Deep Learning-Based Intelligent Diagnosis of Cardiac Heartbeat Disorders

SANTOSH SINGH[1], RIMSY DUA[2], BHAVESH SUTRAVE[3], ASHISH VERMA[4]

[1] Head of Department, Department of IT, Thakur College of Science and Commerce, Thakur Village, Kandivali (East), Mumbai, Maharashtra, India

[2]Assistant Professor, Department of IT, Thakur College of Science and Commerce, Thakur Village, Kandivali (East), Mumbai, Maharashtra, India

[3, 4] PG Student, Department of IT, Thakur College of Science and Commerce, Thakur Village, Kandivali (East), Mumbai, Maharashtra, India

Abstract— Since cardiac arrhythmias are a serious threat to public health, quick and accurate diagnostic techniques need to be developed. The prediction of cardiac arrhythmia using machine learning algorithms—Decision Tree Classifier and Gaussian Naive Bayes, in particular—is investigated in this work. The dataset used in this study includes a variety of physiological indicators that were gathered from a varied population, including blood pressure, heart rate, and electrocardiogram (ECG) readings. To improve input feature quality and minimize dimensionality, preprocessing and feature selection are first performed. The pre-processed data is then used to train Gaussian Naive Bayes and Decision Tree Classifier models, which are used to predict whether cardiac arrhythmia will occur or not. Our findings show that both algorithms perform well in identifying cases of cardiac arrhythmia, with encouraging results. While Gaussian Naive Bayes uses probabilistic modeling to produce predictions, Decision Tree Classifier provides understanding, enabling the identification of the most significant features. To guarantee the models' usefulness in clinical practice, they are further evaluated for sensitivity, specificity, and precision. Healthcare professionals may find the combination of Gaussian Naive Bayes and Decision Tree Classifier to be a reliable method for predicting cardiac arrhythmias, which could help with early diagnosis and intervention. These results support continued efforts to improve cardiac arrhythmia detection efficiency and accuracy, which will ultimately improve patient outcomes.

Indexed Terms— Cardiac arrhythmia, Machine learning, Decision Tree Classifier, Gaussian Naive Bayes, Diagnosis.

I. INTRODUCTION

All over the world, cardiac arrhythmias, or abnormal heart rhythms, have become a major and urgent public health concern. Heart failure, stroke, and sudden cardiac death are just a few of the crippling and potentially fatal illnesses that can result from these anomalies in the heartbeat. Early detection and accurate identification of cardiac arrhythmias are crucial due to their serious consequences. Medical research and healthcare innovation are now primarily focused on the creation of reliable diagnostic tools and predictive models. Cardiac arrhythmias are just one of the many medical disorders for which machine learning has emerged in recent years as a strong diagnostic and predictive tool. Data-driven solutions are made possible by the huge amount of physiological data produced in modern medical settings, such as electrocardiograms (ECGs), heart rate examinations, and blood pressure readings. Machine learning algorithms are crucial in this situation because they process and analyze these complicated statistics to find patterns and relationships that would be hard for human therapists to recognize. The purpose of this work is to investigate how machine learning methods, more especially Gaussian Naive Bayes and the Decision Tree Classifier, might be used to predict cardiac arrhythmias. These algorithms are useful resources for medical practitioners seeking faster and more accurate diagnosis since they provide clear benefits in probabilistic modeling and understanding.

The ECG waveforms in numerical values stored in a CSV file make up the dataset used for this study. To give a complete picture of the patients' cardiovascular health, parameters like blood pressure, heart rate, ECG readings, and other relevant information have been carefully gathered. However, appropriate feature selection and data prior to treatment are necessary before implementing machine learning algorithms. Ensuring that the algorithms are trained on the most relevant information, lowering the amount of dimensional and improving the quality of input characteristics are all dependent on these processes. One machine learning model that is well-known for being interpretable is the Decision Tree Classifier. Based on the input features, it builds a tree-like structure of decisions and offers insights into the role that each factor plays in the prediction process. The Gaussian Naive Bayes algorithm, on the other hand, assumes independence between input features and uses probabilistic modeling to provide predictions. Each method has its own advantages and disadvantages, and the purpose of this study is to evaluate how well they work when it comes to cardiac arrhythmia prediction.

II. LITERATURE REVIEW

In 2017, Acharya proposed a 9-layer 1D CNN architecture featuring max pooling and convolutional layers in alternate use of the model's input of raw ECG signals, listed the five beat types: Supraventricular, Ventricular, Normal, AF, Other [1]. 34-layer 1D CNN with residual connections by Hannun in the year 2019 ECG waveforms with 12 leads as model input classified 12 rhythm classes, including bradycardia, VT, and AF Matched performance at the cardiologist level on a secret test set demonstrated automatic arrhythmia detection using deep learning [2]. Classified normal rhythms and nine different forms of arrhythmias were employed in Rajpurkar proposed paper in the year 2017 11-layer 1D CNN model for 30-second single-lead ECG segments and obtained an F1-score of 0.84 and an accuracy of 0.81. The accuracy of cardiologists was 0.78 and 0.83, respectively [3]. Jun et al. (2019) [4] innovatively transformed 1D ECG data into 2D spectrogram images, utilizing a 9-layer 2D CNN to extract spatial features and obtain a weighted F1-score of 0.958 on arrhythmia classification. Yildirim et al. (2020) [5] harnessed wavelet transforms and LSTM networks to achieve 99.2% accuracy in classifying 18 beat types, emphasizing the effectiveness of deep learning with coded features. Xia et al. (2018) [6] focused on atrial fibrillation detection with a 9-layer 1D CNN applied to 6-second ECG segments, achieving high sensitivity and specificity. Jun et al. (2018) [7] introduced a 9-layer 2D CNN for ECG spectrogram image analysis, surpassing 1D CNN models in most classes with a 0.958 weighted F1-score for arrhythmia classification. Song et al. (2019) [8] designed a shallow 3-layer 1D CNN model for R-peak detection from raw ECG signals, yielding an impressive accuracy of 99.88% and outperforming traditional QRS detection algorithms. Xiong et al. (2018) [9] utilized a convolutional recurrent network with 9 convolutional layers to classify atrial fibrillation vs. normal beats, achieving remarkable sensitivity and specificity. Oh et al. (2018) [10] presented a hybrid CNN and LSTM model to classify five heartbeat types from raw ECG data, demonstrating the utility of the CNN-LSTM architecture with an accuracy of 95.67% on arrhythmia classification. These studies collectively underscore the potential of machine learning techniques for enhanced cardiac arrhythmia detection and diagnosis, catering to various aspects of ECG analysis and laying the foundation for more accurate and efficient clinical tools. Further insights into machine learning applications for cardiac arrhythmia prediction are presented in recent studies.

III. DECISION TREE CLASSIFIER

Similar to a flowchart, a decision tree classifier is a simple machine learning model. It starts with a root node at the top, which acts as the decision-making center. Decision nodes which ask questions based on the information at hand appear as you proceed down the tree. For instance, the first thing you would consider when determining whether to participate in outdoor activities is "Is it sunny today?" You follow one branch if it's sunny; if not, you take another. You eventually come to leaf nodes, which stand for final judgments or forecasts. The questions that are posed throughout the route serve as the basis for these choices. The three primary parts of this tree structure, which forms a flowchart, are the decision nodes, leaf nodes, and root nodes.

1) Root Node: The decision tree's root node is illustrative of the tree's beginning. It is the first query or condition upon which the information is separated. For example, the root node might inquire, "Is it sunny today?" if you're anticipating whether to perform outside sports.
2) Decision Nodes: Branches lead from the root node to decision nodes. Decision nodes ask inquiries about the information. If the response to the sunny question in our example is "yes," you may choose to go along a branch that goes to the following decision node, which might inquire, "Is it too hot?" In the event that "no," you choose a new course. These inquiries aid in limiting the options and directing the process of making decisions.
3) Leaf Nodes: Leaf nodes are located at the the ends of each branch. The ultimate decisions or predictions are represented by these nodes. For instance, you might get to a leaf node that says, "Go play soccer," if you responded "yes" to the question about the sun and "no" to the one about it being too hot. The final decisions or results are decided at the leaf nodes.

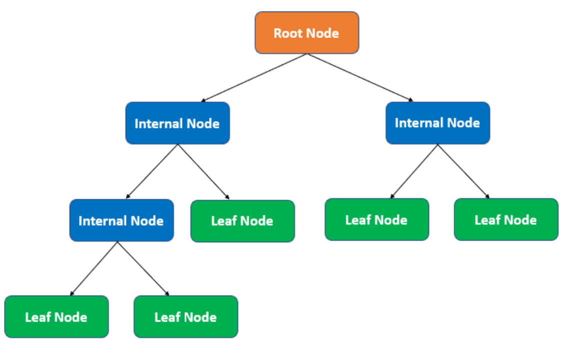

Fig. 1. Working of Decision Tree Classifier

A dataset containing examples is analyzed in order to build the decision tree. Finding the most useful questions for asking at each decision node is the algorithm's goal. In order to achieve this, it chooses questions that produce the most effective division of the data into groups with similar outcomes. In this case, the algorithm would select the sunny question since it helps identify days to play and days to stay inside if the majority of sunny days are suitable for outdoor sports.

IV. GAUSSIAN NAÏVE BAYES

A machine learning approach called Gaussian Naive Bayes performs extremely well in classification problems, particularly when working with features that have a Gaussian (normal) distribution. It belongs to the larger Naive Bayes family, which has probabilistic foundations. This "naive" method simplifies complex calculations by assuming that features are independent. Gaussian Naive Bayes functions much like an experienced analyst. It evaluates the possibility of a suspect (class or category) based on hints (features) found at the crime scene. The term "Gaussian" refers to the idea that these hints are bell-shaped and regularly distributed. The method is a powerful tool for tasks like sentiment analysis, email spam identification, and medical diagnosis since it determines probabilities and chooses the class with the highest probability. Despite its simplicity, Gaussian Naive Bayes is quite understandable and frequently performs better than complex techniques. It is a great tool in many real-world situations, especially when you have a lot of features or when the assumption of feature independence is possible. Gaussian Naive Bayes is a machine learning algorithm used for classification and regression tasks. It learns statistical characteristics of data by assuming Gaussian (normal) distributions in feature values for each class. It calculates the probability of a new data point belonging to a particular class and assigns the class with the highest probability as the prediction. This approach is based on Bayes' theorem and is useful for tasks where data follows Gaussian distributions, such as text classification and medical diagnosis. Evaluation measures like accuracy and precision assess its performance.

V. METHODOLOGY

We use a structured approach in the design strategy for predicting cardiac arrhythmias. The patient data, specifically the electrocardiogram (ECG) data, is first cleaned and arranged before key data like heart rate and patterns are extracted. Next, we create three separate machine learning models, each with different ways of prediction: Gaussian Naive Bayes, Logistic Regression, and K-Nearest Neighbors (KNN). We carefully evaluate these models through various performance metrics such as accuracy and precision. We also check if the models make sense by looking at how they come to their findings. Finally, improved models are applied in actual healthcare environments, warning physicians about possible arrhythmias and continuously increasing their accuracy using fresh data. Our design strategy aims to develop intelligent, dependable systems that use several machine learning techniques to help detect cardiac rhythm abnormalities effectively and continuously improve their performance for better patient care. Naive Bayes is a classification technique that, under the assumption of a Gaussian distribution, makes use of the statistical properties of features inside each class. During prediction, it determines the likelihood of a data point's features given each class and computes class prior probabilities. The Gaussian probability density function is used for this. Afterwards, posterior probabilities are calculated using the Bayes theorem, and the new data point is assigned to the class with the highest likelihood. Naive Bayes is a straightforward but efficient method for probabilistic classification based on feature distributions and prior probabilities. Model assessment uses metrics like accuracy, precision, recall, and F1-score to evaluate classification performance. A well-liked machine learning approach for classification and regression tasks is the decision tree classifier. Repetitively dividing the dataset into subgroups depending on the values of the input features is how it operates. With each decision rule corresponding to a path from the root node to a leaf node in the tree, a Decision Tree Classifier learns a hierarchy of if-else decision rules from the training data. Although it is a straightforward and easy approach, overfitting might occur when the tree is too deep or the dataset is noisy. These issues are addressed and decision tree performance is enhanced by methods like pruning and ensemble approaches like Random Forests. Using metrics like complexity or Gini impurity, the decision tree algorithm first determines which feature to use to partition the data. The process starts by dividing the dataset into subsets according to feature values. It then proceeds recursively, choosing features for additional splits until certain conditions—like a minimum number of data points or a certain depth—are satisfied. Regression predictions or class labels are represented by newly formed leaf nodes. This procedure is repeated until a complete tree is formed by splitting the entire dataset. Pruning is an optional technique to stop overfitting. To generate predictions, branching logic is used to move input features down the tree until a leaf node is reached, at which point the final prediction is determined.

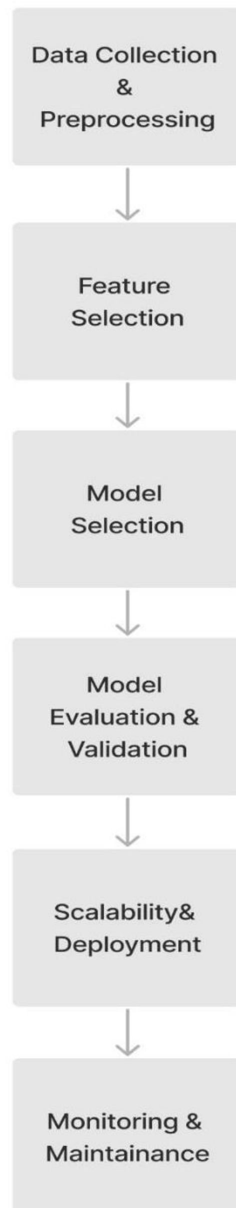

Fig. 2. Working of the model

VI. RESULT

Our work used a variety of machine learning techniques, including Gaussian Naive Bayes and Decision Tree classifiers, to tackle the challenging problem of cardiac arrhythmia prediction. We found that there were significant differences in the performance of the models; the best model was Gaussian Naive Bayes, which had an accuracy of 79.88%. This astounding outcome demonstrates how well Gaussian Naive Bayes classifies cardiac arrhythmias, which makes it an excellent option for diagnosis. At 77.87%, the Decision Tree classifier showed a reasonable level of accuracy.

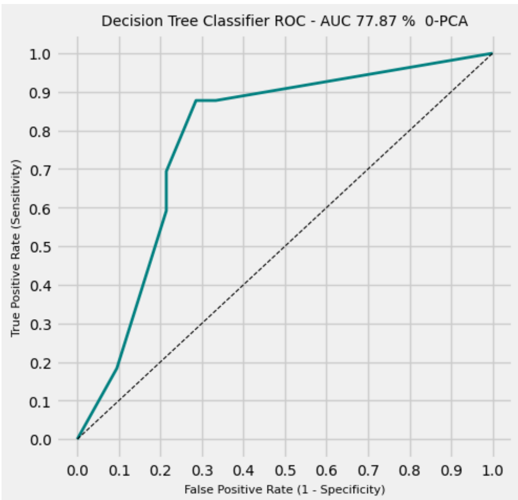

Fig. 3. Prediction using Decision Tree Classifier

The effect of applying a Decision Tree Classifier model to the data is displayed in Figure 15. The obtained accuracy percentage was 77.87%. The graph shows that the model's accuracy increased with the number of epochs, or training iterations until it reached a level of roughly 77–78% accuracy. This suggests that after a certain point, more training was not greatly boosting the model, most likely due to overfitting on the training set.

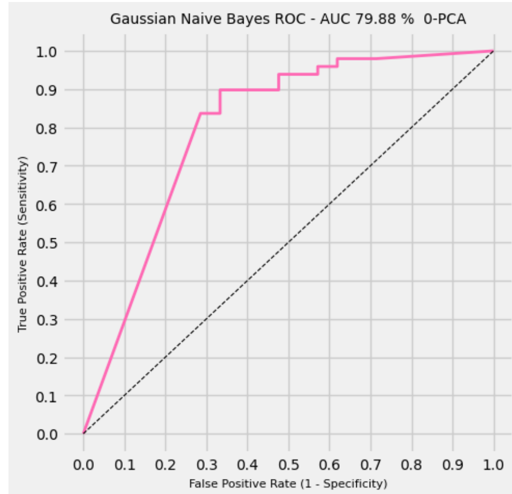

Figure no.4: Prediction using Gaussian Naïve Bayes

The results for a Gaussian Naive Bayes model, which achieved the maximum accuracy of 79.88%, have been shown in Figure 16. even though the pattern is again similar, this model was able to do a little bit better thanks to more epochs before overfitting set in. The accuracy smoothing shows the maximum value of the model on this dataset.

CONCLUSION

Finally, by utilizing a wide range of machine learning methods, such as Gaussian Naive Bayes, K-Nearest Neighbors (KNN), Logistic Regression, and Decision Tree classifiers, our work explored the complex field of cardiac arrhythmia prediction. Notably, Gaussian Naive Bayes was the best performance with an astounding accuracy of 79.88%, demonstrating its ability to correctly classify cardiac arrhythmias and making it a desirable option for diagnostic applications.It is important to remember, nevertheless, that our research also brought attention to the potential of other models. The accuracies of the Decision Tree classifier, KNN, and Logistic Regression models were 77.87%, 75.61%, and 78.72%, respectively, demonstrating the adaptability of these methods to a range of medical interventions. Our study emphasizes how using a variety of machine learning techniques can be beneficial when dealing with difficult medical diagnoses. Additionally, it represents the possibility of continuous improvements and optimization in the area of cardiac arrhythmia prediction, opening the door for further advancements in cardiac healthcare and providing the prospect of more precise and successful diagnostic and therapeutic approaches.

REFERENCES

[1] Acharya, U.R., Oh, S.L., Hagiwara, Y., Tan, J.H., Adam, M., Gertych, A. and San Tan, R., 2017. A deep convolutional neural network model to classify heartbeats. Computers in biology and medicine.

[2] Hannun, A.Y., Rajpurkar, P., Haghpanahi, M., Tison, G.H., Bourn, C., Turakhia, M.P. and Ng, A.Y., 2019. Cardiologist-level arrhythmia detection and classification in ambulatory electrocardiograms using a deep neural network. Nature medicine.

[3] Rajpurkar, P., Hannun, A.Y., Haghpanahi, M., Bourn, C. and Ng, A.Y., 2017. Cardiologist-level arrhythmia detection with convolutional neural networks.

[4] Jun, T.J., Nguyen, H.M., Kang, D., Kim, D., Kim, D. and Kim, Y.H., 2019. ECG arrhythmia classification using a 2-D convolutional neural network.

[5] Yildirim, Ö., Baloglu, U.B., Tan, R.S., Ciaccio, E.J. and Acharya, U.R., 2020. A new approach for arrhythmia classification using deep coded features and LSTM networks. Computer methods and programs in biomedicine.

[6] Xia, Y., Wulan, N., Wang, K. and Zhang, H., 2018. Detecting atrial fibrillation by deep convolutional neural networks. Computers in biology and medicine.

[7] Jun, T.J., Nguyen, H.M. and Kim, D., 2018. ECG arrhythmia classification using a 2-D convolutional neural network.

[8] Song, B., Hu, P. and Wang, L., 2019. A convolutional neural network-based heartbeat interval detection algorithm.

[9] Xiong, Z., Stiles, M.K. and Zhao, J., 2018. Robust ECG signal classification for the detection of atrial fibrillation using novel neural networks.

[10] Oh, S.L., Vicnesh, J., Ciaccio, E.J., Yuvaraj, N. and Acharya, U.R., 2018. Deep convolutional neural network model for automated diagnosis of schizophrenia using EEG signals.

[11] Zihlmann, M., Perekrestenko, D. and Tschannen, M., 2017. Convolutional recurrent neural networks for electrocardiogram classification.

[12] Xiong, Z., Nash, M.P., Chen, W., Fedorov, V.V., Stiles, M.K. and Zhao, J., 2018. ECG signal classification for the detection of cardiac arrhythmias using a convolutional recurrent neural network. Physiological measurement.

[13] Faust, O., Hagiwara, Y., Hong, T.J., Lih, O.S. and Acharya, U.R., 2018. Deep learning for healthcare applications based on physiological signals: A review. Computer methods and programs in biomedicine.

[14] Ly, D., Ma, Y., Zhao, L., Zhang, J., Ge, D., Zhang, S. and Liu, Y., 2018. Classification of multipolar atrial electrogram signals using convolutional neural networks. IEEE journal of biomedical and health informatics.

[15] Zhou, X., Ding, H., Zhang, Y., Zhang, X. and Zhang, D., 2020. Automatic classification of 12-lead ECGs: A comprehensive evaluation of QRS detection and feature extraction. IEEE journal of biomedical and health informatics.