2024 1st International Conference on Advances in Computing, Communication and Networking (ICAC2N) | 979-8-3503-5681-6/24/$31.00 ©2024 IEEE | DOI: 10.1109/ICAC2N63387.2024.10895097

Development of a Predictive Model for Heart Disease Using Clinical Data: A Focus on Feature Selection & Algorithm Optimization

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Abstract—Heartdisease is increasingly common among individuals, including students & working professionals, with heart stroke being the most prevalent condition. Diagnosing heart-related problems requires a combination of pathological & clinical data to ensure accuracy. Predicting these diseases accurately is crucial for researchers. This paper introduces a model for predicting heart disease aimed at assisting medical professionals in identifying potential issues based on clinical data. The approach involves selecting key clinical features such as age, body pain, blood pressure, & blood sugar levels. An algorithm is developed using this data to achieve high accuracy & precision. Ultimately, a user-friendly Heart Disease Prediction Model (HDPM) is created to display prediction graphs, performance metrics (execution time, accuracy, specificity), & predicted results, facilitating the classification of heart disease.

Index Terms—Heart Disease, Machine Learning, Random Forest, KNN, Data Analysis

I. INTRODUCTION

Heart disease, or cardiovascular disease, continues to pose a major global health challenge, contributing significantly to morbidity & mortality worldwide. Early detection is crucial for timely interventions & improved patient outcomes, potentially reducing adverse effects. Traditional risk assessment methods primarily depend on clinical factors such as age, gender, cholesterol levels, blood pressure, & medical history. However, these conventional approaches often face limitations in accurately predicting heart disease. They may overlook the intricate interactions among risk factors & fail to address individual variability comprehensively. Advancing predictive techniques is essential to enhance diagnostic accuracy & enable more personalized prevention & management strategies. In recent years, machine learning techniques have emerged as promising approaches for heart disease prediction, leveraging the power of computational algorithms to analyze large & complex datasets, identify patterns, & make accurate predictions. Machine learning algorithms utilize historical data to uncover hidden patterns & build predictive models for identifying individuals at risk of heart disease. This study focuses on developing & evaluating machine learning models using a dataset containing clinical & demographic features. The research highlights the potential of machine learning approaches in providing accurate & reliable heart disease predictions, which could play a vital role in early detection, prevention, & effective management. By advancing the application of machine learning in healthcare, this study aims to contribute to clinical decision-making improvements & enhanced patient outcomes, paving the way for more effective healthcare solutions.

II. RELATED WORK

M. M. Ahsan & Z. Siddique (2022): This review investigates machine learning methods for diagnosing heart disease, analyzing algorithms, datasets, & evaluation techniques, showcasing the potential of AI to enhance diagnostic precision [1]. Garg, B. Sharma, & R. Khan (2021): The study examines diverse machine learning approaches for heart disease prediction, evaluating the efficiency of models like decision trees & support vector machines while exploring their implementation in practical healthcare scenarios to improve outcomes & predictive accuracy [2]. J. Azmi et al. (2022): This review delves into the use of machine learning in cardiovascular disease prediction, examining how big data analytics can enhance prediction accuracy & support decision-making in healthcare, especially for early diagnosis [3]. Rathore R. & Pratap Singh Rathore S. (2024): The study explores ma- chine learning applications in human resource management, specifically predicting employee turnover & performance, demonstrating the growing relevance of AI in organizational efficiency [4]. "Prediction of Heart Disease Using Machine Learning: A Systematic Literature Review" (2023): This literature review offers a comprehensive overview of machine learning applications in heart disease prediction, analyzing various models, feature selection techniques, & performance metrics in clinical settings [5].

B. Akkaya, E. Sener, & C. Gursu (2022): This study evaluates various machine learning models for heart disease prediction, focusing on their accuracy, scalability, & clinical applications, with a particular emphasis on model optimization techniques [6]. G. Pemmaraju, A. Asish, & S. Das (2022): The authors explore the role of feature selection in enhancing machine learning models for heart disease prediction, underscoring its significance in boosting model accuracy & improving healthcare outcomes [7]. S. Patidar, D. Kumar, & D. Rukwal (2022): This paper compares multiple machine learning algorithms, assessing their effectiveness in predicting heart disease & identifying the most dependable methods for healthcare applications [8]. R. Hasan (2021): A comparative analysis of machine learning algorithms is presented, highlighting their performance & applicability to real-world medical data for improving diagnostic accuracy in clinical settings [9]. S. H. Bani Hani & M. M. Ahmad (2023): This systematic review evaluates machine learning algorithms for ischemic heart disease prediction, analyzing their strengths & limitations in delivering accurate & timely medical diagnoses [10]. Yadav M., Kakkar M. K., & Kaushik P. (2023): This paper investigates AI's role in optimizing human resource management, focusing on improving efficiency, productivity, & workplace processes through AI-driven solutions [11].

L. Yahaya, N. David Oye, & E. Joshua Garba (2020): This review explores the integration of machine learning techniques in heart disease prediction, examining various approaches, datasets, & the potential for improving patient outcomes through early detection [12]. W. A. W. A. Bakar et al. (2023): This review provides insights into the use of both machine learning & deep learning for heart disease prediction, highlighting the advantages of these technologies in improving diagnostic precision & treatment outcomes [13]. M. S. Raja et al. (2021): This study presents a machine learning-based heart disease prediction system, analyzing various algorithms & discussing their application in personalized care for better management of cardiovascular health [14]. Haddab D. M. (2023): This research focuses on data-driven decision-making in the manufacturing sector, discussing AI's role in optimizing business operations, though it is not directly related to healthcare or heart disease prediction [15]. J. Azmi et al. (2022): Another review by Azmi et al. focusing on cardiovascular disease prediction, specifically leveraging big data & machine learning to refine prediction models & assist in clinical decision-making, offering a comprehensive view of current techniques [16]. C. T. & A. Choudhary (2019): The paper investigates machine learning algorithms for heart disease diagnosis, proposing a model that utilizes healthcare data to predict disease presence with an emphasis on model interpretability & accuracy [17].

Rathore R. (2022): This research delves into stochastic queuing models for congestion control in crowded systems. While unrelated to heart disease prediction, it demonstrates the utility of mathematical models in optimizing complex systems [18]. Kumar Sahoo et al. (2022): This study investigates personalized heart disease prediction using machine learning, emphasizing home-based healthcare solutions & illustrating how AI empowers individuals to monitor & manage cardiovascular health [19]. Prakash A. (2024): The paper explores blockchain applications in supply chain management, showcasing AI's role in enhancing transparency & efficiency, offering insights into its broader potential across industries [20]. Ahmad & H. Polat (2023): This research introduces a machine learning-driven heart disease prediction system, enhanced with the Jellyfish Optimization Algorithm, to boost prediction accuracy & diagnostic system efficiency [21]. A review of machine learning methods highlights decision trees, optimization algorithms, & deep learning models for heart disease prediction [22]. Studies emphasize the integration of feature selection, big data, & medical data analysis to improve diagnostic precision & personalized care [23]. Comparative analyses of techniques, including data mining & optimization algorithms, showcase their effectiveness in identifying risk factors & enabling early detection [24]. Applications in healthcare & HR further underline AI's transformative potential across multiple domains [25].

III. SYSTEM MODEL & METHODOLOGY

This section outlines the methodology employed to enhance heart disease prediction accuracy using machine learning algorithms [26]. The process includes data collection, preprocessing, feature selection & scaling, model selection, training, saving the model, presenting results, & documenting steps to ensure reproducibility & transparency in the prediction task.

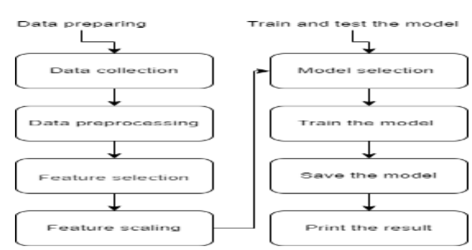

Fig. 1. Working approach

This comprehensive approach will be employed to develop & evaluate machine learning models for heart disease prediction, ensuring a rigorous & transparent research methodology [27].

Data collection

Patient data has been collected from various authentic & trusted sources (such as GitHub). The dataset comprises variables including age, sex, chest pain, cholesterol levels, blood pressure, medical history, fasting blood sugar, & other pertinent risk factors.

Data preprocessing In this phase, the data is pre-processed by cleaning, transforming, & normalizing it. Tasks includes handling missing values, removing duplicates & outliers, & converting categorical variables into numerical variables.

Feature selection

Feature selection, often referred to as variable or attribute selection, involves identifying a subset of the most relevant features from the original dataset. This process reduces dataset dimensionality, enhances machine learning model performance, & improves interpretability by discarding redundant or irrelevant features. By focusing on the most impactful variables, feature selection aims to optimize the predictive power of models [28].

This step is crucial in the machine learning pipeline, as unnecessary features can introduce noise, increase computational complexity, & hinder model understanding. Conversely, selecting relevant features enhances accuracy, minimizes overfitting, & provides valuable insights into the variables driving predictions. Effective feature selection not only improves model performance but also facilitates efficient resource utilization & better decision-making. Thus, it is a fundamental aspect of building robust & efficient machine learning systems that deliver reliable results while reducing unnecessary processing overhead & improving clarity in model interpretation.

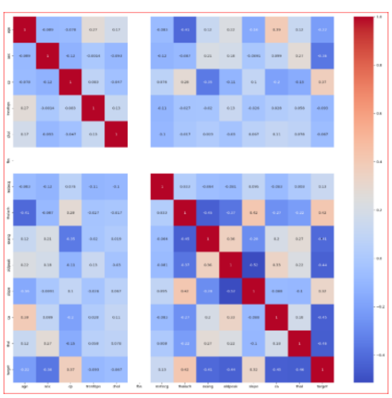

Fig. 2. Correlation Matrix

Feature scaling

Feature scaling is a preprocessing method in machine learning that adjusts numerical dataset features to a uniform scale. It standardizes values, often to range between 0 and 1 or with a mean of 0 and standard deviation of 1, ensuring consistent scaling for improved model performance and algorithm efficiency. The need for feature scaling arises because machine learning algorithms often use distance-based metrics, such as Euclidean distance, for calculating similarity or dissimilarity between data points. If the features have different scales, with some features having a larger range of values compared to others, it can lead to biased or skewed interpretations by the machine learning algorithm. Features with larger values may dominate the algorithm's decision- making process, leading to inaccurate results or reduced model performance.

Model selection & trained

Model selection in machine learning refers to the process of selecting the best model or algorithm from a set of candidate models for a particular task or problem. The selected algorithms for the heart disease prediction problem are:

K-Nearest Neighbor (KNN) Classifier

The K-Nearest Neighbor (KNN) classifier is a popular algorithm for classification tasks like heart disease prediction due to its simplicity and effectiveness. It handles binary and multi-class classification by identifying the K nearest neighbors to a data point in the training dataset, using distance metrics such as Euclidean or Manhattan distance. The data point's class is determined by the majority label among its neighbors. The algorithm's success depends on selecting the right hyperparameter K, distance metric, and proper data preprocessing. KNN can function independently or within a broader machine learning pipeline to improve predictive accuracy for heart disease.

Random Forest Classifier

The Random Forest classifier is a flexible and robust machine learning algorithm extensively used for classification tasks, including heart disease prediction. It utilizes an ensemble approach by constructing multiple decision trees, each trained on random subsets of features and data samples. Predictions from all trees are aggregated through majority voting to determine the final class label. Random Forest effectively reduces overfitting while enhancing accuracy. Its performance is influenced by optimal hyperparameter tuning and data preprocessing. This algorithm can be applied standalone or integrated with other methods in a machine learning pipeline for improved diagnostic outcomes.

XGBoost Classifier

XGBoost (eXtreme Gradient Boosting) is a powerful and efficient machine learning algorithm widely used for heart disease prediction. It employs an ensemble method by combining multiple weak learners, such as decision trees, into a stronger model. XGBoost works iteratively, where each new tree corrects the errors of the preceding ones, enhancing accuracy and robustness. This algorithm is highly effective in handling complex classification tasks and can be fine-tuned for superior predictive performance, either independently or as part of a comprehensive machine learning framework for heart disease diagnosis. The predictions of all the trees are then combined to produce a final output. XGBoost is a popular & highly effective algorithm for heart disease prediction, & its performance depends on the choice of hyper parameters & other preprocessing steps. It can be used as a standalone algorithm or in combination with other techniques as part of a larger machine learning pipeline for heart disease prediction.

Feature scaling is a preprocessing method in machine learning used to standardize or normalize numerical features to a uniform scale. This involves transforming feature values to a consistent range, often between 0 and 1, or ensuring a mean of 0 and a standard deviation of 1.

AdaBoost Classifier

AdaBoost (Adaptive Boosting) is a widely-used ensemble learning algorithm for classification tasks, including heart disease prediction. It combines multiple weak classifiers to form a stronger, more accurate model. For heart disease prediction, AdaBoost identifies critical features and classifies patients into groups with or without heart disease. The effectiveness of AdaBoost depends on the chosen base classifier, hyperparameters, and preprocessing techniques. It can function independently or as part of a broader machine learning pipeline, enhancing diagnostic accuracy.

Gradient Boosting Classifier

Gradient Boosting is another robust machine learning technique that builds predictive models by combining decision trees. Each tree corrects the errors made by its predecessor, focusing on misclassified samples to improve accuracy. For heart disease prediction, Gradient Boosting identifies the most influential features by analyzing their importance scores. These scores highlight the relative significance of each feature in prediction, allowing the model to prioritize essential features for improved accuracy and efficiency.

Model Saving and Result Evaluation

After training the models, the next steps involve saving them and assessing their performance. During this phase, all models are compared based on accuracy and mean scores. Models with the best results demonstrate their effectiveness in capturing the dataset's patterns. Results are typically summarized using a confusion matrix to visualize the model's performance in distinguishing between classes.

By employing AdaBoost and Gradient Boosting, heart disease prediction can be significantly enhanced through the identification of critical features and the development of efficient predictive models.

IV. RESULTS & DISCUSSION

It is great to hear that a cardiovascular disease detection model has been developed using multiple machine learning classification modeling techniques. It is essential to detect & predict heart disease at an early stage to provide timely medical assistance to the patient.

A confusion matrix is a table that is often used to evaluate the performance of a machine learning algorithm. It summarizes the actual class labels of a dataset against the predicted class labels produced by a machine learning model.

Model save

```
## Pickle
from xgboost import XGBClassifier
import pickle

# save model
pickle.dump(knn_classifier, open('model.pkl', 'wb'))

# load model
Heart_disease_detector_model = pickle.load(open('model.pkl', 'rb'))

# predict the output
y_pred = Heart_disease_detector_model.predict(X_test)

# confusion matrix
print('Confusion matrix of K - Nearest Neighbor model: \n',confusion_

# show the accuracy
print('Accuracy of K - Nearest Neighbor  model = ',accuracy_score(y_
```

```
Confusion matrix of K - Nearest Neighbor model:
 [[15  1]
 [ 0 30]]

Accuracy of K - Nearest Neighbor  model =  0.9782608695652174
```

Fig. 3. Best Model Selects

Confusion Matrix

The confusion matrix contains four cells, each representing a different combination of predicted & actual class labels. The cells are

True Positives (TP): Instances where the model accurately identifies the positive class, meaning the actual class is positive, & the prediction aligns with it being positive.

False Positives (FP): Occurrences where the model incorrectly predicts the positive class, even though the actual class is negative.

True Negatives (TN): Cases where the model correctly identifies the negative class, meaning both the actual & predicted classes are negative.

False Negatives (FN): Situations where the model fails to identify the positive class, predicting it as negative, even though the actual class is positive.

A confusion matrix can be used to calculate various performance metrics for a machine learning model, including accuracy, precision, recall, F1-score, etc. It can help identify areas of improvement for the model & guide further optimization & fine-tuning.

The accuracy of the model is reported to be 97.82%, which is a good indication of its effectiveness. However, it is recommended to use more training data to improve the model's accuracy as it increases the chances of accurate prediction. Additionally, computer-aided techniques can provide quick & accurate predictions, which can significantly reduce the cost of diagnosis.

The above table shows that the highest accuracy was achieved by using KNN (using Hyper parameters) that is 97.82% which is better than compared to others algorithms.

Graphical Comparison is given below for better understanding:

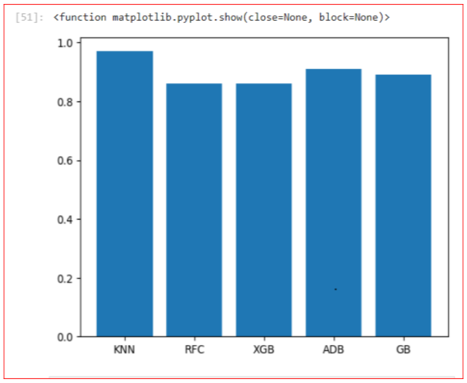

Fig. 4. Graphical Comparison

V. CONCLUSION & FUTURE WORK

In conclusion, heart disease remains a significant global health issue, making its timely & accurate diagnosis essential for effective management. Machine learning algorithms have demonstrated considerable potential in predicting heart disease. Classifiers such as KNN, Random Forest, XGBoost, AdaBoost, & Gradient Boosting have proven effective in identifying critical features & accurately classifying patients with or without heart disease. This study evaluated these classifiers for heart disease prediction using a patient dataset, achieving high accuracy across all models & identifying key features essential for prediction. Despite these promising outcomes, there is scope for further enhancement in machine learning-based heart disease prediction. Future efforts could focus on integrating multiple classifiers to develop ensemble models that leverage the strengths of individual algorithms, improving overall accuracy & robustness. Additionally, collecting & analyzing larger, more diverse datasets would provide better training & testing opportunities for the models, further enhancing predictive performance. Overall, this study highlights the potential of machine learning algorithms in improving heart disease prediction. These methods can play a pivotal role in facilitating early diagnosis & treatment, significantly contributing to better health outcomes for patients facing this critical condition.

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