Early prediction of Atrial fibrillation and Congestive heart failure

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Abstract:

(CHF) is a chronic progressive condition that affects the pumping power of the heart muscle. It specifically refers to the stage in which fluid builds up within the heart and causes it to pump inefficiently. (AF) is a heart condition that causes an irregular and often abnormally fast heart rate it can be considerably higher than 100 beats a minute. Sometimes AF does not cause any symptoms and a person who has it been completely unaware that their heart rate is irregular. As we concerned about healthcare and providing early prediction, we used ML model to provide early prediction. By using the ML model, which could predict the early stages of both CHF & AF with an accuracy of 98.87% & 99.67%. We tested the model by using the hardware device that we built to capture real-time ECG signals from CHF & AF patients. The device will be existed and be available in hospitals and sports fields. Then the results will be displayed in our Mobile Application which is connected to the model that analyzes the ECG signals. Figure1

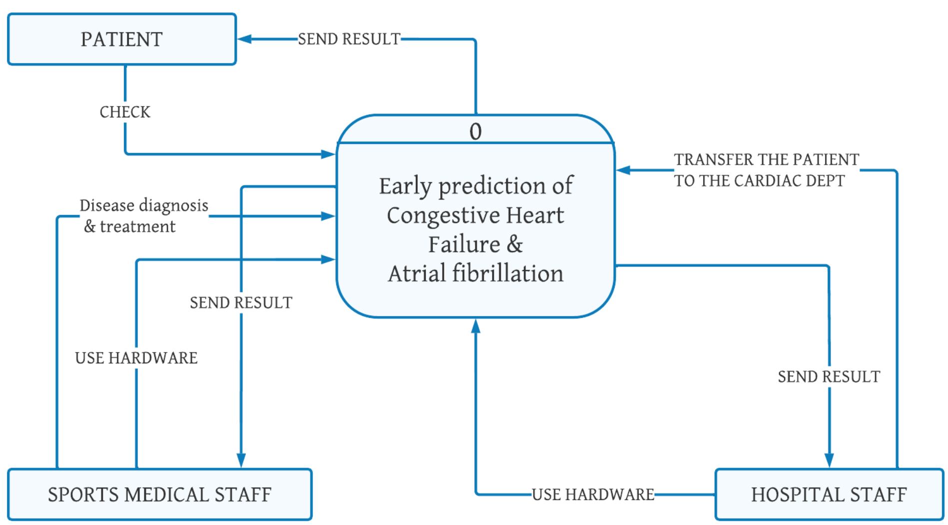

Figure 1: Context Diagram that shows the project workflow.

Keywords:

CHF: Congestive Heart Failure, AF: Atrial Fibrillation, ML: Machine Learning, DL: Deep Learning, LV: Left Ventricle, ECG: Electrocardiogram, CNN: Convolutional Neural Network, SVM: Support Vector Machine, KNN: K-Nearest Neighborhood, ANN: Artificial Neural Network, PTB: Physikalisch-Technische Bundesanstalt, DT: Decision Tree, RF: Random Forest.

Introduction:

Heart disease affects over twenty-three million people worldwide, making it a serious public health issue as well as a significant economic burden. Heart disease is regarded as one of the world's most severe and life-threatening chronic diseases. In heart illness, the heart generally fails to deliver enough blood to other regions of the body to allow them to operate normally. We will concentrate on two major cardiac disorders in this project:

1. Atrial fibrillation (AF):
It is a heart condition that causes an irregular and often abnormally fast heart rate. The heart rate is irregular and can sometimes be very fast. In some cases, it can be considerably higher than 100 beats a minute. A normal heart rate should be regular and between 60 and 100 beats a minute when you are resting. Sometimes atrial fibrillation does not cause any symptoms and a person who has it is completely unaware that their heart rate is irregular.

2. Congestive Heart Failure (CHF):
CHF is a chronic illness that affects the heart chambers. It occurs when the heart is unable to pump blood adequately throughout the body without an increase in intracardiac pressure. The kidneys respond by retaining body fluid, which results in lung congestion and swelling in the arms and legs. CHF is caused by functional impairment of the left ventricle, which is the dominant contractile chamber that pumps blood systemically. The systolic contractile function of the LV is conventionally quantitated using the LV ejection fraction (EF), defined as the ratio of LV stroke and end-diastolic volumes, with normal LVEF being 50% or more. CHF can be stratified into two main types: heart failure with reduced (HFrEF) and preserved EF (HFpEF) ejection fraction, characterized by predominance of either inadequate LV systolic contraction (EF less than 50% typically) or inability of the LV to expand or fill efficiently during diastole, respectively. While classification of HFrEF and HFpEF is arbitrarily based on the level of EF, elements of LV, both systolic contractile and diastolic filling pathophysiological changes, can co-exist in the same patient. This project aims at early detection of patients in emergency rooms in hospitals, clinics, medical institutions, and Sports Field.

Related Work:

After searching and reading of papers related to our project, we found that many papers used different methods and techniques to provide the highest accuracy,

Deep convolutional neural network for the automated diagnosis of congestive heart failure using ECG signals [1]

In this paper, they develop an 11-layer deep convolutional neural network (CNN) model for detecting CHF. This suggested CNN model requires very little pre-processing of ECG signals and does not require any engineered features or classification. The suggested CNN model was trained and tested using four different sets of data (A, B, C, and D). Set B had the best accuracy of 98.97 percent, as well as the highest specificity and sensitivity of 99.01 percent and 98.87 percent, respectively, among the four sets. By providing more objective and faster interpretation of ECG signals, the suggested CNN model can be put into practice and serve as a diagnostic assistance for cardiologists.

Congestive heart failure waveform classification based on short time-step analysis with recurrent network.[2]

They develop 15 models using a data base consisting of 10 recordings, divide them into 80 percent for training and 20 percent for testing and validation, and then choose the best model with accuracy 99.36 percent by using deep learning techniques and recurrent neural networks and LSTM.

Machine learning based congestive heart failure detection using feature importance ranking of multimodal features.[3]

Empirical Receiver Operating Characteristics (EROC) values were used to classify patients into five groups. They determine the highest performance and accuracy classifier among (Decision tree-Nave Bayes –SVM) which was SVM with accuracy 88.79 percent.

Regularized HessELM and Inclined Entropy Measurement for Congestive Heart Failure Prediction [4]

The research focuses on the automated prediction of congestive heart failure using ECG signals Regularized hessenberg decomposition based extreme learning machine (R-HessELM) and feature models; squared, circular, inclined, and grid entropy measurement were introduced and applied for CHF prediction. This study demonstrated that aspects of inclined entropy measurements accurately depict ECG signal properties, and that when combined with the R-HessELM technique, overall accuracy of 98.49 percent was attained.

Use of Accumulated Entropies for Automated Detection of Congestive Heart Failure in Flexible AnalyticWavelet Transform Framework Based on Short-Term HRV Signals [5]

The Flexible AnalyticWavelet Transform, which decomposes HRV signals into distinct sub-band signals, is used in this technique. Furthermore, the cumulative sums of these sub-band signals are used to construct Accumulated Fuzzy Entropy and Accumulated Permutation Entropy. This gives complexity analysis at various frequency scales utilizing fuzzy and permutation entropies. From the signals acquired at different frequency ranges of HRV signals, we identified 20 characteristics. The collected features from three distinct lengths of HRV signals are ranked using the Bhattacharyya ranking algorithm (500,1000 and 2000 samples). The Least Squares Support Vector Machine (LS-SVM) classifier is fed these rated features. For the 500-sample duration of HRV signals, our suggested method achieved a sensitivity of 98.07 percent, specificity of 98.33 percent, and accuracy of 98.21 percent. For HRV signals with a length of 1000 samples, our system had a sensitivity of 97.95 percent, specificity of 98.07 percent, and accuracy of 98.01 percent, and for signals with a length of 2000 samples, our system had a sensitivity of 97.76 percent, specificity of 97.67 percent, and accuracy of 97.71 percent.

Detection of Atrial Fibrillation Using a Machine Learning Approach [6]

They built six models based on deep learning methodologies (SVM-LSTM-CNN) after researching heart rate variability, and then tested them on 13 patients with overall accuracy 87.5 percent.

Early Detection of Atrial Fibrillation Based on ECG Signals [7]

The aim is to develop an intelligent wireless system with a built-in abnormal ECG detection mechanism and an alert expert system for the early detection of cardiac disorders. The first part of the Arduino algorithm was developed to extract and plot the raw ECG signal and to convert the signal using transfer function and process it with digital filtering method. The second part of the algorithm determined the heart beats per minute of the healthy ECG signal, followed by the RR interval of the ECG signal. The third part of the algorithm was developed to compare the result acquired from second part with the normal values which was included in the algorithm as the threshold value to show the alert for any potential cardiac events. The accuracy was about 96 percent –98.5 percent.

Machine learning detection of Atrial Fibrillation using wearable technology [8]

An inexpensive wearable heart rate monitor and machine learning algorithm can be used to detect AF with very high accuracy and has the capability to transmit ECG data which could be used to confirm AF. It could potentially be used for intermittent screening or continuously for prolonged periods to detect paroxysmal AF.

Further work could lead to cost-effective and accurate estimation of AF burden and improved risk stratification in AF. The SVM algorithm demonstrated excellent discrimination with sensitivity and specificity both exceeding 99 percent for the training data set. This compares favorably with other algorithms results using the same databases in the literature.

Deep Neural Networks Can Predict New-Onset Atrial Fibrillation From the 12-Lead ECG and Help Identify Those at Risk of Atrial Fibrillation [9]

Deep neural networks were trained to predict new-onset AF in patients without a history of AF. Performance was evaluated using areas under the receiver operating characteristic curve and precision-recall curve. For all experiments, data were divided into training, internal validation, and test sets. The composition of the training and test sets varied by experiment, as described in Study Design; however, the internal validation set in all cases was defined as a 20 percent subset of the training data to track validation area under the receiver operating characteristic curve (AUROC) during training to avoid overfitting. Accuracy was about 95 percent.

Detection of Atrial Fibrillation Using 1D Convolutional Neural Network [10]

To improve detection accuracy and reduce network complexity, this research offers an AF detection approach based on an end-to-end 1D CNN architecture. We create a simple, yet effective 1D CNN (10-layers) by analyzing the effects of key components of a convolutional block on detection accuracy and using grid search to acquire optimal hyperparameters of the CNN. Because the PhysioNet Challenge 2017 dataset contains ECG recordings of varying durations, we propose a length normalization approach to generate equal-length records to meet the CNN criterion. Our method of 1D CNN obtains an average F1 score of 78.2 percent, according to experimental findings and analyses.

Material and Methods:

Hardware:

We developed a device that can capture Real-time ECG data from patients by attaching electrodes or needles to the left arm, right arm, and left leg of the patients [11]. Then Send ECG data to the ML model to be predicted. Figure 2

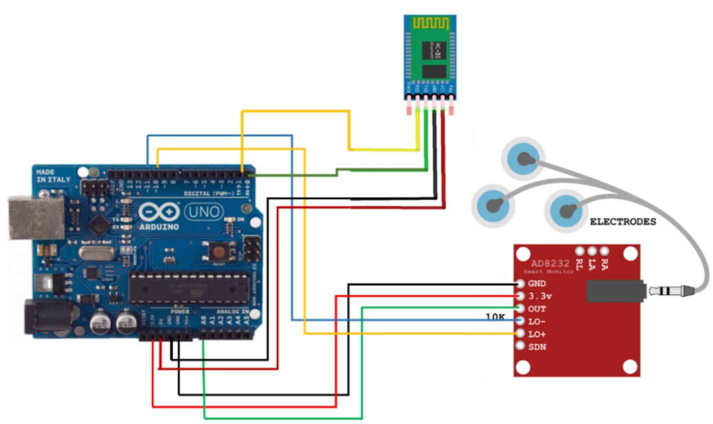

Figure 2: Component of the device.

Datasets:

The ECG signals our study depends on were from public resource databases (PhysioBank & PhysioNet), and they were as Table 1 shows:

Data Set	Disease	Source	Ref
MIT-BIH Atrial Fibrillation Database	AF	PhysioNet	[12]
Predicting Paroxysmal Atrial Fibrillation/Flutter: The PhysioNet/Computing in Cardiology Challenge 2001	AF	PhysioNet	[13]
MIT-BIH Arrhythmia Database	Normal	PhysioNet	[14]
BIDMC Congestive Heart Failure Database	CHF	PhysioNet	[15]
PTB Diagnostic ECG Database	CHF	PhysioNet	[16]

Table 1: The used Datasets & their Source

Methodology:

CHF Machine learning:

Reading the data set first, then using some feature extractions to extract labels based on time and sample frequency.

Then, using machine learning, classify data using various algorithms and compare them to choose the best one. DT resulted 95.38% accuracy, KNN resulted in 96.33% accuracy, ANN resulted in 98.21% accuracy, SVM resulted in 98.29 % accuracy, and RF resulted in 98.87 % accuracy.

CHF Deep Learning:

Reading the data set and input signals was the first step, followed by feature extraction based on time and sample frequency, and label extraction

Then, using three layers of deep learning CNN model and classify data into normal beats, which indicate a healthy patient, and abnormal beats, which indicate a CHF patient. The data was then splitting into training and test resulted 97.86% accuracy.

AF Machine learning:

Initially, we used three different data sets: one for atrial fibrillation, one for atrial flatter, and one for a normal rhythm. We read the data, then apply some feature extraction to extract labels and save them in a csv file. We then classify the input into two labels, (A)for atrial and (O) for ordinary, and do some preprocessing to remove num values. Split data into training and validation groups, then used machine learning's K-fold algorithm to test the data, resulting 99.31% accuracy .

AF Deep learning:

We do it all over again until the data is classified, at this point we convert it to a numeric float with (one) mean atrial and (zero) mean normal.

Started building deep learning CNN model using 3 layers resulted. 99% same percentage in 10 epoch which cause over fitting, so we use machine learning technique.

Results:

We analyzed the two models to discover which one best fit our dataset because each one generates results either in Machine Learning (ML) or Deep Learning (DL).

- In CHF Machine learning model, we used different algorithms to determine the best algorithm
  - The RF algorithm was the best by accuracy 98.87%
  - The other algorithms accuracy is shown in Table 2, Figure 3.
- In CHF Deep learning model, we used CNN algorithm
  - The CNN algorithm gives accuracy is shown Table3, Figure4.
- AF Machine learning model used k-fold algorithm
  - The K-Fold accuracy is shown in Table 4.
- In AF Deep learning model, we used CNN algorithm
  - The CNN algorithm gives accuracy is shown in Table 5

CHF prediction using ML	
Algorithm	**Accuracy**
Decision Tree (DT)	95.38%
K-Nearest Neighbor (KNN)	96.33%
Artificial Neural Network (ANN)	98.21%
Support Vector Machine (SVM)	98.29%
Random Forest (RF)	98.87%

Table 2

CHF prediction using DL	
Algorithm	**Accuracy**
CNN (3-Layers)	97.86%

Table 3

AF prediction using ML	
Algorithm	**Accuracy**
K-Fold	99.67%

Table 4

AF prediction using DL	
Algorithm	**Accuracy**
CNN(3-layers)	99.31%

Table 5

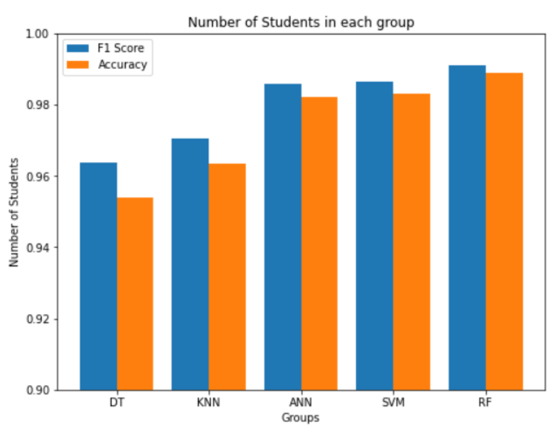

Figure 3: CHF ML Algorithms Accuracy

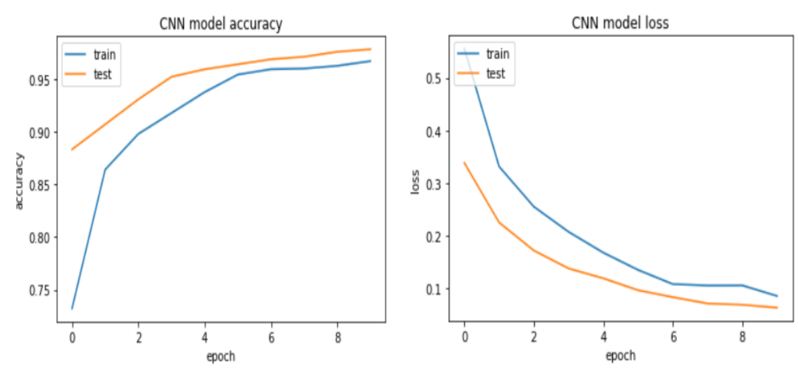

Figure 4: CHF DL Algorithm Accuracy & Loss

- Even if AF Deep Learning (DL) model shows a high accuracy ,But Overfitting appeared Figure 5

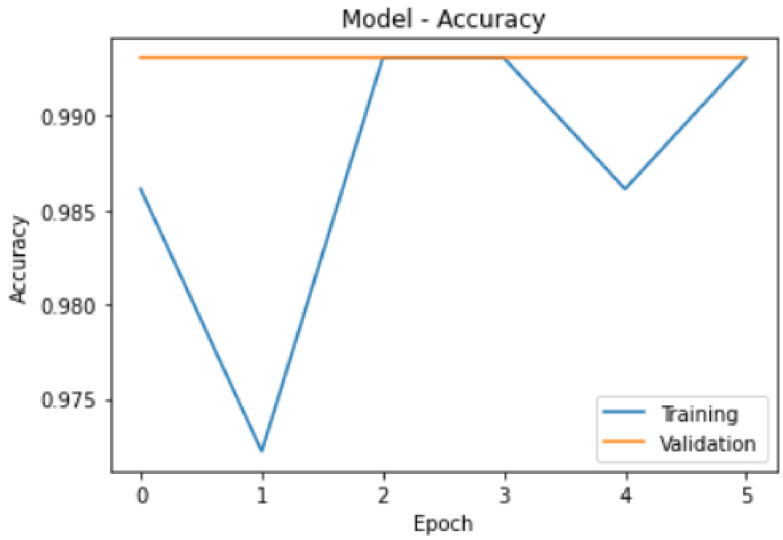

Figure 5 : Overfitting problem appears in AF DL Model

We verified ML Model to predict each of AF and CHF after the appearing of overfitting in DL Model.

Compared to other papers Results we Found that :

Paper	Algorithm	Accuracy
Deep convolutional neural network for the automated diagnosis of congestive heart failure using ECG signals[1]	Deep learning CNN	98.97%
Machine learning based congestive heart failure detection using feature importance ranking of multimodal features[3]	SVM	88.79%
Use of Accumulated Entropies for Automated Detection of Congestive Heart Failure in Flexible AnalyticWavelet Transform Framework Based on Short-Term HRV Signals[5]	LS-SVM	97.7%
Detection of Atrial Fibrillation Using a Machine Learning Approach[6]	SVM Deep learning CNN	87.5%
Machine learning detection of Atrial Fibrillation using wearable technology[8]	SVM	99%
Detection of Atrial Fibrillation Using 1D Convolutional Neural Network[10]	Deep learning CNN	78.2

Table 6 : Result of Related paper with Same Algorithms we used

Conclusion:

An application that predicts atrial fibrillation (AF) and congestive heart failure (CHF), two types of chronic heart disease.

The application is linked to a machine learning model that compares various algorithms of Machine learning such as SVM, DT, RF, ANN, KNN, and K-FOLD and compares them to CNN deep learning

We rely on machine learning algorithms because of overfitting in deep learning. It is also linked to hardware that we created and developed to gather signals from patients in real-time and display the results (Atrial fibrillated patient, Congestive Heart Failure patient, or Normal Healthy patient).

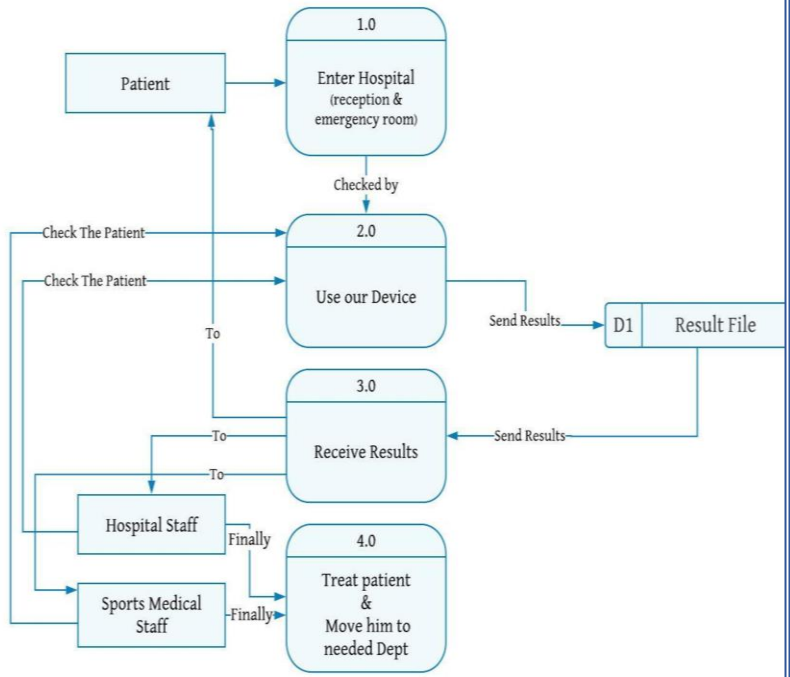

Figure: Data Flow Diagram that summarize our project

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