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Heart Attack Detection Using Machine Learning

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Abstract

The primary goal of this work is to leverage machine learning algorithms to detect heart attacks in patients. Cardiovascular diseases (CVDs), including heart-related conditions, have become the leading cause of death globally in recent decades. The prevalence of these diseases poses a significant health threat, not only in India but across the world. The ability to accurately predict and detect heart attacks through advanced machine learning techniques could significantly improve early diagnosis, enabling timely interventions and reducing mortality rates associated with heart conditions. There is an urgent requirement for a dependable, precise, and practical diagnostic system that can promptly identify these diseases to facilitate appropriate treatment. To mitigate the high mortality rate associated with heart diseases, it is imperative to discover quick and efficient detection techniques. Several data mining and machine learning techniques, such as Logistic Regression Algorithm, Random Forest, ensemble learning methods and Decision tree are employed to detect heart attack.

Keywords: Cardiovascular Diseases, Machine Learning, Deep Neural Network.

1. Introduction

Heart failure diseases have become a global health concern, surpassing many autoimmune conditions in terms of prevalence. Cardiovascular diseases (CVDs) involve disorders that affect the heart and disrupt normal blood flow through the blood vessels. These diseases include a variety of chronic conditions, such as heart attacks, strokes, congestive heart failure, and other related pathologies. CVDs often arise when the heart is unable to pump blood efficiently, leading to complications like high blood pressure, diabetes, chest pain, and other cardiac issues. Typically, hospitals rely on standard diagnostic tools like electrocardiograms (ECGs) to assess the condition and severity of these diseases. While more advanced technologies such as magneto cardiograms (MCGs) can detect these conditions at earlier stages, they are often prohibitively expensive and impractical for smaller healthcare settings. Additionally, these tools can be time-consuming and susceptible to interference from various external factors. An automated system capable of performing heart disease tests and providing early warnings for CVD risks could be highly beneficial for both technicians and clinicians, making early diagnosis more accessible and efficient.
Heart disease prediction can be enhanced by combining various factors such as preexisting health conditions, age, chest pain intensity, blood test results, and other relevant variables. By integrating

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these well-defined parameters, machine learning technologies offer a powerful, data-driven approach to predicting heart attacks. With the growth of data science, computational models can effectively analyze these diverse factors, enabling more accurate detection of heart-related issues and improving early diagnosis and treatment strategies. Early detection of attack using a prediction model can be recommended for a fatality rate reduction, and decision- making is improved for further treatment and prevention.

This work deals with the early detection of heart attack with the help of various machine learning classifiers.

Electrocardiogram (ECG)

Electrocardiography (ECG or EKG) is a fundamental diagnostic tool used in cardiology to monitor the heart's electrical activity. This test records the electrical impulses generated by the heart, which regulate its mechanical function, offering crucial insights into its health. Typically, ECG examinations are non-invasive, involving electrodes placed on the skin to detect electrical signals. However, in certain situations, ECGs can also be measured from the heart's surface or the oesophagus.

As the electrical activity of the heart plays a critical role in its mechanical pumping action, the ECG is invaluable for diagnosing a wide range of heart diseases. The procedure involves placing temporary electrodes on the chest and limbs to track the heart's electrical activity, which controls its rhythm. This information is then translated into a wave pattern that can be interpreted by a healthcare provider. ECGs are quick, non-invasive, and painless, typically conducted while the patient is lying down and relaxed. The result of this test is a graph displaying voltage versus time, known as the electrocardiogram.

The ECG is important for several reasons:

- It helps to confirm the diagnosis of a heart attack.
- It aids in determining the type of heart attack, which is critical for deciding on the most appropriate treatment.

A standard 12-lead ECG involves placing ten electrodes on the patient's limbs and chest. These electrodes record the electrical activity from twelve different angles or "leads" and display the heart's electrical depolarization throughout the cardiac cycle, typically over ten seconds. This allows healthcare providers to understand the heart's electrical magnitude and direction at each moment.

There are three key components in an ECG:

1. ***P Wave:*** This wave represents the depolarization of both the left and right atria and corresponds to atrial contraction. Atrial repolarization, however, is too small to be visible in most cases. Typically, the P wave appears smooth and rounded, no taller than 2.5 mm and lasting no longer than 0.11 seconds.
2. ***QRS Complex:*** This complex consists of the Q, R, and S waves, which occur quickly in succession. It reflects the spread of the electrical impulse through the ventricles, marking ventricular depolarization. The QRS complex starts just before the ventricles contract. Not every QRS complex includes all three waves; for example, a complex with only an upward (positive) deflection is labelled an R wave. The duration of the QRS complex in a healthy adult is typically between 0.06 and 0.10 seconds.

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3. ***T Wave:*** The T wave follows the QRS complex and indicates ventricular repolarization. It is slightly asymmetric, with the peak closer to the end of the wave. Usually, the T wave follows the same direction as the preceding QRS complex (positive or negative). If the T wave is in the opposite direction, it may indicate a cardiac abnormality.

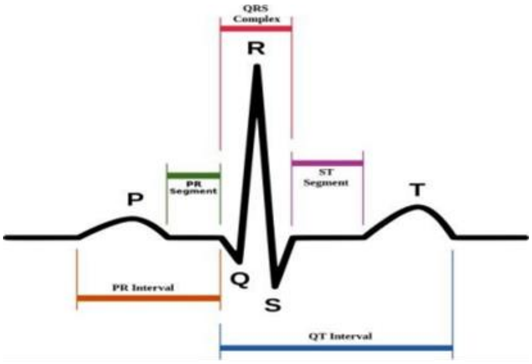

Figure 1. ECG Interpretation

With each heartbeat, a healthy heart experiences a well-coordinated sequence of depolarization that begins with the pacemaker cells in the sinoatrial (SA) node. This electrical impulse spreads across the atria, travels through the atrioventricular (AV) node, then moves down the bundle of His and into the Purkinje fibres, eventually spreading throughout the ventricles. This systematic pattern of depolarization generates the distinctive ECG waveforms.

For a skilled clinician, the ECG provides a wealth of information about the heart's structure and its electrical conduction system. The ECG can be used to assess various factors, such as the heart's rate and rhythm, the size and positioning of the heart chambers, any damage to the heart's muscle or conduction pathways, the effects of cardiac medications, and the functioning of implanted pacemakers. This makes the ECG a critical tool for evaluating the overall health and performance of the heart.

2. Methodology

This system is divided into

(1) Data Collection Patient heart rate is collected from ECG sensor AD8232.
(2) Data Transmission The data collected from sensors is transmitted to the device that performs calculations on data.
(3) Analytics Various machine learning classifiers are used in the analysis of the data and prediction of heart attack.
(4) Prediction

3. Architecture

Collection of Data Set: Initially, I collect a dataset for our heart disease prediction system. Use a publicly available dataset from Kaggle. After the collection of the dataset, split the data set into training data and testing data. The training dataset is used for prediction model learning and testing data is used for evaluating the prediction model.

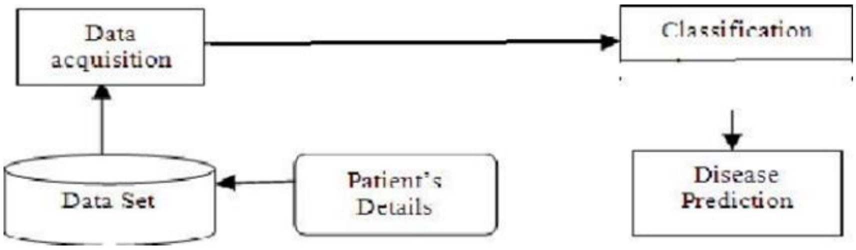

Figure 2. Block Diagram

Data Pre-processing: Data pre-processing is the process of detecting or correcting inaccurate records from a dataset. The preprocessing steps involve several key procedures to ensure the dataset is suitable for analysis and modeling. In case of preprocessing of data, have to ensure the data has no missing values. Correlation matrix is plotted which is used to show the relationship between attributes. Also use box plot which is a data visualization technique. They are useful as they show outliers within a data set. It shows the min, max, median, first quartile, and third quartile. They represent errors in measurement and they could be removed using IQR (Interquartile Range) method.

Classifiers: There are various machine learning classifiers like logistic regression, KNN, Decision Tree, Random Forest, Ensemble learning methods like voting and stacking is used for the classification. Comparative analysis is performed among the algorithms and the one with the gives highest accuracy is preferred.

Prediction: Using the highest accuracy machine learning algorithm, heart attack detection is done.

4. Working Principle

The system architecture gives an overview of the working of the system. The working of this system is described as follows:

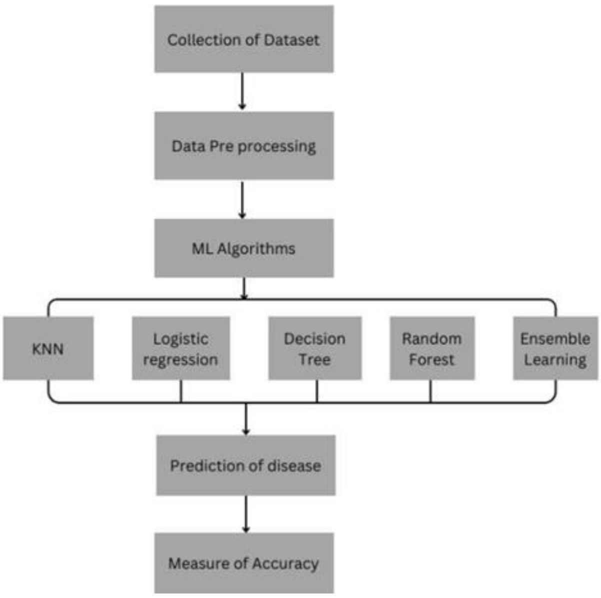

Figure 3. System Architecture

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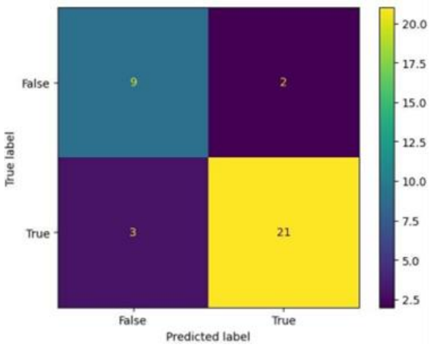
5. Performance Analysis

In this work, various machine learning algorithms like Decision Tree, Random Forest, Logistic Regression, KNN and ensemble learning are used to predict heart disease. The accuracy for individual algorithms has to measure and whichever algorithm is giving the best accuracy, that is considered for the heart disease prediction. For evaluating the experiment, various evaluation metrics like accuracy, confusion matrix, precision, recall, and f1 -score are considered.

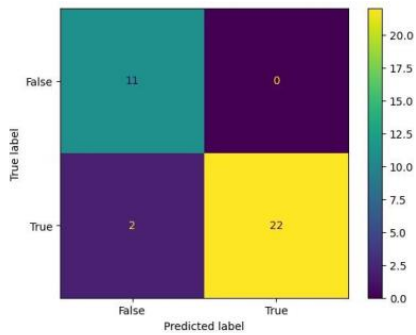
Accuracy- Accuracy is the ratio of the number of correct predictions to the total number of inputs in the dataset. It is expressed as:

$$\text{Accuracy} = (TP + TN) / (TP+FP+FN+TN) \qquad (1)$$

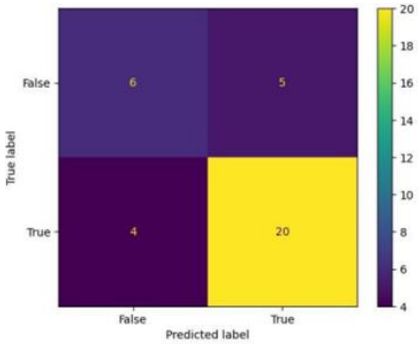
Confusion Matrix- It gives a matrix as output and gives the total performance of the system.



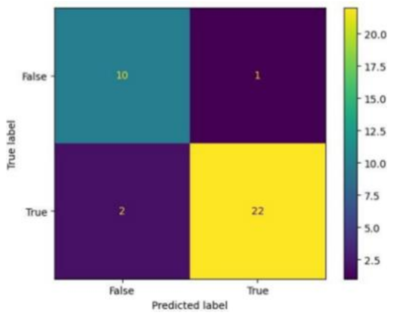
a) Logistic Regression



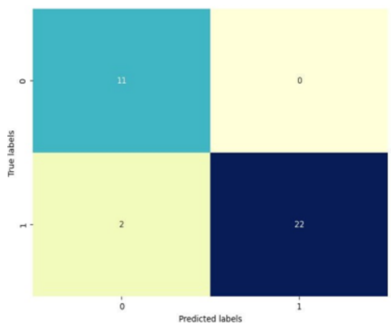
b) Decision Tree

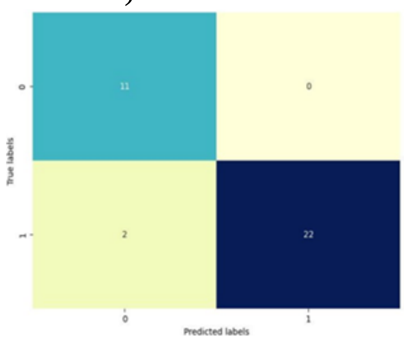


c) KNN



d) Random Forest





e) Ensemble Learning

Figure 4. Confusion Matrix for Voting and Stacking

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6. Result

Figure 5. Output Email

7. Discussions

After performing the machine learning approach for training and testing I find that accuracy of the Random Forest algorithm is better compared to other algorithms. Accuracy is calculated with the support of the confusion matrix of each algorithm, here the number count of TP, TN, FP, FN is given and using the equation of accuracy, value has been calculated and it is concluded that Random Forest algorithm has the highest accuracy of 97% and the comparison table is shown below.

Table 1. Accuracy Table

Algorithm	Accuracy
Logistic Regression	85.7%
Decision tree	94.3%
KNN	74.3%
Random forest	91.4%
Voting	94.28%
Stacking	97.4%

8. Conclusion & Future Scope

This shows that the best performing model for the considered databases in this study is found by the analysis of the accuracy, sensitivity, precision, and F-score of Random Forest is higher than KNN and Simple Logistic models. Therefore, it is decisive that Ensemble Learning is the most efficient algorithm to be implemented on the heart disease prediction system as found in the study.

In the previous research works concerning comparison among various machine learning algorithms, it was found that no algorithm attained an accuracy level of more than 90 percent in heart disease prediction using the ptb diagnostic database. As a result, the accuracy of predicting early-stage conditions is effectively improved.

In the future, this can be implemented as a wearable device for the continuous monitoring of heart disease of patients.

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