3] shown the use of an algorithm called SAX (Symbolic Aggregate Approximation) to detect different types of arrhythmias. The LSTM as well as Softmax activation function was used to obtain the output. Each disease was identified correctly but this approach took more time than processing with CNN and obtained a classification accuracy of 97%.The training dataset used was MIT-BIH dataset. MH Vafaie et al. [4] evaluated the use fuzzy classifier and genetic algorithm of to identify vivid arrhythmias. The use of genetic algorithm has increased the accuracy percentage. Each disease was identified correctly with a classification accuracy of 98.67% by training the model by MIT-BIH dataset.

Eduardo Jose da S. Luz et al. [5] enforced classification using signal processing , segmentation and features extraction. The approach was based on the overview of the pre-processing. This paper contains evaluation of process workflow for future works. The limitations and drawbacks of various methods were also discussed. V. Sai Krishna et al. [6] improved the accuracy by testing both machine learning and AINN approaches. For denoising of the data Hilbert Transform is used. The arrhythmias were identified correctly with a classification accuracy of 98.66% by using AINN approach. The database named as MIT-BIH is used.

Y. Ozbay et al. [7] proposed an algorithm to detect different type of arrhythmias from ECG classification using AINN approach.The ECG patterns were tested with most appropriate structures of Neural Network and mixed classification case. Each disease was identified correctly with a classification accuracy of 97.8%. Özal Yıldırım et al. [8] proposed system to detect different type of arrhythmias from ECG classification using deep learning approach. A 16 layer CNN algorithm was applied and the final output layer was of Softmax activation function. Each disease was identified correctly with a classification accuracy of 91 percent.

Pranav Rajpurkar et al. [9] developed 34 layer CNN to detect different type of arrhythmias from ECG classification. The deep learning approach was used. This was the proposal of a solution for detecting Ventricular Hypertrophy. The paper has detected the difficulty on a single- lead ECG and suggested to use a multi- lead ECG.

After the necessary analysis of works and various methodologies like SAX, Pan Tompkins, CNN, SVM, etc, the approach of using LSTM in addition with the softmax function have been proven to achieve a high accuracy rate but was limited by the time it took for processing. Therefore, this approach was discarded. CNN proved to overcome the shortcoming of LSTM and was therefore chosen the algorithm of choice to proceed.

IV. PROPOSED ARCHITECTURE

The proposed architecture consists of Data Acquisition System and Classification Model. The Data Acquisition is used to take the input and classification model is used to identify PVC by proper training and the model.

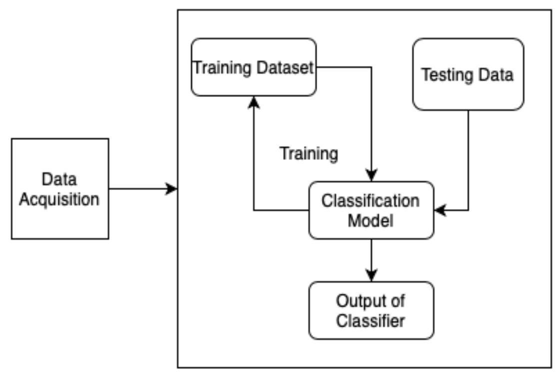

Fig. 1. Proposed System Architecture

V. PROPOSED METHODOLOGY

To initiate the functionality of the method proposed, data acquisition for gaining the necessary data parameters from the ECG is carried at the first stage. To classify heart disease we train a Convolutional Neural Network (CNN) model using MIT-BIH dataset. By converting 1D-ECG signals to 2D images the noise filtering and extraction of features are no longer required. The augmentation of the images is used to train the model. The model involves the following steps:

The training of the CNN is done with Batch Normalization. It is a technique used for training deep neural networks. There is the standardization of the input to a layer for each mini batch. The Normalization is also known as the regularization. The sole task of the regularization is to lessen the overfitting of the data. The use of Batch Normalization allows higher learning rate and speed with which the training of the model is done. It reduces internal covariant shift. After training, the following layers are used to identify PVC:

A. Convolution Layer

This is the first layer. The image of each ECG beats of ECG signals is considered as an input to layer.

Then the image is converted into matrix of pixels. After that the matrix is reduced into the smaller matrix by applying some filters(rules). The value of filters is multiplied by original pixel values when filters displaces in line with the image grid.

The summing of multiplication is done to give one final number at last, since the filter reads the image from top to bottom and left to right. So, in this format the filters are applied and we get a reduced matrix. In this paper, our proposal is a method using two-dimensional convolutional neural networks with an image of the ECG as an input. From, the MIT-BIH database of ECG recordings are transformed into 128 x 128 grayscale images. The representation is shown in Fig.2.

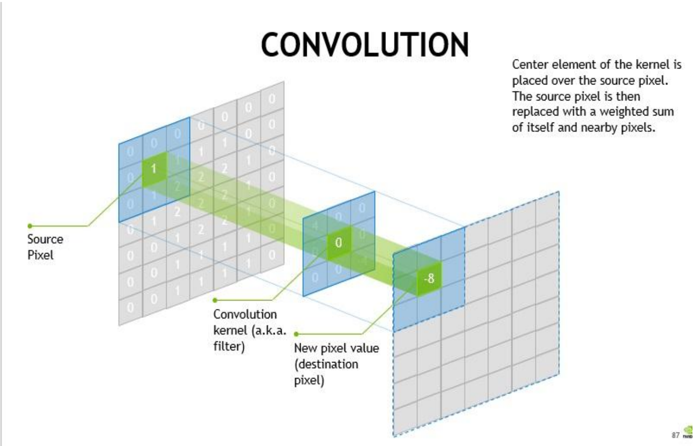

Fig. 2. Convolutional Layer (source: https://www.embedded-vision.com)

B. ELU Layer

This layer is the activation function layer which is the modified version of ReLU activation function to produce more accurate results known as Exponential Liner Unit. The layer tends to coverage cost to zero as shown in Fig.3.

The ELU layer has an extra alpha constant which should be a positive number as shown by:

$$f(x) = \begin{cases} x, & x \geq 0 \\ \alpha(e^x - 1), & x < 0 \end{cases} \tag{1}$$

where α is hyper-parameter.

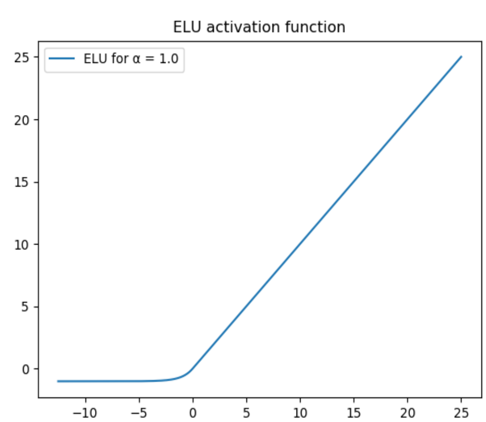

Fig. 3. Graph of ELU activation (source: https://www.machinecurve.com)

C. Pooling Layer

This layer is used to reduce dimensions of the feature map and computations. It uses down sampling method. They can Max, Average from rectified and downsized feature map as shown in Fig. 4.

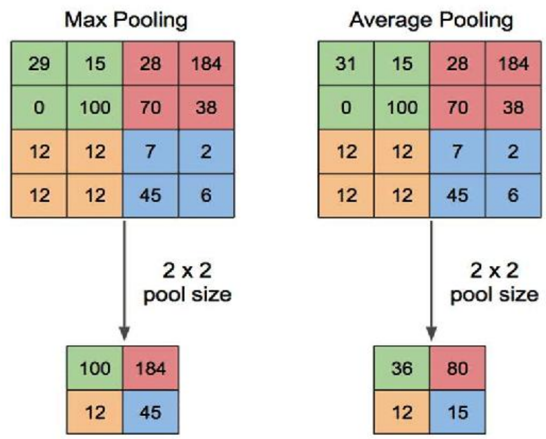

Fig. 4. Feature map reduction by Pooling layer

D. Fully Connected Layer (FCC)

This portion is responsible for taking output from convolutional networks. The fully connected layer at end of the network results in N dimensional vector, where N is the number of classes from which the softmax activation function layer selects the class having greater probability. The pictorial representation is shown in Fig. 5.

E. Softmax Layer

This is activation function layer which is responsible for multi-class classification. The layer converts outputs from Fully Connected Layer into probability distributions and the class having greater probability of occurrence than other classes is selected as the final classification output. The output from this layer ranges from [0,1] as the sum of probabilities for the outcomes of an event is one. This is the last layer of the model for the final classification and its equation is shown below:

$$\sigma(x_j) = \frac{e^{x_j}}{\sum_{k=1}^{K} e^{x_k}} \tag{2}$$

where x is the inputs as vectors to output layer and j indexes the output units from 1,2,3…., K. The layer is shown in Fig.6.

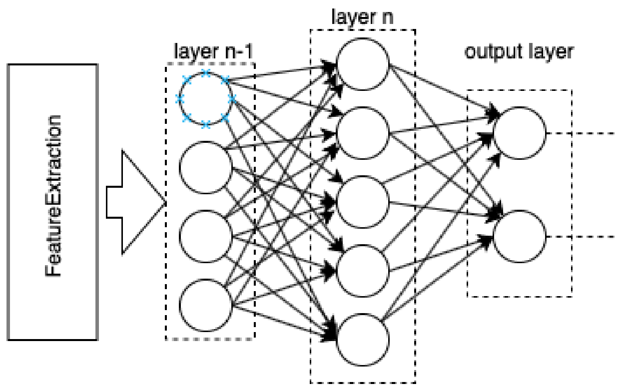

Fig. 5. Layers in FCC

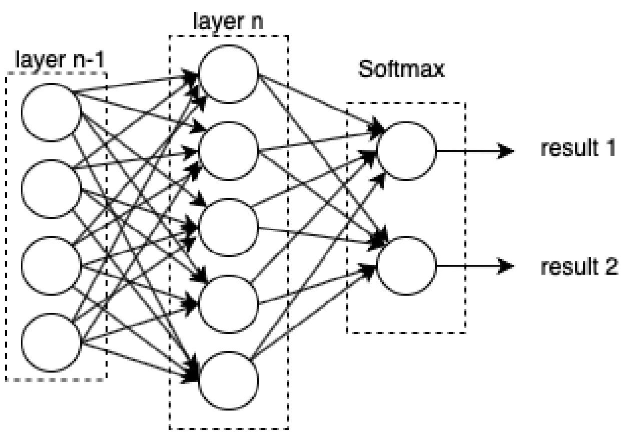

Fig. 6. Softmax- Activation Function

The accuracy of the classification model is given by:

$$Accuracy = \frac{Total\ number\ of\ correct\ predictions}{Total\ number\ of\ predictions} \quad (3)$$

VI. RESULTS

The database used was MIT-BIH Arrhythmia, includes 48 half-hour extracts from ECG record collection. The recordings were gained from 47 under observations subjects. The digitization of recordings was done at 360 samples per second per channel with 11-bit resolution over 10mV range. As a result, the model trained using the MIT-BIH database achieved 91.05% average accuracy when considering the numerical record of 35,000 ECG values. In the obtained accuracy, Premature Ventricular Contraction (PVC) heartbeats accounts for the most accurate classification of 99.05% from the rest. The classification of normal heartbeats and its count in a sample test data were found to have a variance up to four percent. With data augmentation, CNN model shows the best accuracy results for PVC when compared to other approaches such as SVM, ATI-CNN, VGG-12 and 1-D CNN. However, in our proposed model in this paper, we achieved a successfully good computational performance compared to other works while introducing an approach of arrhythmia classification with two dimensional images which also occurs to be different from the rest. The accuracy obtained when followed different approaches for classification of PVC are listed in the table below.

Table I: Comparative Results

Methodologies and Accuracies			
Serial Number	**Method**	**Reference Paper**	**Accuracy for PVC**
1	SVM	[10]	88.21
2	ATI-CNN	[11]	86.10%
3	VGG-12	[11]	73.90%
4	1-D CNN	[1]	95.90%
5	2-D CNN	This paper	99.05%

VII. CONCLUSION

Prediction of PVC Arrhythmia can be performed by implementing Neural Network algorithms. In this paper, different types of Deep Learning(DL) and Machine Learning(ML) models used for the prediction as well as classification of cardiac arrhythmia have been discussed. Various artificial neural network models such as Back Propagation, Convolution Neural Networks and ensemble of neural networks have been discussed. It is inferred that the performance of Artificial Neural Networks is high compared to the usual machine learning models. The selection of appropriate algorithms or a set can drastically improve the quality of results and can be deployed to use in real time for treating patients. As a result, our proposed approach of identifying PVC arrhythmia heart beats from normal healthy ones using CNN yielded a system with high performance accuracy that can be implemented and used in medical sciences.

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AUTHORS PROFILE

Akanksha Kothari is a Final Year B. Tech student. She is pursuing her B.Tech degree in Computer Engineering from MIT Academy of Computer Engineering, Pune. She has done projects in the field of machine learning and deep learning. The titles of the projects are Hand Gesture Recognition, Credit Card Fraud Detection, Movie Rating Prediction, and Image Segmentation. She has a deep interest in the field of machine learning and deep learning. She is also a member of CSI. She has also worked as a project intern at the Indian Institue of Tropical Meteorology under the guidance of Director of SAFAR.

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Kedar Kale is pursuing BTech degree in Computer Engineering from MITAOE. During his undergraduate degree, he had worked on lots of projects but the projects that actually caught his interest were related to Artificial Intelligence and Machine Learning.The Projects included Patient Health Monitoring System, Classification of Animals and its Species and Object Activity Detection.Apart from this, he has also completed an internship at Danalitic India. Pvt. Ltd. which is a AI based company.

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