Diagnosis of Heart Failure using Simple AI Techniques

Abstract. Human body contains many organs, but one of the prime organs is the heart, which is a network of vessels which help the blood to flow into our body. Cardiovascular disease is any disturbance in the heart's normal functioning or performance. In this work, closely worked with the heart disease prediction and for that, the team will be looking into the heart disease dataset from where work will be derived various perceptions that help us to know the value of each feature and their connections. Also, here the aim is to detect the possibility of person will be affected by a savior heart disease or not. This research paper presents various algorithms of machine learning by which a projection of heart disease can be made and required steps can be taken as early as possible for prevention. This paper consists of five algorithms (SVM, Decision Tree, K-NN, Ensemble Method and ANN) which are applied to the dataset that is publicly available. On applying Ensemble Method (combination of K-NN, Decision Tree, and SVM) on the dataset an accuracy of 89.88% was attained. ANN was able to outperform all the other algorithms with accuracy of 95.33%.

Keywords: Heart Disease, Machine Learning, SVM, K-NN, Decision Tree (DT), Ensemble Model, ANN

1 Introduction

Heart is a principal organ for a human to live. Major functions of heart are to circulate the blood throughout the body, maintain the blood pressure and many more. Heart failure and heart disorders are the biggest cause of death worldwide. As per WHO (World health organization), 17.9 million people die each year from cardiovascular disease [2]. Major causes of these heart diseases are the regular habits of an individual like their caffeine and alcohol intake, smoking, lack of physical activities etc. Most of the times cardiovascular diseases can be prevented by choosing a healthier lifestyle and taking other measure, for which making an early and accurate prediction of the cardiovascular diseases is extremely important.

In this work we will be comparing accuracy of different ML (Machine learning) algorithms and based on this comparison will be seeing which one is the best among all. Machine learning is a technique which can be used when huge amount of data is available. It learns from the data i.e., it looks at the trends and then based on these trends further predictions can be made. Many types of ML algorithms are present. ML analyses the characteristics of dataset and checks if a person have a heart disease [11].

The dataset is split into testing and training portion. In this work we have implemented SVM, K-NN, Decision Tree, Ensemble model and ANN. The main goal of this paper is to identify a well-functioning model for the prediction of heart disease. Further section 2 of the paper consist of literature review followed by methodology in section 3, result in section 4 and section 5 having conclusion and section 6 are the reference.

2 Related work

Rajdhan et al. [1] predicted a model where they have implemented various data mining algorithms on a dataset. The dataset on which the work was done is from UCI repository. They have compared different ML algorithms like DT, Naïve Bayes (NB), Random Forest (RF), and Logistic Regression to predict the accuracy. They have RF as their best classifier after their prediction with the accuracy of 90.16%. Shah et al. [2] researched using dataset available in UCI repository. The algorithms which are executed as DT, NB, RF, and K-NN. The motive of the paper is to check if a patient will have a heart disease or not. Highest accuracy is predicted with K-NN of 90.78%.

Singh et al. [3] calculated the accuracy of four various machine learning approaches, they are SVM, LR(Linear Regression), K-NN, and DT. By looking at the calculation we conclude which one is best among them. As a result, they found out KNN has the best accuracy of 87% with the use of confusion matrix.

Kavitha et al. [4] used "Cleveland Heart Disease Database" for their research work. In the research work they have applied Machine learning algorithms. The three ML algorithms they have applied are RF, DT, and Hybrid model (RF + DT). By using DT, they got 79% accuracy, by using RF they got 80% accuracy and by using hybrid model they got 88% accuracy. In this research paper they have combined two algorithms and made a hybrid model and attained the accuracy of 88%. [5] worked on the combination of Machine Learning and Deep Learning. In the research work they used algorithms of ML along with DL (Deep Learning) by which they have enhanced the results. They got 94.2% accuracy. They used confusion matrix to validate their result. Katarya et al. [6] has used supervised algorithms of ML for the prediction of heart-disease. Their motive was to predict heart-disease in early stage so that a cure for the disease can be found, and necessary steps can be taken as early as possible to overcome the disease. They have used algorithms like SVM, DT, ANN, NB, KNN, and RF algorithm on the dataset.

Ramprakash et al. [7] developed a framework using Deep neural networks, X^2- statistical model, and machine learning. They have used dataset from the UCI repository. DNN (Deep Neural Network) has been used with more than one hidden layer on the dataset because of which they have achieved higher accuracy than ANN. [8] has created a deep learning neural network model along with which Talos tools for the prediction. In the work they have used Heart Disease UCI dataset. They have used algorithms like NB, LR, K-NN, Hyper-parameter optimization, RF, SVM and found out that Hyper-parameter optimization has the bests prediction overall with the accuracy of 90.78%.

Yadav et al. [9] have applied four tree algorithms to the UCI repository dataset. The four tree algorithms are Random Forest tree, Reduced Error Pruning, M5P and Random Forest ensemble method. They have done three experiments in the research papers namely Lasso Regularization, Pearson Correlation and Recursive Features Elimination. After completion of all the experiments they have concluded that Random Forest Ensemble Method gives best accuracy among the four.

Waigi et al. [10] have implemented models of ML on the attributes of dataset which they have downloaded from Kaggle. They have implemented DT model on the dataset and got 73% accuracy. Princy et al. [11] used supervised algorithms of ML on the dataset as they are precisely used for prediction. They have implemented algorithms like LR, NB, RF, SVM, DT and K-NN out of which decision tree overcomes all the algorithms in the prediction. The dataset which they have used is cardiovascular disease dataset which is present in Kaggle.

[12] have used machine learning algorithms along with ANN and Adaptive Boosting and compared which one of this provides better result. Data was from UCI repository of Hungarian, Cleveland and Sani Z-Alizadeh. ANN given the best result in this case.

[13] worked on a hybrid model to enhance the performance by combining Linear Regression and Random Forest and referred it as HRFLM (hybrid random forest with a linear model). Cleveland dataset of UCI repository is used for experimentation. Repaka et al. [14] applied the NB algorithm on the data to predict the accuracy of heart disease prediction. They have compared Bayes Net, NB with SMO (Sequential Minimal Optimization) and MLP(Multi-Layer-perception). NB gives accuracy of 89.77% which outcomes other algorithms.

Tarawneh et al. [15] have applied DT, SVM, NB, K-NN for the classification but they eliminate the one whose performs is lowest. They notice that NB and SVM performs better and are not eliminated whereas Decision Tree is sometimes eliminated and most of the time K-Nearest Neighbor is eliminated. So, they build a hybrid model by choosing the model which gives higher accuracy. They have attained an accuracy of 89.2%.

Khan et al. [16] has used machine learning and cloud computing for forecasting of heart disease. The data used was collected from devices enabled from IoMT. The model is split up into two phases: training and validation, if the required criteria is met in the training phase, then only the model is stored on the cloud. The model uses SVM algorithm. The trained model is taken from the cloud and input data from IoMT devices in the validation phase. Their model gives 93.33% & 95.31% accuracy during validation and training phases.

Jindal et al. [17] have selected the dataset available in UCI with patient's medical history. The algorithms used by them are K-NN and Logistic Regression for prediction and classification of the patient with a heart disease. This model showed a better performance in comparison to the previously used classifier such as Naïve Bayes. They got an accuracy of 88.5%

Arroyo et al. [18] proposed an optimized neural network Using genetic algorithm for cardiovascular disease where they have used the publicly available dataset for cardiovascular disease on which they have applied ANN by which they have firstly mined the dataset and then they have improved the accuracy by the help of ANN by the help of optimization technique. They have used Genetic Algorithm and Neural Network which is hybrid algorithm to improve their accuracy. They got 73.43% accuracy which overtakes other machine algorithms such as DT, K-NN and RF etc. [19] have proposed a hybrid approach using multiple ML algorithm for the prediction of the heart disease for enhancement of the prediction's accuracy. They have used UCI Repository dataset and chose Cleveland database for their prediction.

Motarwar et al. [20] put forward a cognitive approach for heart disease prediction where they have implemented framework of machine learning. The framework consists of Hoeffding Decision Tree, NB, RF, Logistic Model Tree, and SVM. They executed all these algorithms on the dataset to predict accuracy. Cleveland dataset was used on which they have executed the algorithms and as the conclusion, Random Forest has given the maximum accuracy 95.08%.

Maji et al. [21] have built a hybrid model by combining ANN and DT. The data used is from UCI on which they have applied DT Algorithm, ANN and Hybrid Decision Tree model and predicted the accuracy for each of the algorithm and validated it using tenfold validation test. The highest accuracy was 78.14% which was achieved by the Hybrid model.

Krishnan et al. [22] have used supervised machine leaning algorithms Naïve Bayes and DT for the prediction. The dataset they used is from UCI repository. DT gives an accuracy of 91% and Naïve Bayes gives an accuracy of 87%. [23] used K-NN and DT on the dataset. Accuracy gained by Decision tree is 81% whereas K-nearest Neighbor gains and accuracy of 67%. UCI repository dataset was used with 303 records.

Authors [24] surveyed 5 popular algorithms of ML namely NB, K-NN, RF, SVM, and Decision Tree. It was found that all the machine learning algorithms have performed well but in some cases the performance of the algorithms was not up to that mark. Naïve Bayes performs faster than the other algorithms whereas Decision Tree performs well when used with Principal Component Analysis (PCA) and SVM performed well for most cases. They concluded that ML algorithms predict accurately but still a lot more research can be done in this field.

[25] wrought about heart disease prediction where K-NN and Random Forest are used which are supervised algorithms of ML for the heart diseases prognosis. Algorithms were applied on the dataset which is taken from Kaggle having 14 attributes in it. The two algorithms performed well on the dataset so the conclusion is made that machine learning can predict heart disease and helps in reducing the harm which can be caused to a person. KNN gives an accuracy of 86.86% and RF (Random Forest) gives an accuracy of 81.97%.

Table 1 consist of all the information collected from different sources for the review of heart disease prediction methods.

Table 1. Literature collected from various studies of heart disease prediction.

S.No.	Author	Year	Paper Summary	Dataset	Classifier	Accuracy
1.	Rajdhan et al. [1]	2020	Compared different machine learning and found the best one among those for the prediction.	UCI repository	NB, DT, Logistic Regression and RF	Random Forest : 90.16%
2.	Shah et al. [2]	2020	Predicted that weather a patient will have a heart disease or not by the help of ML algorithms.	UCI repository	NB, DT, K-NN, Random Forest Tree	KNN : 90.78%
3.	Singh et al. [3]	2020	Implemented four ML algorithms and found their prediction accuracy then choose the best one among them for prediction.	UCI repository	Linear Regression, DT, SVM and K-NN	KNN : 87%
4.	Kavitha et al. [4]	2021	Created a hybrid model by combining two different ML algorithms.	Cleavela nd Heart Disease Dataset	DT, RF and Hybrid model (RF+DT)	Hybrid model : 88%
5.	Bharti et al. [5]	2021	Machine Learning algorithms is used along with deep learning to enhance the results of the prediction.	UCI repository	Combination of ML and DL	94.20%
6.	Katarya et al. [6]	2020	Used supervised machine learning for heart disease prediction.	UCI repository	ANN, DT, RF, SVM, NB and K-NN	
7.	Ramprakah et al. [7]	2020	Deep Neural Network is used with X^2 statistical model on the dataset for the prediction.	UCI repository	Deep neural networks, X^2-statistical model and machine learning	DNN performs better then ANN
8.	Sharma et al. [8]	2020	Demonstration of Talos hyper-parameterized optimizer to know that weather it is more efficient than other ML algorithms or not.	UCI repository	Logistic Regression, SVM, NB, K-NN Hyper-parameter optimization, RF	HPO : 90.78%
9.	Yadav et al. [9]	2020	Used four different types of trees algorithm and performed three experiments to make the conclusion	UCI repository	M5P, RF Tree, Reduced Error Pruning and Random Forest ensemble method	Random forest ensemble method gives better accuracy then others.
10.	Waigi et al. [10]	2020	Implemented ML classification algorithm to predict the risk of heart disease.	Kaggle	Decision Tree	73%
11.	Princy et al. [11]	2020	To predict the cardiac disease they have implemented six supervised	Kaggle	NB, DT, Logistic Regression,	Decision Tree overcomes all other algorithms

			ML classifiers and found the best one among them to predict the disease.		Random Forest, SVM, K-NN	
12.	Terrada et al. [12]	2020	Worked with ANN and Adaptive Boosting to enhance the accuracy.	UCI repository	Machine learning algorithms and ANN	ANN performs better then ML
13.	Mohan et al. [13]	2019	A hybrid model is made which consists of two ML algorithms and gives better result when compared with them.	Cleavela nd Heart Disease Dataste	Random forest and Linear Regression	
14.	Repaka et al. [14]	2019	Used Naive Bayes ML algorithm and compared it with the result of other algorithm and gets NB as the best one.	UCI repository	NB, Sequential Minimal Optimization, Bayes Net and Multi-Layer Perception	Naïve Bayes : 89.77%
15.	Tarawneh et al. [15]	2019	Applied different ML algorithms and developed a hybrid model with the ones which were selected most of the times.	UCI repository	SVM, NB, DT, K-NNN	Hybrid model : 89.2%
16.	Khan et al. [16]	2020	Cloud computing is used with Machine Learning were the data is collected from the cloud and then algorithms are applied. When the required criteria is matched then the trained model is stored in the cloud.	Internet of medical things (IoMT) enabled devices	SVM	93.33%
17.	Jindal et al. [17]	2021	Two ML algorithms were implemented on the dataset and they found out that these two works better then Naïve bayes algorithm.	UCI repository	Logistic regression and K-NN	88.50%
18.	Arroyo et al. [18]	2022	Prediction of heart disease is done with the help of ANN along with optimization techniques to enhance the accuracy for the prediction.	cardiovas cular disease dataset	Genetic Algorithm and Neural Network	73.43%
19.	Abdeldjou ad et al. [19]	2020	A hybrid approach is used to predict the disease.	UCI repository	Multi-Objective Evolutionary Fuzzy Classifier (MOEFC), and other Fuzzy based methods	
20.	Motarwar et al. [20]	2020	Cognitive approaches were used a ML framework	Cleavela nd Heart	RF, NB, SVM,	Random Forest : 95.08%

			of five algorithms is implemented on the dataset.	Disease Dataste	Hoeffding Decision Tree, and Logistic Model Tree(LMT)	
21.	Maji et al. [21]	2019	A hybrid model and other algorithms is implemented on the dataset and validated the prediction using tenfold validation test.	UCI repository	DT, ANN and Hybrid Decision Tree model(HDT).	HDT : 78.14%
22.	Krishnan et al. [22]	2019	Heart disease prediction is done using supervised algorithms and best two are selected among them.	UCI repository	DT and NB	91%
23.	Jothi et al. [23]	2021	Applied two ML algorithms and compared them with each other.	UCI repository	DT and K-NN	81%
24.	Ramalinga m et al. [24]	2018	Surveyed on five ML algorithms and found the best working way of each algorithm.		SVM, K-NN, NB, DT, RF	
25.	Garg et al. [25]	2021	ML algorithms are implemented on the dataset to predict the heart disease and concluded that ML algorithms predicts accurately and helps in the prediction of diseases.	Kaggle	K-NN and RF	K-NN: 86.86%

3 Proposed Methodology

Multiple approaches for cardiovascular disease prediction are mentioned in this section including ANN, SVM, DT, ensemble learning and K-NN [26-30] .

3.1 Data collection

Data obtained for forecasting heart disease was taken from [31]. The dataset is a labelled dataset consisting of 14 columns which include 13 independent features and 1 target variable. The split up in the dataset is as follows: training set accounts for 75% of data and rest i.e. 25% accounts for the test data. The dataset was checked for the missing value and the outlier, but they were not found.

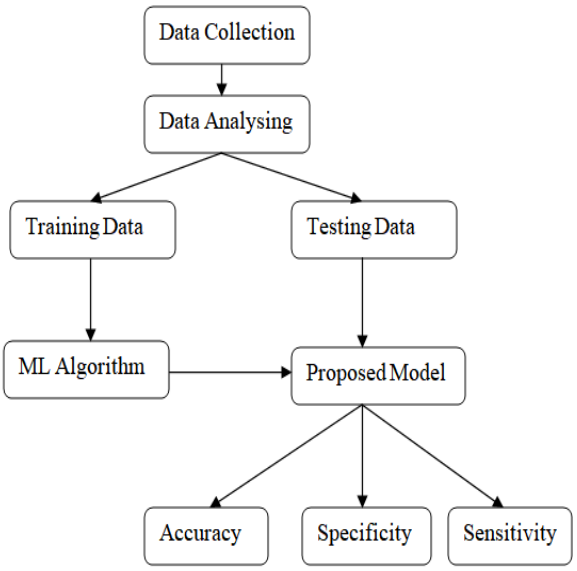


Fig. 1 Workflow for basic ML algorithms

3.2 Basic Machine Learning Models

K-Nearest neighbour(K-NN)

Data point are classified in K-NN based on how the neighbours are classified. Steps followed in K-NN algorithm [32-38].
Step 1: Number K of neighbour is chosen.
Step 2: K nearest neighbour are taken for the new point based on the hamming distance, Euclidean distance, Manhattan distance etc.
Step 3: From the selected neighbors, the frequency of neighbour is counted.
Step 4: Point is assigned to the class having majority.

Support Vector Machine (SVM)

In SVM [16][39-40] the main aim is to create a decision boundary or a hyper plane and based this new points are classified. The hyperplane selected has the maximum margin and is equidistance from the extreme points of the classes.

Decision Tree

Tree like structure is created using decision tree. Entropy of the data attribute is used for creating the tree. Root and other nodes are drawn based on the attributes. Root node, interior node and leaf node are the three nodes based on which analysis is made[2][41-42].

Ensemble Method

In ensemble method different but related analytical model are used which produces a single result due to which accuracy is improved. For the dataset Decision tree, K-NN and SVM are combined and the voting technique is used [43-44].

Artificial neural network (ANN)

ANN [12][45] try to replicate the neuron network that is there in the human brain. Layers present in ANN are input layer, output layer and hidden layer. It is possible that a network have multiple hidden layer. As the number of hidden layer increases the complexity of the network also increases. The nodes are chained together and all work together to perform a task. Weights are instantiated in input layer, which changes as we are trying to minimize the cost function.

4 Results and Discussions

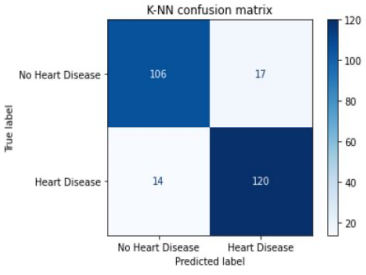
The analysis was performed on the publicly available dataset [31] consisting of 14 features (13 are independent features and one is labelled feature). The data was sliced into two: training set accounting for 75% and the rest i.e. 25% accounting for the test set. On the training set multiple models were trained and tested afterwards.

The accuracy obtained by all the models is mentioned in the Table 2.

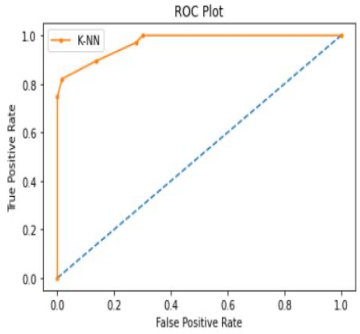
Table 2 Performance of different models.

S.No.	Technique	Accuracy (%)	Specificity (%)	Sensitivity(%)
1.	K-NN	87.93	86.17	89.55
2.	SVM	85.99	80.48	91.04
3.	Decision tree	88.32	86.17	90.29
4.	Ensemble model	89.88	86.99	92.53
5.	ANN	95.33	95.12	95.52

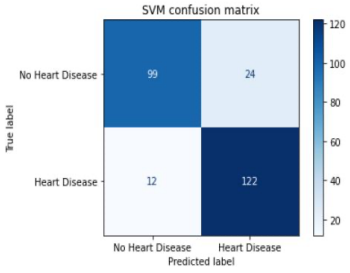
The confusion matrices and ROC curves for various applied models are shown in Fig. 2.



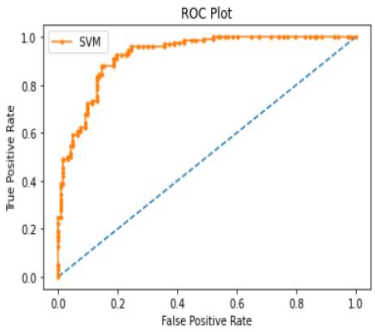
(*a*) K-NN confusion matrix



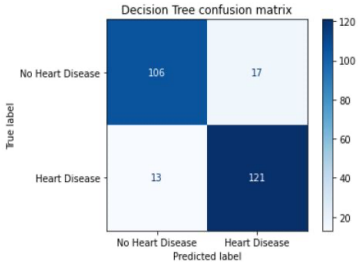
(*b*) K-NN ROC curve



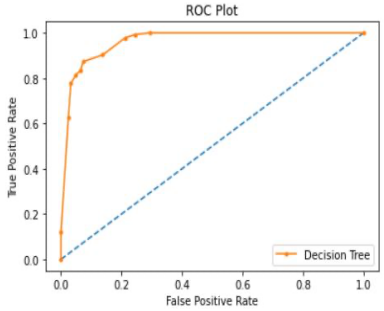
(*c*) SVM confusion matrix



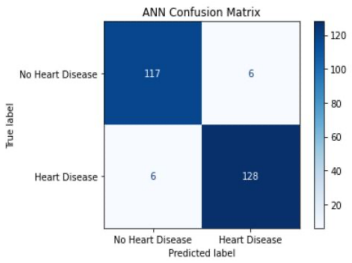
(*d*) SVM ROC curve



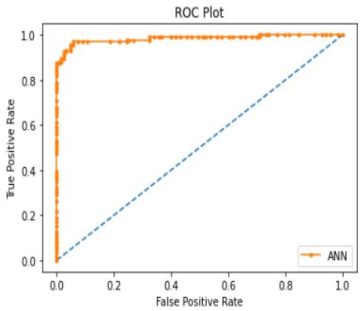
(*e*) Decision tree confusion matrix



(*f*) Decision Tree ROC curve



(*g*) ANN confusion matrix



(*h*) ANN ROC curve

Fig. 2 Confusion Matrices and ROC curves for different applied AI models.

The confusion matrix for the first four models can be seen above; from the test set the patients that are having heart disease and was predicted correctly are 120, 122, 121 and 128 by K-NN, SVM, Decision tree and ANN respectively. Similarly, the patients that are not having heart disease but were predicted as having heart disease are 17, 24, 17 and 6 by K-NN, SVM, Decision tree and ANN respectively. For the models K-NN, SVM, Decision tree and ANN the patients that are not having heart disease and was predicted correctly by the models are 106, 99, 106 and 117 respectively and the patients that are having heart disease but was predicted incorrectly as not having heart disease are 14, 12, 13 and 6 respectively.

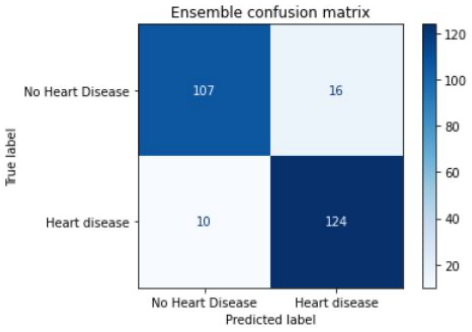


Fig. 3 Confusion matrix for Ensemble Model.

Confusion matrix for ensemble classifier can be seen above. Voting classifier is used for ensemble model and the type of voting that is used is hard voting. In hard voting the output is the class having the highest majority votes from each of the classifier. There are 124 patients that are having heart disease and was predicted correctly by the model whereas there are 16 patients that were not having heart disease but was predicted incorrectly as having heart disease by the

model. Similarly, there are 107 patients that are not having heart disease and were predicted correctly by the model and 10 patients that are having heart disease but were predicted incorrectly as not having heart disease by the model.

Fig. 3 consist of confusion matrix for ensemble classifier. Ensemble model is implemented with voting classifier. This model consisted of K-NN, Decision tree, SVM.

Fig. 4 shows the comparative analysis of the accuracy, sensitivity and specificity performed by different machine learning models (k-NN, SVM, Decision Tree, ANN and Ensemble classifier) on the given dataset.

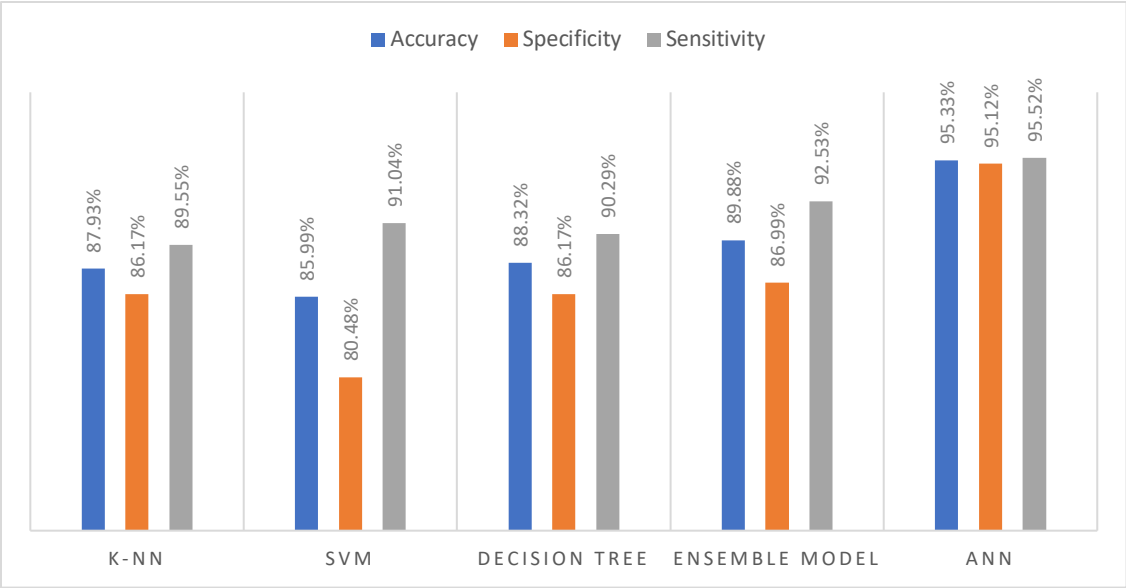


Fig. 4 Performance comparison of different models.

5 Conclusion

The objective of the work is to find the optimal method for correct prediction of heart failure cases. Various AI methods can be utilized by the experts to co-relate the diagnosis. The result of the model depends on the accuracy of algorithms. If the accuracy of the models is low, the ouput generated may be wrong or less accurate. Results can be improved by using more data along with multiple feature. In this study 14 main attributes were selected mentioned and five different techniques i.e. SVM, K-NN, ANN, ensemble model, and decision is applied, and it is found that the accuracy of the ANN was the highest i.e., 95.33%.

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