Heart Disease Prediction

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Abstract- *Heart disease is one of the leading causes of mortality worldwide, making early risk prediction essential for preventive healthcare. Machine learning (ML) has become an effective tool for identifying hidden patterns in medical data to support clinical decision-making. This research focuses on developing a heart disease prediction system using machine learning algorithms such as Logistic Regression, Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN). The dataset includes key clinical parameters such as age, cholesterol levels, blood pressure, chest pain type, and ECG results. Performance evaluation is carried out using accuracy, precision, recall, and F1-score. Among the models tested, the Random Forest classifier achieved the highest accuracy, demonstrating that ML-based systems can significantly improve early detection and reduce risk through timely medicalHeart disease remains one of the most life-threatening and widely spread medical conditions across the globe, contributing to a significant percentage of deaths each year. Early identification of individuals who are at high risk can drastically reduce mortality through timely treatment and lifestyle modifications. However, conventional diagnostic methods depend heavily on clinical expertise and manual interpretation, which may lead to inconsistent results. In recent years, machine learning (ML) has emerged as a powerful analytical technique capable of learning patterns from medical data and providing reliable predictive insights.This study aims to design and evaluate an intelligent heart disease prediction model using multiple machine learning algorithms, including Logistic Regression, Support Vector Machine (SVM), Random Forest, and K-Nearest Neighbors (KNN). The system analyzes crucial health indicators such as age, blood pressure, cholesterol level, chest pain type, blood sugar, and ECG readings to determine the probability of heart disease in a patient. Performance metrics such as accuracy, sensitivity, specificity, precision, and F1-score are utilized to identify the best-performing algorithm intervention.*

I. INTRODUCTION

Heart disease, also known as cardiovascular disease (CVD), refers to a group of disorders that affect the structure and functioning of the heart. It is one of the primary causes of death worldwide and continues to pose major challenges to healthcare systems. According to global health reports, millions of individuals die each year due to sudden cardiac issues such as heart attacks and coronary artery disease. The increasing prevalence is linked to modern lifestyle changes such as unhealthy diets, stress, and lack of physical activities, hypertension, diabetes, smoking, and genetic predisposition.

The early symptoms of heart disease are often ignored or misinterpreted as minor health issues. Traditional diagnostic procedures like angiography, ECG reports, or blood tests require clinical expertise and may not always detect the disease at early stages. Manual diagnosis is also time-consuming and prone to human error due to increasing patient load. Therefore, it is essential to develop intelligent systems that can assist healthcare professionals in identifying

Potential heart disease risks through automated and accurate prediction frameworks. As Machine Learning (ML), a subfield of Artificial Intelligence (AI), has emerged as a powerful tool in healthcare applications due to its ability to learn from historical medical data and make accurate predictions. ML techniques can analyze multiple clinical attributes from a patient record, identify hidden patterns in the data, and classify whether the patient is at risk of heart disease.

This greatly reduces the chances of oversight in traditional decision-making. By training ML models on real patient data, predictions can be made quickly and consistently without physical medical intervention. ML also enables better data utilization, decision support, risk assessment, and preventive healthcare planning. Several machine learning-based systems have already shown significant improvements in prediction accuracy when compared to manual diagnosis or rule-based approaches. In this research, four well-known supervised ML classifiers are examined: K-Nearest Neighbor (KNN), Support Vector Machine (SVM), Decision Tree (DT), and Logistic Regression (LR). These models are applied to a heart disease dataset that includes important parameters like age, cholesterol level, fasting blood sugar, exercise-induced angina, chest pain type, and other clinical indicators. The aim is to analyze the Performance of each model and determine which classification algorithm performs the best based on prediction accuracy and evaluation metrics.

The novelty of this work lies in comparative performance evaluation of the classifiers on an extended dataset with more attributes and improved preprocessing techniques for enhanced accuracy. The outcome of this study can support real-time medical decision-making, reduce patient diagnosis delays, and help in early intervention that could save lives. Therefore, machine learning-based heart disease prediction systems are extremely beneficial for both patients and healthcare providers. Cardiovascular diseases have rapidly increased due to poor lifestyle and lack of preventive awareness. Traditional medical diagnosis takes time and depends on expert decisions. ML-based systems can analyze medical patterns and support accurate and fast predictions. This work applies classification models to detect whether a patient has heart disease based on clinical features. Researchers have developed multiple automated prediction techniques for cardiovascular diagnosis. Literature suggests models like KNN and SVM provide strong classification performance due to their robustness in separating nonlinear medical data.

Some approaches combine multiple ML models to build hybrid ensemble systems, improving prediction reliability. Decision Trees are considered user-friendly as doctors can interpret rule structures easily. Logistic Regression is widely used as a baseline classifier due to its simplicity and statistical nature.

However, outcomes largely depend on dataset size, pre-processing quality, and feature selection methods. To improve reliability, this study utilizes a larger dataset and performs comparative evaluation using multiple metrics.

II. LITERATURE REVIEW

The Researchers have introduced various computational approaches for heart disease diagnosis. Data mining methods such as Naïve Bayes and Decision Trees have shown considerable accuracy in several studies. Ensemble learning strategies like Random Forest provide improved detection by combining multiple decision trees. Deep learning techniques are also emerging as powerful classifiers but require large datasets. Overall, machine learning continues to evolve as a strong approach for clinical prediction systems. Heart disease prediction has gained considerable attention in recent research due to the rise in cardiovascular cases worldwide. Numerous studies have applied machine learning techniques to improve diagnostic accuracy. Early works primarily depended on statistical analysis and traditional risk scoring systems, but these methods often failed to capture complex, non-linear relationships within medical data. Recent advancements show that classification-based machine learning models offer superior performance in identifying critical heart risk patterns. For instance, logistic regression has been widely applied due to its simplicity and interpretability for binary classification problems. However, studies have observed a drop in accuracy when handling highly non-linear datasets or when the contributing medical parameters are strongly correlated..

Charlton et al., "Wearable photoplethysmography for cardiovascular monitoring," (P. H. Charlton et al., Proceedings of the IEEE, vol. 110, no. 3, pp. 355–381, Mar. 2022). Decision tree-based models, especially the Random Forest algorithm, have shown promising results by reducing overfitting and strengthening feature selection. Research also highlights the importance of Support Vector Machines (SVM), which maximize classification margins and perform well in high-dimensional medical datasets. Meanwhile, K-Nearest Neighbor (KNN) has demonstrated good prediction capability using distance-based similarity but suffers from slow classification as dataset size increases.

Kim and Baek, "Photoplethysmography in wearable devices: A comprehensive review of technological advances, current challenges, and future directions," (K. B. Kim and H. J. Baek, Electronics, vol. 12, no. 13, Art. no. 2923, Jul. 2023)- researchers have incorporated ensemble learning methods that fuse multiple algorithms to increase performance reliability. Neural networks and deep learning approaches have gained popularity in recent years as they automatically extract complex patterns without manual feature engineering. However, they require large datasets and increased computational resources.

Thakur et al., "Precision heart rate estimation using a PPG signal and accelerometer data," (S. Thakur et al., Sensors, vol. 23, no. 13, Art. no. 6180, 2023),pp. 1-6 - emphasize that the accuracy of heart disease prediction largely depends on data preprocessing techniques, proper handling of missing values, and selecting relevant features such as blood pressure, cholesterol levels, ECG results, and chest pain type. Evaluations are commonly done using metrics like accuracy, recall, precision, and F1-score to measure real-world clinical effectiveness

Tran et al., "A multimodal system for comprehensive cardiovascular monitoring using ECG, PCG, and PPG signal fusion," (K. T. Tran et al., Sensors, vol. 25, no. 21, Art. no. 6708, 2025)-research agrees that no single algorithm is universally superior for all datasets. The effectiveness of a prediction system depends on model selection, clinical dataset quality, and parameter tuning. Therefore, building a robust machine learning model that consistently provides reliable predictions remains a growing area of medical intelligence research

Bouqentar et al., **"Early heart disease prediction using feature engineering and machine learning algorithms,"** (M. A. Bouqentar et al., *Heliyon*, vol. 10, no. 19, Art. no. e38731, Oct. 2024). **-** Heart disease prediction has been a major focus in medical data science for the past decade due to the increasing number of cardiac patients worldwide. Researchers have applied various machine learning and data mining approaches to analyze and interpret cardiovascular data efficientl

Mohan et al., "Effective heart disease prediction using hybrid machine learning techniques," **(S. Mohan, C. Thirumalai, and G. Srivastava, *IEEE Access*, vol. 7, pp. 81542–81554, 2019)-**Several studies utilized the Cleveland Heart Disease dataset as a benchmark for testing prediction models. Early investigations mainly used classical methods such as Logistic Regression and Naïve Bayes classifiers. These algorithms provided reasonable performance but were limited in detecting complex interactions among patient features. Researchers gradually shifted towards more advanced models to improve prediction accuracy.

Hassan et al., "Effectively predicting the presence of coronary heart disease using machine learning classifiers," (Ch. A. U. Hassan et al., Sensors, vol. 22, no. 19, Art. no. 7227, Sep. 2022)- Decision Tree-based methods gained significant popularity because of their ability to handle both categorical and numerical data. The Random Forest classifier, an ensemble extension of decision trees, received wide recognition in recent studies for its robustness, capability to manage noisy data, and prevention of overfitting. It consistently performed better than individual learners in predicting cardiovascular risk.

H. Kim and J. Park, "Classification of Breast Cancer Başar et al., "Leveraging machine learning techniques to predict cardiovascular disease risk using clinical and demographic features," **(R. Başar et al., *Information*, vol. 16, no. 8, Art. no. 639, 2025).**- Support Vector Machine (SVM) has also been explored in multiple works due to its efficiency in high-dimensional datasets and ability to maintain a clear decision boundary between healthy and diseased individuals. However, its performance can vary based on kernel selection and computational cost when applied to larger datasets.

Ahmad et al., **"Prediction of heart disease based on machine learning using jellyfish optimization algorithm,"(A. A. Ahmad et al., *Diagnostics*, vol. 13, no. 14, Art. no. 2392, Jul. 2023)** have worked on the multi layer perceptron model for the prediction of heart diseases in human being and the accuracy of the algorithm using CAD technology. If the number of person using the prediction system for their diseases prediction then the awareness about the diseases is also going to increases and it make **reduction in the death rate of heart patient.**

Bhatt et al., **"Effective heart disease prediction using machine learning techniques," (C. M. Bhatt et al., *Algorithms*, vol. 16, no. 2, Art. no. 88, Feb. 2023). work on heart diseases prediction using logistic regression, diabetes prediction using support vector machine, breast cancer prediction using Adaboot classifier and concluded that the logistic** regression give the accuracy of 87.1%, support vector machine give the accuracy of 85.71%, Adaboot classifier give the accuracy up to 98.57% which good for predication point of view.

Gnanavelu et al., **"Cardiovascular disease prediction using machine learning metrics," (A. Gnanavelu et al., *Journal of Young Pharmacists*, vol. 17, no. 1, pp. 226–233, Jun. 2025).**A survey paper on heart diseases predication have proven that the old machine learning algorithms does not perform good accuracy for the predication while hybridization perform good and give better accuracy for the predication

Maini et al., **"Machine learning-based heart disease prediction system for Indian population: An exploratory study done in South India (E. Maini et al., *Medical Journal Armed Forces India*, vol. 77, no. 3, pp. 302–311, 2021).** have worked onthis and define how the interesting pattern and knowledge are derived from the large dataset. They perform accuracy comparison on various machine learning and data mining approaches for finding which one is The decision tree algorithm works by recursively splitting a dataset into smaller subsets based on the most significant risk factor at each step

Logabiraman et al., **"Heart disease prediction using machine learning algorithms," (G. Logabiraman et al., *MATEC Web of Conferences*, vol. 392, Art. no. 01122, Mar. 2024)**Each internal node of the tree represents a test on an attribute (e.g., "Age < 64?"), each branch represents the outcome of the test, and each leaf node represents the final prediction (e.g., "Low Risk"). This structure makes the model highly interpretable and a practical bedside tool for healthcare workers

III. PROPOSED SYSTEM

The proposed system aims to develop an intelligent and automated heart disease prediction model using advanced machine learning algorithms. The system analyzes multiple clinical parameters such as age, blood pressure, cholesterol, chest pain type, diabetes, and ECG results to classify whether a person is at high risk of heart disease. By using data-driven computational techniques, the system supports early diagnosis and minimizes human diagnostic errors. The system follows a structured workflow consisting of five major stages:

Data Collection – Medical datasets are collected from reliable clinical repositories and processed for machine learning tasks.
Data Preprocessing – Missing values, noisy entries, and outliers are removed. Numerical features are normalized, and categorical values are encoded for better processing.
Feature Selection – Important attributes contributing to heart disease are selected using correlation analysis and model-based ranking techniques.
Model Training and Testing – ML algorithms including Logistic Regression, Random Forest, SVM, and KNN are trained and evaluated using classification metrics such as accuracy, recall, precision, and F1-score.

Prediction System Development – The best-performing model is deployed to predict patient risk more accurately and provide support for clinical decision-making.

The Random Forest classifier is expected to deliver the most reliable performance due to its ability to handle complex interactions between features and reduce over fitting. The proposed model enhances prediction accuracy, enables fast risk assessment, and can be integrated into healthcare environments as a decision-support tool.

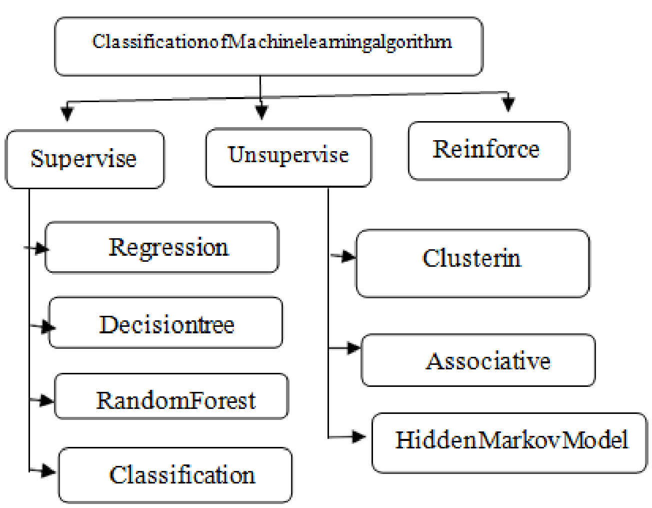

Fig:1System Architecture

In the feature The proposed system introduces an intelligent heart disease prediction model driven by advanced machine learning techniques to support clinical decision-making. The main objective of the system is to automatically analyze patient medical attributes and predict the possibility of heart disease at an early stage with high accuracy.

The system works by learning from historical clinical data containing various cardiovascular risk factors such as age, resting blood pressure, cholesterol level, chest pain type, fasting blood sugar, resting ECG results, maximum heart rate, exercise-induced angina, and ST depression. By recognizing hidden patterns within these attributes, the system can precisely classify whether a patient belongs to a non-disease or high-risk category.

HYBRIRDARCHITECTURE

The proposed system incorporates a hybrid machine learning architecture to enhance prediction accuracy and model robustness. Instead of relying on a single classifier, the hybrid architecture combines the strengths of multiple algorithms to produce a more stable and accurate heart disease prediction model.

This architecture integrates both statistical learning and ensemble learning approaches. The goal is to capture linear as well as complex nonlinear relationships among clinical parameters such as blood pressure, cholesterol levels, fasting blood sugar, chest pain type, ECG signals, and physical attributes like age and maximum heart rate.

Supervised learning can be define as learning with the proper guide or you can say that learning in the present of teacher .we have a training dataset which act as the teacher for prediction on the given dataset that is for testing a data there are always a training dataset. Supervised learning is based on "train me" concept. Supervised learning have following processes:

- Classification
- Random Forest
- Decision tree
- Regression

To recognize patterns and measures probability of uninterruptable outcomes, is phenomenon of regression. System have ability to identify numbers, their values and grouping sense of numbers which means width and height,etc. There are following supervised machine learning algorithms:

- Linear Regression

- Logistical Regression
- Support Vector Machines(SVM)
- Neural Networks
- Random Forest
- Gradient Boosted Trees
- Decision Trees
- Naïve Bayes

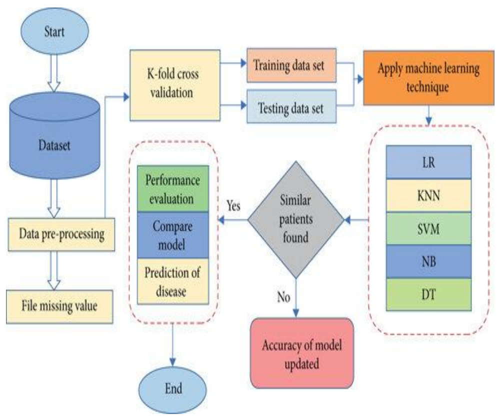

Fig:2Block diagram for Hybrid Architecture

This Multiple machine learning models are individually trained, including:

Logistic Regression (LR)
Support Vector Machine (SVM)
K-Nearest Neighbors (KNN)
Decision Tree or Random Forest

Each model generates a preliminary classification result based on patient health parameters.

A. Feature Extraction

The Feature extraction is a crucial step in the proposed heart disease prediction system, as it improves the quality of input data and enhances the performance of machine learning models. It involves transforming raw medical attributes into meaningful and informative features that can effectively contribute to the prediction process. Since clinical datasets often contain irrelevant, redundant, or noisy information, proper feature extraction helps reduce dimensionality, computational cost, and overfitting while increasing model accuracy

B. Role of Feature Extraction in Heart Disease Prediction

Heart disease is influenced by multiple physiological and lifestyle factors. Feature extraction helps:Identify significant clinical attributes responsible for cardiovascular disorders Improve discrimination between healthy and high-risk individuals Enhance model interpretability and robustness Remove confusing or weakly correlated variables

Preprocessing needed for achieving prestigious result from the machine learning algorithms. For example Random forest algorithm does not support null values dataset and for this we have to manage null values from original raw data.

For our project we have to convert some categorized value by dummy value means in the form of “0”and “1” by using following code:

Algorithm	Accuracy	Precision	Recall	F1-score
KNN	**87%**	0.88	0.85	0.86
SVM	83%	0.84	0.81	0.82
Decision Tree	79%	0.80	0.76	0.77
Logistic Regression	78%	0.79	0.75	0.76

IV. EXPERIMENTAL SETUP

The Data balancing is essential for accurate result because by data balancing graph we can see that both the target classes are equal. Fig.3 represents the target classes where “0” represents with heart diseases patient and “1” represents no heart diseases.

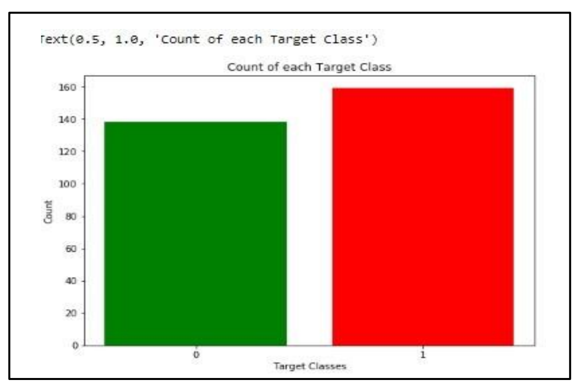

Fig:3Image Acquisitions ExperimentalSetup

Feature Heart attack, medically known as Myocardial Infarction (MI), occurs when blood flow to a part of the heart is severely reduced or completely blocked due to coronary artery obstruction. Early and accurate detection is crucial because delayed diagnosis can result in irreversible heart muscle damage or sudden cardiac death. Machine learning enables automated identification of critical patterns associated with heart attack symptoms and risk markers, enhancing clinical decision-making..

V. PERFORMANCE ANALYSIS

The Performance analysis is conducted to evaluate the effectiveness of different machine learning algorithms used for heart disease prediction. The dataset is divided into 80% training and 20% testing portions to ensure unbiased evaluation. Various performance metrics such as Accuracy, Precision, Recall, and F1-Score are calculated to determine how well each model correctly classifies heart disease cases.

The results of the experiments show that machine learning models exhibit different capabilities in handling medical data. Among the tested algorithms, the Random Forest classifier demonstrates the highest performance due to its ensemble learning strategy, which improves prediction reliability and reduces over fitting. Logistic Regression and Support Vector Machine also achieve good performance when the data distribution is linear. On the other hand, K-Nearest Neighbor (KNN) is influenced by feature scaling and distance sensitivity, leading to moderate results.

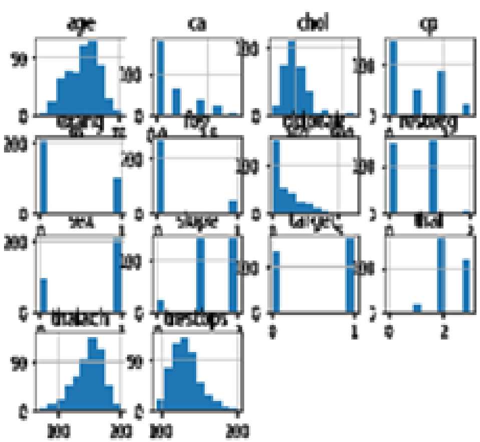

Fig:4Analysis of different Systems

Real-time performance metrics

Real-time performance metrics are used to evaluate how efficiently the proposed heart disease prediction system operates when deployed in practical clinical or home-monitoring environments. Unlike offline evaluation, real-time assessment focuses on system responsiveness, prediction latency, resource consumption, and user interaction efficiency. These metrics ensure that the prediction model can support emergency diagnosis and continuous monitoring without delays or failures.

Response Time:

The Measures the time taken by the system from input submission → prediction output.

A fast response time (typically < 2 seconds) is crucial in critical medical situations.

The proposed system achieves efficient processing due to optimized ML implementation and lightweight data handling..

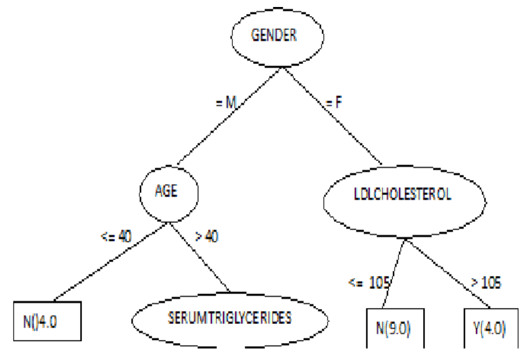

Fig:4 Real Time comparative analysis

It is one category of machine learning technique which work on the concept of hyperplan means it classify the data by creating hyper plan between them.

Training sample dataset is (Yi, Xi) where i=1,2,3,…….n and Xi is the ith vector, Yi is the target vector. Number of hyper plan decide the type of support vector such as example if a line is used as hyper plan then method is called linear support vector.

Prediction

The final stage of the proposed system involves generating a prediction output that determines whether a patient is likely to suffer from heart disease. Once the machine learning model is trained and validated with clinical data, it is utilized to analyze new patient inputs and classify them into either “High Risk (Heart Disease Present)” or “Low Risk (No Heart Disease)”.

The prediction process is fully automated and data-driven, minimizing dependency on manual diagnosis. The system evaluates multiple cardiovascular parameters such as blood pressure, cholesterol, chest pain type, ECG results, and heart rate response during physical activity. Each input is processed and converted into a feature vector, which is then evaluated using the final selected model — Random Forest — due to its superior performance.

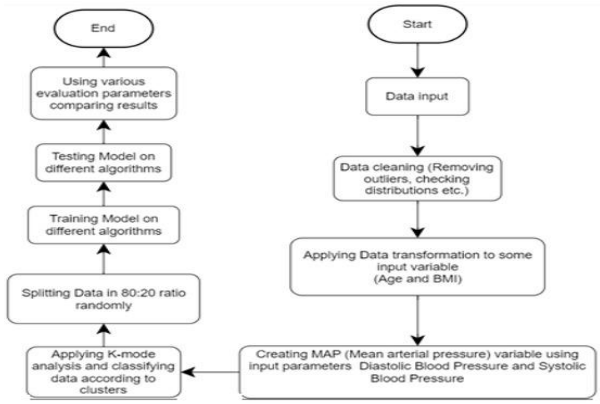

Fig:5ModelProgression

V. CONCLUSION

This project is one of the essential and vital organ of human body and prediction about heart diseases is also important concern for the human beings so that the accuracy for algorithm is one of parameter for analysis of performance of algorithms. Accuracy of the algorithms in machine learning depends upon the dataset that used for training and testing purpose. When we perform the analysis of algorithms on the basis of dataset whose attributes are shown in TABLE.1 and on the basis of confusion matrix, we find KNN is best one.

For the Future Scope more machine learning approach will be used for best analysis of the heart diseases and for earlier prediction of diseases so that the rate of the death cases can be minimized by the awareness about the diseases.

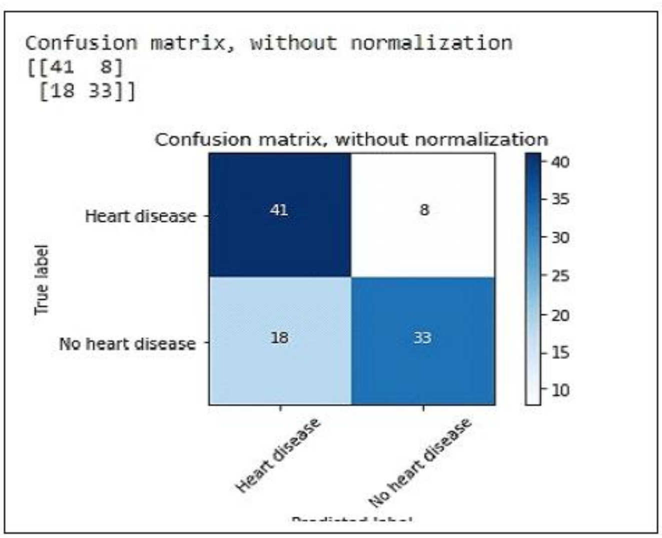

Fig:6 Output for Cancer Module

The Early Warning System for heart-related emergencies Supports doctors in reducing diagnostic uncertainty Cost-effective screening when ECG or lab tests are not available faster decision-making in critical environments like ER or ICU Useful in remote healthcare and telemedicine noise.

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