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# A Comprehensive Study on Different Machine Learning Techniques to Predict Heart Disease

**Pooja Sharma, Sarwesh Site**

***Abstract:*** ***The heart is considered to be one of the most vital organs in the body. It contributes to the purification and circulation of blood throughout the body. Heart Diseases are responsible for the vast majority of fatalities around the world. Some symptoms, such as chest pain, a faster heartbeat, and difficulty breathing, have been documented. This data is reviewed regularly. In this review, a basic introduction related to the topic is first introduced. Furthermore, provide an overview of the healthcare industry. Then, an in-depth discussion of heart disease and the types of heart disease. After that, a summary of heart disease prediction, and different methods of heart disease prediction are also provided. Then, a short description of machine learning, also its different types, and how to use machine learning in the healthcare sector is discussed. And the most relevant classification techniques such as K-nearest neighbor, decision tree, support vector machine, neural network, Bayesian methods, regression, clustering, naïve Bayes classifier, artificial neural network, as well as random forest for heart disease is described in this paper. Then, a related work available on heart disease prediction is briefly elaborated. At last, concluded this paper with future research.***

***Keywords: Healthcare, Heart Disease, Heart Disease Prediction, Machine Learning, Classification.***

## I. INTRODUCTION

One of the most urgent medical issues of our day is CVD. It is one of the deadliest & long-lasting diseases, accounting for a majority of fatalities worldwide. Cardiovascular disease is responsible for 31.5% of all global deaths, according to the most recent WHO statistics. Every year, over 20.5 million people die as a consequence. In 2030, the death toll is expected to rise to 24.2 million every year. Heart attacks & strokes make for around 85 percent of all deaths from cardiovascular disease in the United States. [1]. A build-up of clots is the primary cause of a heart attack, which results in a reduction in blood supply to the heart. A blood clot forms in an artery in the brain, blocking blood flow to the brain, resulting in a stroke. In most cases, heart disease is caused by the heart's inability to provide adequate blood to various sections of the body [2].

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***** Correspondence Author

**Pooja Sharma*,** M. Tech, Scholar, Department of Computer Science Engineering, All Saint College of Technology, Bhopal (MP), India. E-mail: pooja2405sharma@gmail.com

**Sarwesh Site,** Department of Computer Science Engineering, All Saint College of Technology, Bhopal (MP), India. E-mail: Er.sarwesh@gmail.com



Early signs include an increased heart rate, breathlessness, pain in the chest, abrupt disorientation, uneasiness, swollen feet, & a cold sweat. These are all symptoms of an irregular heartbeat. Accurate prognosis and timely diagnosis are critical to increasing survival rates in patients with heart disease. It is significant to note that risk factors that contribute to cardiovascular disease (CVD) include excessive use of alcoholic beverages and tobacco products; obesity; lack of exercise; & genetic abnormalities. Preventative measures, like a healthy diet, regular physical exercise, and regular medical examinations, may minimize the risk of death [3]. Predicting and diagnosing cardiac disease today relies heavily on the medical history, symptoms, & physical examination reports of a patient. In most cases, it is complex for medical specialists to precisely forecast a patient's heart illness [4] since, presently, diagnosis of any disease is done depending upon identical symptoms seen from previously diagnosed patients [5]. To accurately forecast cardiac disease, the medical industry needs an automated and sophisticated method. ML (Machine Learning) algorithms & a vast quantity of patient data readily accessible in the medical industry may be used to do this [6]. Disease prediction has been a major focus for data science researchers in recent years. Health data is becoming more accessible because of the rapid advancements in computer technology in healthcare. Healthcare help in our society might benefit greatly from modern deep learning and intelligent decision-making technologies. For learning new things and collecting critical knowledge, data is the most important resource. Agricultural, business, education, and health care are just a few of the industries that rely on vast volumes of data from technology and research. Structured or unstructured, this is raw data with no further processing. Big data must be analyzed to obtain important information for storage, processing, analysis, management, & visualization purposes. [7] Presently, in the healthcare industry, individuals' medical records are easily accessible in databases, & this data grows exponentially every day. Unbalanced and very redundant raw data is shown here. Extracting key features, reducing training time, & enhancing classification efficiency need pre-processing [8]. Recent developments in processing power & reprogramming abilities of machine learning provide new vistas for study in the healthcare industry [9], particularly in the early prediction of illnesses like CVD & cancer, to enhance survival rates. ML algorithms, however, enable HD detection that dramatically decreases processing time & increases prediction accuracy, allowing for more accurate diagnosis.

Cardiovascular disease diagnosis and categorization may both benefit from the use of machine learning methods. There are several uses for machine learning, ranging from the detection of illness risk factors to the development of improved automotive safety systems. To overcome present constraints, machine learning provides the most prominent predictive modeling techniques [10]. Big data may be effectively transformed in this way to develop predictive algorithms. To reduce the discrepancy between projected & observed results, this method depends on a computer to learn non-linear and complicated connections between features. Some patterns may be learned from an existing dataset & applied to an unknown dataset, which the machine then uses to anticipate the outcome. Classification is a strong machine learning method for making predictions. Using the right information and a supervised machine learning approach, the classification may successfully diagnose illness [11].

## II. HEALTHCARE INDUSTRY

Humanity's health is one of the world's greatest issues. According to the WHO, health is a basic human right. Consequently, health care services must be given to keep individuals fit & healthy. Heart disease is responsible for 31 % of all fatalities globally [12]. Healthcare is one of these areas only to be discovered. The health sector is usually' Data dense,' but not all the information needed to find hidden trends and successful decision-making are sadly gathered. The health sector usually uses the doctor's expertise and experience to render professional decisions. In the medical field, machine-aided decision support plays a major part. The rising amount of research on the heart disease prediction system has resulted in research findings that are necessary to classify cardiac disease and provide readers with an overview of the available prediction approaches for each category of cardiac disease. Healthcare is one of the most concerning fields in terms of data collection and processing. With the advent of the digital era and advancement in technology, a large amount of multi-dimensional information is generated about patients, which includes clinical parameters, hospital resources, disease diagnostic details, patients' records, and medical devices [13]. Technological improvements in healthcare generally mean that healthcare facilities are becoming more reliant on ML methods, which are valuable for doctors in many different ways. With a focus on enhancing service quality and care, machine learning (ML) has gained traction in numerous industries recently, including healthcare. Up to this point, advanced ML approaches in healthcare have been employed to solve prognostic challenges, including those in mental health [14] and the behavior of human domains. Some believe that the usage of ML techniques in medicine will lead to better patient care. Advances in sensor technology have already proved the worldwide influence of ML in clinical care, allowing doctors to monitor a patient's well-being in real-time [15]. It has the potential to enhance physician productivity & quality of patient treatment [16].

## III. HEART DISEASE

Heart disease is one of the most frequent disorders nowadays that may lower a person's life expectancy. Heart disease kills 17.5 million individuals per year. Because the heart is an essential organ in our bodies, its proper operation is essential to our survival. Heart disease is a disorder that causes the heart's capacity to pump blood to be impaired or impaired [17]. Numerous aspects of health promotion and clinical treatment rely on determining a person's risk for coronary heart disease, and this determination is crucial. Multivariate regression analysis may be used to develop a risk prediction model from longitudinal research. The left atrium, right atrium, right ventricle, & left ventricle are all demonstrated in Fig. 1, as are aortic and pulmonary arteries and veins as well as Tricuspid and Aortic valves as well as Mitral and Superior vena cava.

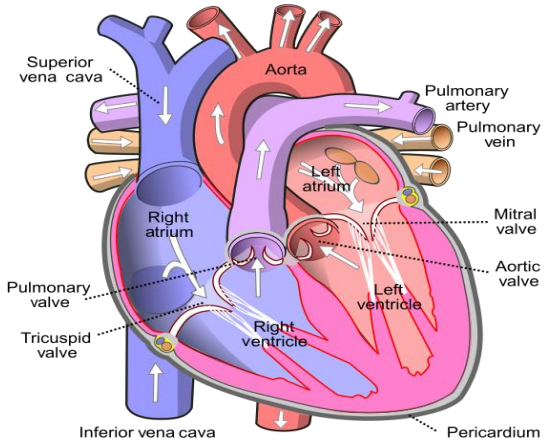


**Fig. 1.Human Heart**

### A. Types of Heart Disease

Heart disease may be classified into several different subtypes. When it comes to heart disease, several subtypes are depending on the patient's condition. Cardiomyopathy, angina pectoris, myocardial infarction, and atrial fibrillation are all clinically proven conditions that fall under the category of heart failure. There are several characteristics of cardiac disease that impact the heart's function or structure [18].

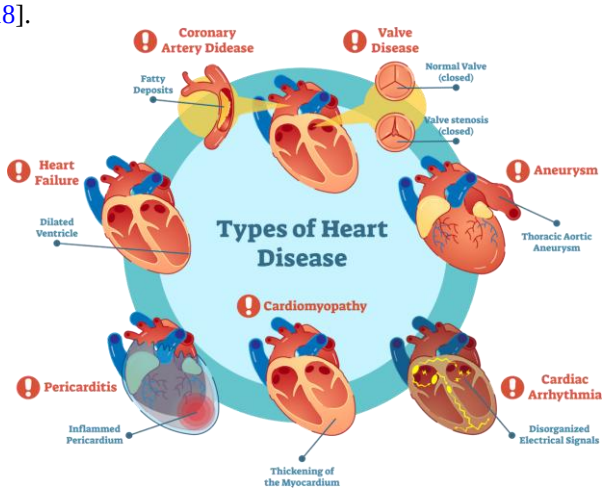


**Fig. 2.Types of Heart Disease**

HDs are included in the table below, along with brief explanations of some of the most common cardiac problems that they are associated with [19].

**TABLE 1: DIFFERENT TYPES OF HD**

| Types of HDs | Description |
|---|---|
| Arrhythmia | Atypical heart rhythm |
| Acute coronary syndrome | The blood flow to the heart muscle is severely restricted very quickly. |
| Coronary artery disease | Obstruction of blood vessels causes this condition to occur. |
| Angina | Chest discomfort caused by a lack of oxygen and nutrients reaching the heart muscle |
| Congenital heart disease | Heart anomalies that are present at birth are called congenital anomalies. |
| Cardiomyopathy | Heart muscle disease |
| Rheumatic heart diseases | Rheumatic fever |

## IV. HEART DISEASE PREDICTION

Heart disease has received the most attention in the medical study of the many deadly illnesses. One of the most demanding tasks in cardiology is making a diagnosis that can accurately forecast a patient's cardiac health, allowing them to get the best possible therapy. In most cases, a patient's symptoms and physical examination are used to make the diagnosis of heart disease. All of these, as well as a family history of HD, increase the chance of developing heart disease: high cholesterol, smoking, being overweight, having high blood pressure, & not exercising enough. Hospitals and medical facilities, for example, confront the difficult task of providing high-quality treatment at reasonable prices. Providing a high-quality service means correctly identifying and treating patients [20]. A prediction is a helpful technique in healthcare situations when physicians lack more knowledge and experience, as well as when there are no experts accessible. Those professionals, for instance, may choose their own that results in a poor outcome for the patient or even the patient's death. High-Definition Prediction is used in healthcare institutions to automate the diagnosis of sickness and to deliver acceptable levels of service quality to save lives. Using prediction methods helps all stakeholders, particularly professionals who must make acceptable judgments about how to treat patients, make accurate decisions more quickly and efficiently [21].

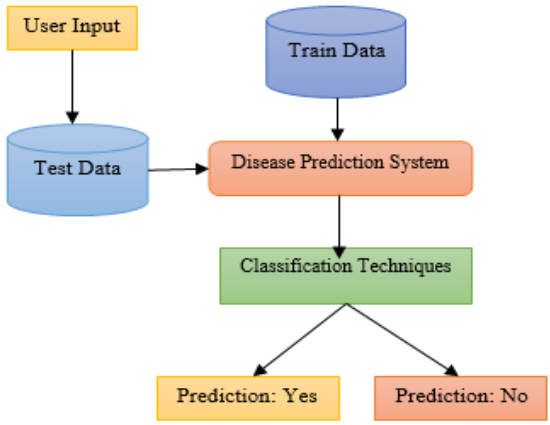


**Fig. 3.Heart Disease Prediction in Data Mining**

### A. Heart Disease Prediction Methods

#### a) Data Mining (DM)

In the domains of technology, business, and research, DM is a well-known way to foster organic development in information technology. As time passes, the amount of data that can be gleaned from various prediction approaches grows exponentially. It is necessary to retrieve the relevant data contained within these massive volumes of data. As a result, in today's competitive world, information is becoming more vital.

#### b) Machine Learning (ML)

ML is a branch of science that studies how computers utilize data to learn. Data mining and statistics meet in this field, which aims to discover patterns in large amounts of data. Billions or trillions of data points provide a unique set of computing hurdles when attempting to construct statistical models from such vast datasets. Supervised learning and unsupervised learning are the categories into which computer-based learning may be readily subdivided.

#### c) Deep Learning (DL)

DL is a technique that enables computers to construct more complex ideas from simpler ones. As we've learned more about the human brain, statistics, and applied arithmetic, DL has become a popular technique for ML. In the last several years, DL has been more popular and effective for training more complex networks [22].

## V. MACHINE LEARNING

In the field of ML, theory, performance, & characteristics of learning systems and algorithms are examined. Because of this, it is a highly interdisciplinary field that incorporates ideas from a variety of different scientific and technical fields. These include artificial intelligence (AI) systems as well as optimization, control, information theory, and more. Machine learning has encompassed practically every scientific topic due to its use in a broad variety of applications, which has had a significant influence on research and society. To solve a broad variety of issues, like recommendation engines, recognition & data mining systems, as well as self-control systems, it has been employed [23].

### A. Types of Machine Learning

According to Fig. 4, machine learning algorithms may be categorized into four primary groups: unsupervised learning, supervised learning, semi-supervised learning, and reinforcement learning [24]. Our next section focuses on how each sort of learning approach might be used to tackle real-world issues.

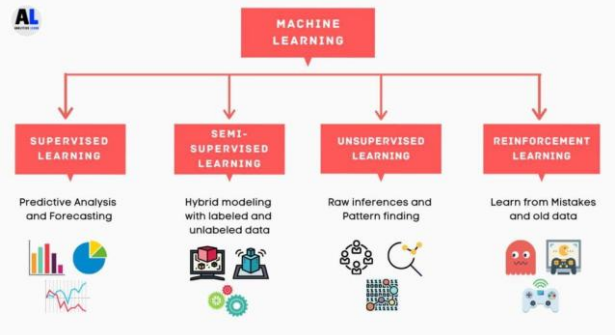


**Fig. 4.Different Types of Machine Learning**

### B. Supervised Learning

Many functions which are used to convert inputs to outputs are taught to machines via the use of examples of these types of input-output pairings.

A collection of training cases and a set of labeled training data are used by the algorithm to derive a function. For example, when a task-driven method is used to attain a certain objective, supervised learning may be used to accomplish that goal. Two of the most often utilized supervised tasks are "classification" and "regression," both of them separate & fit data. Unsupervised learning may be seen, for example, in the categorization of text such as that found in tweets or product reviews.

### C. Unsupervised Learning

Unlabeled datasets may be examined using this approach, which is based on data rather than human input. In most cases, this is utilized to extract the generative qualities, uncover important patterns & structures, groupings in results, & explore purposes. Clustering, density estimation, feature learning, dimensionality reduction, establishing association rules, anomaly detection, and other unsupervised learning tasks are examples of typical unsupervised learning tasks.

### D. Semi-supervised Learning

Due to its use of both labeled & unlabeled data, semi-supervised learning might be considered an amalgamation of the two types of learning techniques previously discussed.

When learning "without supervision," it's somewhere in the middle of that spectrum. Semi-supervised learning is effective in situations when labeled data are few and unlabeled data are plentiful. Semi-supervised learning has the objective of improving prediction accuracy above unsupervised learning by utilizing the model's labeled data alone. Translation, fraud detection, data labeling, and text classification are just a few of the available applications of semi-supervised learning.

### E. Reinforcement Learning

Software agents and computers may use reinforcement learning to automatically assess the best possible behavior in a given context or environment, which is an environment-driven approach to machine learning. By using environmental activists' insights to take action to raise benefit or decrease danger, this learning method is based on reward or punishment. Although it may be used to train AI models for complex systems like autonomous driving, robotics, manufacturing, & supply chain logistics, it is not recommended to use it for tackling simple or uncomplicated issues.

## VI. HEALTHCARE USING MACHINE LEARNING

In the healthcare sector, ML is likely to have modest societal consequences [25].

Using machine learning, healthcare costs may be reduced while also improving patient-clinician communication. Many health-related applications for ML solutions are on the horizon, some of which include helping physicians discover a large number of patient-specific medicines and therapies, as well as helping patients choose when and if they need to keep track of follow-up visits. A vast amount of data is now available in the field of health care.

It comprises electronic medical records (EMRs) that store data in both organized and unstructured formats. Patients' weights and general symptoms like stomach pain, headache, and so on are all examples of structured health information that may be easily accessed in a database for analysis.

Unstructured data in the form of numerous separate notes, pictures, audio and video recordings, reports, and discharge summaries make up the bulk of medical information. Dialogue between a provider and a patient is challenging to assess since it is highly personalized and may take several forms [25].

### A. Application of Machine Learning in Healthcare

There are several uses for machine learning in healthcare. It may help with time-consuming & difficult work in this field. In general, ML applications in medicine may be classified into 3 types:

- First Category- Improving Available Medical Structures: These are the most fundamental machine learning applications in the medical field. They improve the energy efficiency of existing buildings [26] [27]. These machine learning-based solutions provide particular & rule-based tasks for popular applications like simulation & data validation. One of these ML applications is a classification of digitized medical pictures in healthcare services. As a result, current image processing systems now have better accuracy. To determine whether or not a disease is present in a patient's radiological images, machine learning may be employed.
- Second Category-Upgrading Medical Structures: Machine learning applications in this area offer structures with additional capabilities. They are moving toward personalization. One of these ML applications is precision medicine [28]. Personalized medicine is a type of medical treatment that focuses on a person's unique needs based on her or his physical characteristics (e.g., genetic arrangement of person). A good example of this is Carbone, which aims to provide personalized healthcare. Artificial intelligence, large databases & biotechnology are used to achieve this goal.
- Third Category-Independent Medical Structures: This subcategory of ML applications has lately grown in popularity. They develop ML-based models to conduct activities autonomously based on predefined objectives. One of the future uses in healthcare, for example, is the construction of a hospital without the need for doctors. As a result, we must be prepared for a robotic future based on machine learning & AI. However, these components must be thoroughly examined by a variety of international standards. Robots are increasingly being used by surgeons to speed up the procedure.

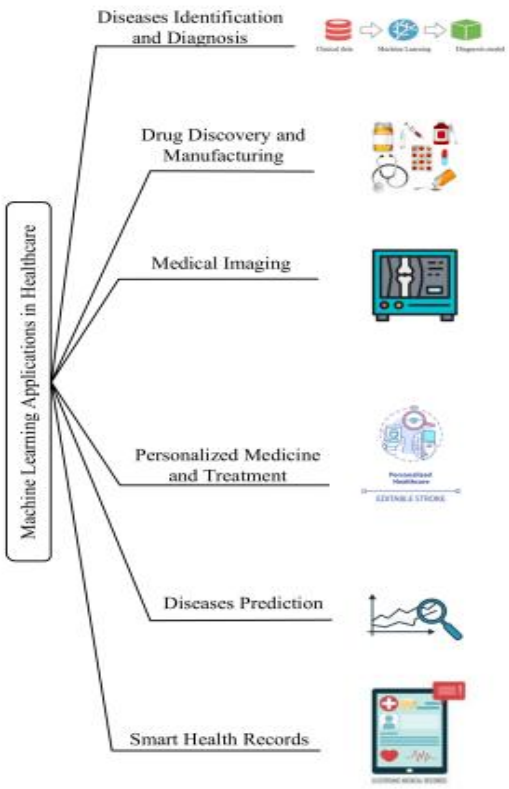


**Fig. 5. Various ML Application in Healthcare**

## VII. CLASSIFICATION TECHNIQUES FOR HEART DISEASE

Classification is the process of categorizing data models into desired classifications. The classification approach forecasts the target class for every data point based on the data points themselves. For example, based on their illness pattern, patients might be categorized as "high risk" or "low risk" patients using the data classification technique [29].

### a) K-Nearest Neighbour (K-NN)

The KNN method is a straightforward learning technique that runs inside the machine. The general concept is straightforward: compute the distance between such a point A and other such points, delete the k points that are closest to A, and then count the k points that are part of the classification. Point A is included in the classification if it represents the greatest fraction of the total.

### b) Decision Tree (DT)

DT is a kind of supervised learning algorithm classifier that is easy to comprehend and interpret. It is one of the most widely used algorithms nowadays. It is capable of dealing with both numerical and categorical data.

### c) Support Vector Machine (SVM)

SVM is a classification approach that can cope with both linear & non-linear data sets and is used in many applications. The SVM generates a hyper plane or many hyperplanes in high-dimensional space, which may be utilized for regression, classification, as well as other effective tasks such as clustering and regression analysis.

### d) Neural Network (NN)

It is possible to extract rules from a trained Neural Network (NN), which may aid in improving the interoperability of the learned network. For specific issues, NN employed neurons, which are ordered processing components that were used to solve it.

### e) Bayesian Methods

Bayesian classification is the term used to describe classification built on Bayes theory. It is a straightforward classifier, obtained by the use of a classification algorithm. The Bayes theorem serves as the foundation for techniques such as Naive Bayesian Classifier as well as Bayesian Belief Networks (BBN).

### f) Regression

Regression is a technique for determining the functions that identify the relationship between two or more variables. A regression model may be confidential in 2 forms depending on the percentage of independent variables: a linear model and a non-linear model.

### g) Clustering

Distinct from classification, clustering is an unsupervised learning strategy that may be used to solve problems. Clustering is the process of dividing a huge database into tiny subgroups or clusters that are distinct from one another.

### h) Naïve Bayes (NB) classifier

The Bayes' theorem-based classification approach known as NB is utilized for classification. NB technique is utilized to determine the posterior probability of every class, which is based on probabilistic reasoning when categorizing data sets.

### i) Artificial Neural Network (ANN)

The ANN computational model is a biological NN computational model. NN is sometimes referred to as ANN. The concept of ANN originates principally in the field of biology, where the NN plays an important role in the human body.

### j) Random Forest (RF)

Regression and classification strategies are based on bootstraps, and this is the basis for the RF's formulation. When it comes to identifying trees, increasing and bagging are two of the most often used strategies. It is feasible to predict class labels for a particular data point using a categorical dependent variable as well as an RF, based on the tree configurations used to create the dependent variable.

## VIII. LITERATURE REVIEW

ML, DL, & DM have been used extensively to predict HD. Researchers employ a variety of datasets, algorithms, and procedures, as well as their findings and future research, to identify the most effective medical diagnostic methods for cardiovascular disease. Currently, the most difficult real-world medical challenge is the automated prediction and detection of cardiovascular disease. A better prognosis is dependent on detecting cardiac disease in its early stages.

Early detection of heart disease has been studied using a variety of methods from across the globe. The following are some of the most common methods for predicting cardiovascular disease:

R. Atallah and A. Al-Mousa (2019) provide a majority voting ensemble method for predicting HD in humans. An affordable and simple medical test can be performed at any local clinic to make the prediction. By using real-world data from healthy & ill patients to train models, researchers hope to increase patient trust in the doctor's diagnosis. It uses a combination of different ML models to classify the patient, instead of relying just on a single model. A 90 percent accuracy rate was achieved by using the hard voting ensemble model. [30].

L. A. Alqahtani et al. (2020) Naive Bayes (NB), Multi-Layer Perceptrons (MLP), RF, and DT are some of the ML methods that will be compared in their research. We'll employ a variety of preprocessing methods, including the brute force strategy for selecting features. The parameters will be optimized using a grid search method. With an AUC of 0.95 and an accuracy of 0.93, RF was found to be best [31].

P. Khurana et al. (2021) provide a comparison of several supervised learning algorithms & feature selection methods for the prediction of HD. NB, DTs, LR, & RF are just a few of the 6 ML classifiers & 5 feature selection techniques that have been tested on a Cleveland benchmark dataset from the UCI Machine Learning Repository. Results demonstrate that all of these methods perform well on the benchmark dataset. Prediction accuracy of 82.81% has been shown in experiments using machine learning classifiers. Using feature selection approaches, classification performance is further enhanced and may reach a prediction accuracy of 83.41%. [32].

D. P. Yadav et al. (2021) Here, an automated approach that uses machine learning techniques to evaluate their effectiveness has been established. They first used a dataset for heart disease prediction to test well-known ML algorithms including SVM, KNN, NB, and RF. As a precautionary measure, a three-fold cross-validation procedure is used. The Naive Bayes has the greatest average accuracy of 87.78%. The model's performance is satisfactory. Additionally, they used a genetic algorithm to improve the dataset's characteristics. After optimization, the naive Base has the greatest average accuracy of 96 percent. [33].

S. Anbukkarasi et al. (2021) KNN, NB, & RF are some of the machine learning methods used in the suggested strategy for identifying HD in the dataset. Finally, a model is put into action using a combination of characteristics & tried-and-true classification approaches for predicting heart-related illnesses. The combined accuracy of the Random Forest and Feature Model approaches, out of all the techniques, is 81%. [34].

J. R. V. Jeny et al. (2021) Four machine learning classification methods were used here. A Support Vector Classifier was first added (SVC). Predicts the model depending on the parameters that have been taken into account. The second is a Logistic regression model (LR). Problems with classification based on input parameters are described using this term. Finally, DT Algorithm and NB classifier are utilized. Classifiers of many kinds were used to improve accuracy and overall performance. Our proposal's main goal is to use ML classifier approaches to increase accuracy and detect heart disease. [35].

A. Kumari and A. K. Mehta (2021) With the use of seven ML algorithms, this research aims at predicting heart disease by employing ensemble techniques like AdaBoost and voting ensemble methods. Algorithms such as Linear Discriminate Analysis perform well in terms of accuracy, with a mean of 0.847, a mean absolute error of 0.185, and a false acceptance rate of 0.33. However, the accuracy of Linear Discriminate Analysis is lower than that of Logistic Regression, which is 80 %. [36].

A. Lakshmanarao et al. (2021) machine learning algorithm for predicting heart disease has been developed. Both Kaggle and UCI datasets were used to evaluate the suggested technique. It was necessary to employ sampling and feature selection approaches to balance an uneven dataset. Later, a variety of classifier models were used, and the ensemble classifier proved to be quite accurate. The suggested model was tested on two datasets and found to be accurate in predicting heart disease. All implementations utilized Python. [37].

Y. Lin (2021) According to preliminary results, males were shown to be more likely to have HD than females in Cleveland heart-disease dataset that was preprocessed using one-hot encoding & standardization. Following hyperparameter tuning and cross-validation, the RF model was shown to be the best model, outperforming other models with higher accuracy (0.848), f1 (0.829), PRC-AUC (0.909), & ROC-AUC (0.909). It was also possible to uncover the most important characteristics, such as the reversible thallium stress test defect, exercise-induced ST depression, and nonspecific chest discomfort, by using the Random Forest classifier's permutation feature significance and partial importance plots, etc. [38].

## IX. CONCLUSION

Heart disease is the most pressing social issue. Manually calculating the likelihood of developing heart disease based on risk variables such as age and gender is difficult. Machine Learning is a valuable technique that may be used to anticipate the outcome of data from a set of data. In this study, we have developed a method that is suitable for the prediction of heart disease and that may be utilized by users who are suffering from coronary heart disease. The diagnostic system of the system is capable of predicting heart disease via the use of machine learning algorithms, and the prediction findings are based on an instance of the heart disease dataset. To detect and issue an alert if the user's heart rate increases over the typical rate of the heart. To demonstrate the efficacy of the system, we conducted trials on both monitoring and diagnosing systems simultaneously. In the future, we will offer an approach for early detection of heart disease that will be very accurate while still being low in cost and complexity.

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## AUTHORS PROFILE

**I am Pooja Sharma,** student of All Saints' college of Technology, Bhopal (Affiliated by AICTE/ Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal). I had done multiple researches on the Artificial Intelligence. My latest research is on Machine Learning Algorithm. Now I am working on A Hybrid Model for Predicting Heart Disease Using CNN and Bi-LSTM Algorithm.

**I am Sarwesh Site,** Professor of All Saints' college of Technology, Bhopal (Affiliated by AICTE/ Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal). I had done multiple researches on the Artificial Intelligence. My latest research is on Machine Learning Algorithm. Now I am working on A Hybrid Model for Predicting Heart Disease Using CNN and BiLSTM Algorithm.