Artificial Intelligence Based Diagnosis of Heart Disease Using ECG and Deep Neural Networks

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***Abstract*— Health is the most important part of life. Unfortunately, people get sick from diseases from time to time which can further lead to deaths. The most common cause of deaths these days is cardiovascular diseases (CVDs). CVD is a term used for all types of diseases that affect the heart, the blood vessels, and circulatory diseases. This paper focuses on a supervised machine learning technique namely Deep Learning (DL) in diagnosing heart disease efficiently and effectively.**

Keywords—Artificial intelligence, Machine Learning, Deep Learning, Convolutional Neural Network, Cardiovascular Diseases, Heart Diseases, Electrocardiogram, Medical Diagnosis

I. Introduction

CVDs are the number one cause of death worldwide. It is estimated that in 2019, 17.9 million people died from this disease which contribute to 32% of deaths globally [1]. 7.6 million of the population is living with heart and circulatory diseases in the UK. The National Health Service (NHS) categorises CVD as a clinical priority [2].

There are several tests used to diagnose heart disease such as: electrocardiogram (ECG), Magnetic Resonance Imaging (MRI) and Computerised Tomography (CT) scan. This paper focuses on ECG as it is the golden standard diagnostic test when a patient goes to the hospital.

Healthcare is an industry that is always improving with new technologies and treatments. Now with the help of emerging technologies, big data, and computational power, many sectors including the healthcare sector can benefit hugely. The healthcare sector can benefit by adopting AI in the medical settings which can help with faster diagnosis and prognosis. Other applications include AI being used to develop drugs [3], identifying skin cancers, identifying eye diseases and detect diabetes.

There are different branches of AI namely: Machine Learning (ML), Deep Learning (DL), Natural Language Processing (NLP), Rule-based Expert Systems, Fuzzy Logic, and Robotics. In this paper a DL algorithm namely Convolutional Neural Network (CNN) is used for heart disease prediction as it proves to be very effective in processing complex medical image.

II. Choice of Analysis

A. *Electrocardiogram (ECG)*

ECG is used to evaluate a patient's heart. It is non-invasive and a simple test which does not send electricity into the body. ECG is effective in detecting arrhythmias, coronary heart disease, heart attacks and cardiomyopathy. Furthermore, two important key information are provided in an ECG. Firstly, the time intervals can be measured on it which as a result can help the medical professional to detect whether the electrical activity is normal, fast, irregular, or slow. Secondly, they can detect if any part of the heart is enlarged or overworked, by measuring the amount of electrical activity travelling through the heart muscle.

The ECG interpretation as shown in figure [1] is represented in waves namely P, Q, R, S, T and U waves.

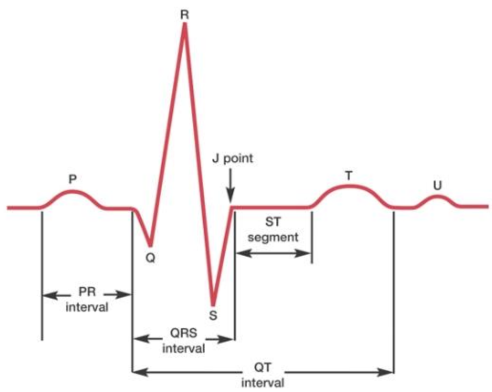

Fig. 1. ECG electrical activity [4]

The P wave represents the atrial depolarisation. The QRS wave shows the ventricles depolarisation. The T wave is the ventricular repolarisation after which the heart is resetting.

The ECG signals used are opened-sourced and collected from Physikalisch-Technische Bundesanstalt (PTB) diagnostic ECG database and consists of 14,552 number of labelled samples. These signals are pre-processed and segmented where each segment correspond to a heartbeat. The pre-processing of the dataset consists of cropping, down-sampling and padded with zeros to fit 188 dimensions. The dataset is in the format of CSV file.

B. *Convolutional Neural Network (CNN)*

CNN is the sub-category of Neural Network. It has proved to be very effective in image classification [5]. It has also proved to work well in medical imaging tasks such as: disease classification, detection, and segmentation. The architecture of the CNN includes convolutional layer, pooling layer, activation layer, the dropout layer, and the fully connected layer. The CNN architecture is designed using the steps as shown in figure [2].

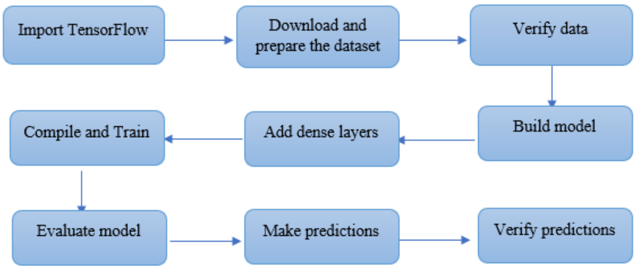

Fig. 2. CNN architecture process

The algorithm designed and used to diagnose whether a patient's ECG shows heart disease or no heart disease is a CNN with a number of set layers as shown in figure [3]. The algorithm consists of an input layer, convolution 1D layer 1, convolution 1D layers 2, max pooling, drop out layer to regularise the network, convolution layer 3, convolution layer 4, max pooling to downsize the input by half, drop out layer to regularise the network for training, flatten layer to create 1 dimensional array from the previous layer and followed by three dense layers with two outputs .

Input layer (187,1)
Convolution Layer 1 (Filter=16, Kernel size=3x1, padding=same, activation=relu)
Convolution Layer 2 (Filter=16, Kernel size=3x1, padding=same, activation=relu)
Max pooling 1 (pool size=2x1, stride=2)
drop out 1 (0.2)
Convolution Layer 3 (Filter=32, Kernel size=3x1, padding=same, activation=relu)
Convolution Layer 4 (Filter=32, Kernel size=3x1, padding=same, activation=relu)
Max pooling 2 (pool size=2x1, stride=2)
drop out 2 (0.5)
Flatten
dense layer 1 (units=16, activation=relu)
dense layer 2 (units=32, activation=relu)
dense layer 3 (units=2, activation=softmax)

Fig. 3. CNN algorithm design

As shown in section III, this architecture produces a great result and is able to learn patterns and abnormalities in the ECG data.

III. EXPERIMENTAL RESULTS

To have a reliable model, the dataset is split into three sets namely: training, validation, and test sets. The test data and training data are splitting as 30% and 70% respectively.

In the training set, the model learns the hidden patterns in the data, where at each epoch the same training data is fed repeatedly into the model to learn the features in the data. In the validation set, a set of data is separated from the training set. This process is important as it prevents our model from overfitting. In the case of overfitting, this means that the model is very good at classifying data during training, however, when it comes to accurately classify data which it has not seen before, the model will not be able to do so. Lastly, the test set is a separate set of data that is used to test the model after the training is done. Here, it shows how well the model performs.

The experiment includes testing and tweaking the architecture along with train_test_split of 0.3 (30%), KFold k=10 and Stratified KFold K=10.

The use of LeakyReLu produced a similar result as ReLu (Rectified Linear Unit). The test is conducted on different batch size, epochs, and seeds. The optimum batch size for the given dataset with the proposed architecture was 128 with epoch of 125.

The model is able to achieve 99% accuracy with 128 batch size, 125 epoch with train_test_split of 0.3. It also performs well with the test data. The validation accuracy seems to be higher than Train- training accuracy because the model has a drop out of 20%. The drop out is used to prevent any overfitting and improve generalization error. While training, 20% of features are dropped out so the model should be robust during test or real time use. Figure [4] shows the CNN model results.

loss: 0.0262
accuracy: 0.9899
val_loss: 0.0375
val_accuracy: 0.9908

Fig. 4. CNN model results with 128 batch size, 125 epoch and seed 42

IV. CONCLUSION

AI is here to stay. It can help deliver quality patient care by supporting medical staffs. However, due to ethical issues, it remains a challenge to maintain confidentiality to patient's data. With ethical approval, this algorithm can be further developed using data from several hospitals. It can bring numerous benefits to the healthcare sector such as being used in remote areas and developing countries where fewer medical professionals exist. It can also help the less experienced doctors with a second opinion on diagnosis. Hence, allowing a stronger confidence in giving patients their diagnosis.

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