

AI-DRIVEN DETECTION OF CHRONIC HEART FAILURE VIA HEART SOUND ANALYSIS WITH CHRONIC NET

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ABSTRACT

Chronic heart failure (CHF) is a progressive condition characterized by the heart's inability to pump sufficient blood to meet the metabolic demands of tissues and organs. CHF has reached epidemic proportions, with its incidence increasing by approximately 2% annually. In developed countries, it affects 1–2% of the total population and nearly 10% of individuals over 65 years of age. The diagnosis and management of CHF consume about 2% of the annual healthcare budget; in the United States alone, an estimated 35 billion USD was spent on CHF treatment in 2018, with costs projected to double over the next decade. Despite advancements in medical and device-based therapies, CHF prognosis remains poor, with a five-year survival rate of only 50%. Clinically, CHF alternates between compensated and decompensated phases. During decompensation, symptoms like breathlessness, edema, and pulmonary congestion often necessitate hospitalization for intravenous therapy. Early detection of CHF worsening could allow for timely outpatient interventions and reduce hospital admissions. Traditionally, clinicians detect CHF progression through physical examinations and biomarker assessments. However, these methods often identify the condition only after significant decompensation. Notably, changes in heart sounds, captured through phonocardiography (PCG), can signal CHF progression. This project proposes ChronicNet, an integrated machine learning (ML) and deep learning (DL) model that detects CHF from PCG data using an end-to-end average aggregate recording approach. Extracted features from both ML and DL models are fused to enhance diagnostic accuracy. The performance of ChronicNet is benchmarked against standalone ML and DL models, demonstrating its potential in early CHF detection.

Keywords: Heart Failure, Deep learning, Artificial Intelligence, Heart sound analysis, Chronic net.

1. INTRODUCTION

Chronic Heart Failure (CHF) is a leading cause of morbidity and mortality worldwide, marked by the heart's inability to pump sufficient blood to meet the body's metabolic demands. Early detection of CHF is critical, as timely intervention can significantly improve patient outcomes and reduce healthcare burdens. Traditional diagnostic approaches, including physical examination, imaging, and blood-based biomarkers, often detect the disease only after clinical symptoms have become evident.

Heart sound analysis, through phonocardiography (PCG), offers a non-invasive and accessible method for capturing physiological indicators of cardiac dysfunction. Subtle acoustic variations in heart sounds can reflect underlying abnormalities associated with CHF, making PCG a valuable diagnostic tool when analyzed effectively. With recent advances in artificial intelligence (AI), particularly in machine learning (ML) and deep learning (DL), there is growing potential to automate and enhance the analysis of complex biomedical signals. This research introduces ChronicNet, an AI-driven model that integrates both ML and DL techniques to detect CHF from PCG recordings. By combining the interpretability of ML with the representational power of DL, ChronicNet aims to improve the accuracy and reliability of CHF detection from heart sound data. This work explores the development, training, and evaluation of the ChronicNet model, and demonstrates its potential to support early, efficient, and scalable CHF screening in clinical and remote healthcare settings.

2.LITERATURE SURVEY

Gjoreski, Martin, et al (2020) [1] presented a method for CHF detection based on heart sounds. This method combines classic Machine-Learning (ML) and end-to-end Deep Learning (DL). The classic ML learns from expert features, and the DL learns from a spectro-temporal representation of the signal. This method was evaluated on recordings from 947 subjects from six publicly available datasets and one CHF dataset that was collected for this study. Using the same evaluation method as a recent PhysoNet challenge, the proposed method achieved a score of 89.3, which is 9.1 higher than the challenge's baseline method. This method's aggregated accuracy is 92.9% (error of 7.1%); while the experimental results are not directly comparable, this error rate is relatively close to the percentage of recordings labeled as “unknown” by experts (9.7%). Finally, we identified 15 expert features that are useful for building ML models to differentiate between CHF phases (i.e., in the decompensated phase during hospitalization and in the recompensated phase) with an accuracy of 93.2%. The proposed method shows promising results both for the distinction of recordings between healthy subjects and patients and for the detection of different CHF phases.

Gahane, Aroh, and Chinnaiah Kotadi(2022) [2] investigated different approaches for detecting CHF based on the heart sounds produced by the patient. The perception of heart rate, as well as the relationship between heart sounds and cardiovascular disease, are important considerations. The basic techniques used in the processing and interpretation of cardiac signals seem to be de-noising, categorization, extraction, feature extraction, and classification, among others. Because of the emphasis on the usage of Machine Learning (ML) algorithms for analysing heart sounds, classic Machine-Learning (ML) technologies are merged with IoT end-to-end technologies, and both are integrated with a wide range of defined techniques. The primary goal is to examine the many technologies that are comprised of the internet of things that are used to forecast heart attack disease and how they are used. It is not only to explain the existing heart attack prediction, but also to address the aware and monitoring system for the patient who is likely to be suffering from cardiovascular illness.

Shuvo, Samiul Based, et al (2021) [3] proposed CardioXNet, a novel lightweight end-to-end CRNN architecture for automatic detection of five classes of cardiac auscultation namely normal, aortic stenosis, mitral stenosis, mitral regurgitation and mitral valve prolapse using raw PCG signal. The process has been automated by the involvement of two learning phases namely, representation learning and sequence residual learning. Three parallel CNN pathways have been implemented in the representation learning phase to learn the coarse and fine-grained features from the PCG and to explore the salient features from variable receptive fields involving 2D-CNN based squeeze-expansion. Thus, in the representation learning phase, the network extracts efficient time-invariant features and converges with great rapidity. It outperforms any previous works using the same database by a considerable margin. Moreover, the proposed model was tested on PhysioNet/CinC 2016 challenge dataset achieving an accuracy of 86.57%. Finally the model was evaluated on a merged dataset of Github PCG dataset and PhysioNet dataset achieving excellent accuracy of 88.09%. The high accuracy metrics on both primary and secondary dataset combined with a significantly low number of parameters and end-to-end prediction approach makes the proposed network especially suitable for point of care CVD screening in low resource setups using memory constraint mobile devices.

Li, Suyi, et al(2020) [4]. detected techniques play an important role in the prediction of cardiovascular diseases. The latest development of the computer-aided heart sound detection techniques over the last five years has been reviewed. There are mainly the following aspects: the theories of heart sounds and the relationship between heart sounds and cardiovascular diseases; the key technologies used in the processing and analysis of heart sound signals, including denoising, segmentation, feature extraction

and classification; with emphasis, the applications of deep learning algorithm in heart sound processing. In the end, some areas for future research in computer-aided heart sound detection techniques are explored, hoping to provide reference to the prediction of cardiovascular diseases.

Miotto, Riccardo, et al.(2018) [5] provided new effective paradigms to obtain end-to-end learning models from complex data. They reviewed the recent literature on applying deep learning technologies to advance the health care domain. Based on the analyzed work, we suggest that deep learning approaches could be the vehicle for translating big biomedical data into improved human health. However, they also note limitations and needs for improved methods development and applications, especially in terms of ease-of-understanding for domain experts and citizen scientists. They discuss such challenges and suggest developing holistic and meaningful interpretable architectures to bridge deep learning models and human interpretability.

Allugunti, Viswanatha Reddy[6] provided an efficient answer to the problem of making decisions and accurate forecasts. This application of machine learning strategies is making significant headway in the medical sector. They presented, a unique technique to machine learning is proposed for the purpose of predicting cardiac disease. The PhysioNet Dataset was utilised for the study that was proposed, and data mining algorithms like regression and classification were utilised. Support Vector Machine, Decision Tree and Random Forest are both the machine learning approaches that are utilised here. The cutting-edge strategy for the machine learning model has been devised. Support Vector Machine, Random Forest, Decision Tree, and the Hybrid model (Hybrid of SVM, RF and DT) are the four types of machine learning algorithms that are utilised in the implementation process. The accuracy level of the heart disease prediction model using the hybrid model was found to be 88.7 percent based on the results of the experiments. The user's input parameter will be utilised to predict heart illness, which will be done with a model that is a hybrid of Decision Tree and Random Forest. This interface is built to acquire the user's input parameter.

Zubair, Muhammad(2021) [7] detected sounds S1 and S2, the features like envelopograms, Mel frequency cepstral coefficients (MFCC), kurtosis, etc., of these sounds are extracted. These features are used for the classification of normal and abnormal heart sounds, which leads to an increase in computational complexity. They had proposed a fully automated algorithm to localize heart sounds using K-means clustering. The K-means clustering model can differentiate between the primitive heart sounds like S1, S2, S3, S4 and the rest of the insignificant sounds like murmurs without requiring the excessive pre-processing of data. The peaks detected from the noisy data are validated by implementing five classification models with 30 fold cross-validation. These models have been implemented on a publicly available PhysioNet/Cinc challenge 2016 database. Lastly, to classify between normal and abnormal heart sounds, the localized labelled peaks from all the datasets were fed as an input to the various classifiers such as support vector machine (SVM), K-nearest neighbours (KNN)

Valera, HH Alvarez, and M. Luštrek (2022) [8] investigated chronic heart failure (HF) diagnosis with the application of machine learning (ML) approaches. They simulated the procedure that is followed in clinical practice, as the models they built are based on various combinations of feature categories, e.g., clinical features, echocardiogram, and laboratory findings. We also investigated the incremental value of each feature type. The total number of subjects utilized was 422. An ML approach is proposed, comprising of feature selection, handling class imbalance, and classification steps. The results for HF diagnosis were quite satisfactory with a high accuracy (91.23%), sensitivity (93.83%), and specificity (89.62%) when features from all categories were utilized. The results remained quite high, even in cases where single feature types were employed.

Ravi, Rohit, and P. Madhavan (2022) [9] investigated using different algorithms to fetch out precise information for various domains. Across the world approximately 3 quintillion bytes/day information generated and this data stored for further examination. As data is in huge quantity therefore, appropriate methods applied to examine the perfect analysis so that prediction can be carried out optimally. Clinical decision making is dominant to all patient care happenings which includes choosing a deed, between replacements. These days emerging field like Machine Learning play prime role in healthcare to analyze and predict the diseases. After investigating numerous research article on Machine Learning, it was found that for same data set accuracy was different for various algorithms.

Susic, D., Gregor Poglajen, and Anton Gradišek.(2022) [10] implemented medical therapy which would in turn prevent the development of more severe heart failure decompensation thus avoiding the need for heart failure-related hospitalizations. Currently, heart failure worsening is recognized by the clinicians through characteristic changes of heart failure- related symptoms and signs, including the changes in heart sounds. The latter has proven to be largely unreliable as its interpretation is highly subjective and dependent on the clinicians' skills and preferences. Previous studies have indicated that the algorithms of artificial intelligence are promising in distinguishing the heart sounds of heart failure patients from those of healthy individuals.They focussed on the analysis of heart sounds of chronic heart failure patients in their decompensated and recompensated phase. The data was recorded on 37 patients using two types of electronic stethoscopes. Using a combination of machine learning approaches, we obtained up to 72% classification accuracy between the two phases, which is better than the accuracy of the interpretation by cardiologists, which reached 50%. Their results demonstrate that machine learning algorithms are promising in improving early detection of heart failure decompensation episodes.

3.PROPOSED METHODOLOGY

Chronic heart failure (CHF) is a serious condition that requires early detection and treatment to prevent its progression. One way to detect CHF is by analyzing the phonocardiogram (PCG) sounds using machine learning techniques. Fig. 1 shows the proposed block diagram.

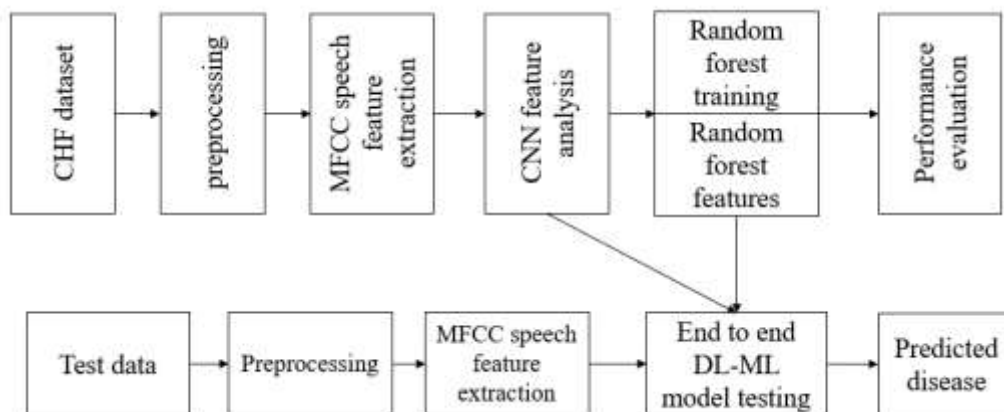


Fig. 1: Proposed block diagram.

3.1 CNN

A Convolutional Neural Network (CNN) is a type of deep learning model that is especially effective for analyzing data with a grid-like structure, such as images or time-series signals. It automatically detects important features from raw data by applying filters (also called kernels) that scan across the input to capture patterns like edges, textures, or shapes. In each layer, CNNs learn to recognize more complex features by combining information from previous layers. This makes them highly effective for

tasks like image classification, object detection, and signal analysis. In medical applications, CNNs are often used to analyze data like heart sounds, ECGs, or medical images, helping to detect diseases such as chronic heart failure by identifying subtle patterns that may not be visible to the human eye.

3.2 RANDOM FOREST

Random Forest is a popular machine learning algorithm used for both classification and regression tasks. It works by creating an ensemble (a collection) of decision trees, where each tree is trained on a random subset of the data.

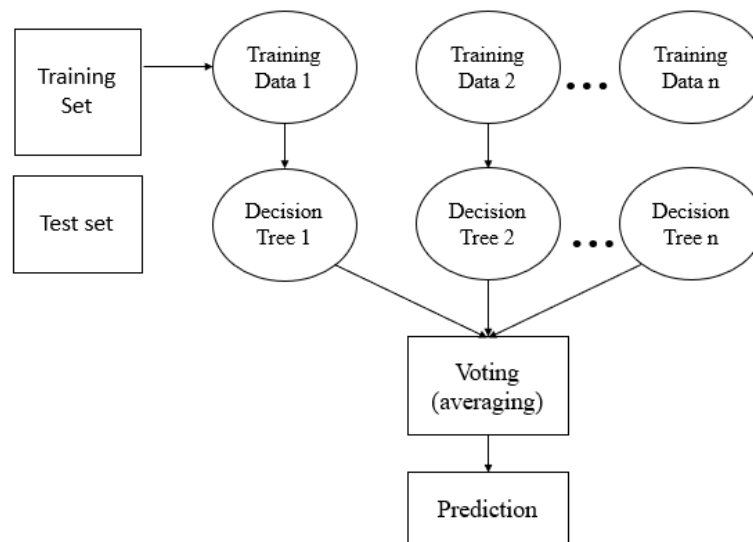


Fig. 2: Random forest algorithm.

During prediction, each tree gives a result, and the final output is based on the majority vote (for classification) or average (for regression) of all the trees. This approach helps improve accuracy and reduces the risk of overfitting that can occur with a single decision tree. Random Forest is known for its high performance, ability to handle large datasets, and robustness to noise. In medical applications, it is often used to classify patient data, such as identifying whether heart sound features indicate chronic heart failure or not.

4.RESULTS AND DISCUSSION

In fig. 3 we can see dataset contains 405 heart sound files from 405 different person and 117 are the Normal sound and 288 are abnormal and in graph x-axis represents normal or abnormal and y-axis represents number of persons for normal or abnormal. Now close above graph and then click on 'ML Segmented Model with FE & FS' button to train Classic ML segmented model on above dataset and get below output.

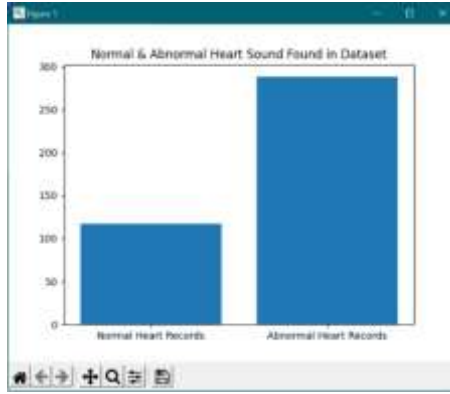


Fig. 3: Count plot for count of each label.

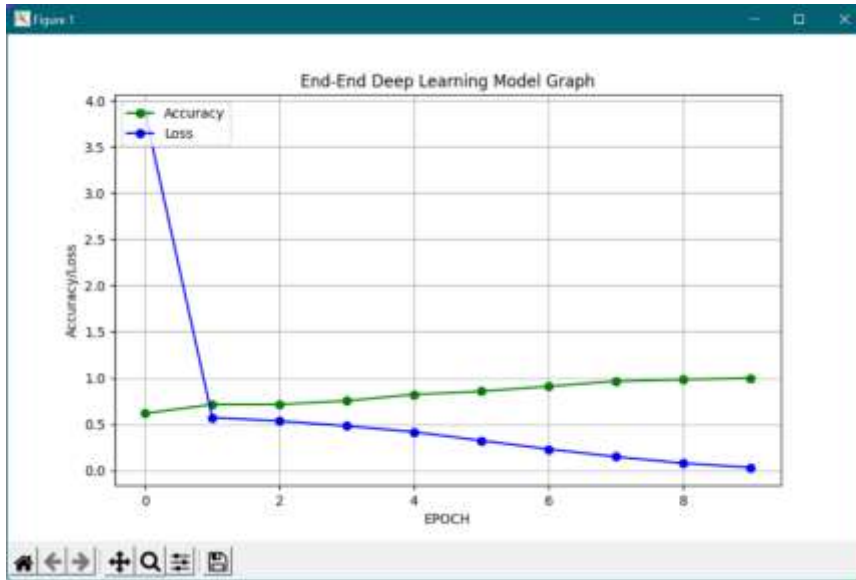


Fig. 4: Performance evaluation of CNN model per epoch.

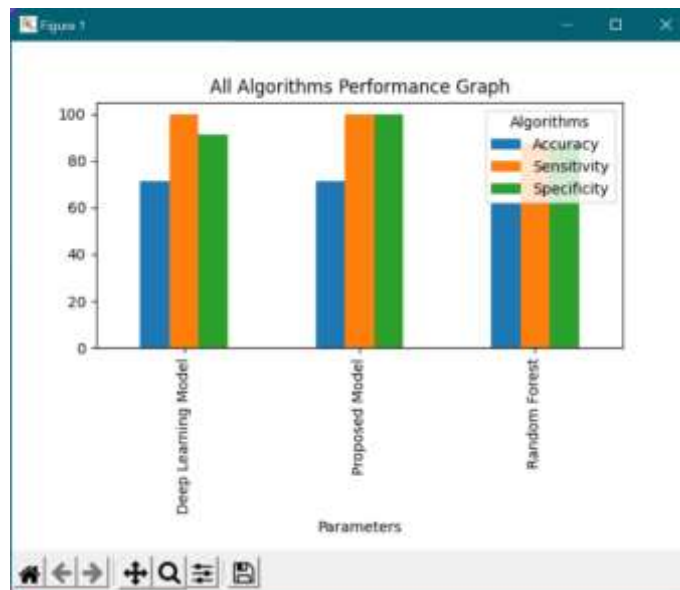


Fig. 5: Displays the performance evaluation comparison of all models.

In Fig.4 DL model, we got 93.9% accuracy and in graph x-axis represents epoch or iterations and y-axis represents accuracy or loss values, and green line represents accuracy and blue line represents LOSS and we can see with each increasing epoch accuracy got increase and loss got decrease. In Fig.4 x-axis represents algorithm names and y-axis represents accuracy, sensitivity and specificity and in all algorithm's proposed model has got high accuracy.

5.CONCLUSION

The development of ChronicNet represents a significant advancement in the early detection of chronic heart failure (CHF) through the integration of machine learning (ML) and deep learning (DL) models applied to phonocardiography (PCG) data. By leveraging the latest advancements in artificial intelligence, ChronicNet offers a promising solution for identifying subtle changes in heart sounds indicative of CHF deterioration, enabling timely intervention and improved patient management.

Comprehensive evaluation and comparison with individual ML and DL models have demonstrated the superior performance of ChronicNet, underscoring the effectiveness of the integrated approach. By harnessing the complementary strengths of ML and DL techniques, ChronicNet achieves greater accuracy and reliability in detecting CHF exacerbations, thereby reducing the risk of hospital admissions and enhancing the overall quality of patient care.

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