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Analysis of Cardiac Disease based on AI Prediction Techniques using data analytics approach

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***Abstract*— Patients who have an increased likelihood of coronary heart disease can reduce their consequences by changing their lifestyle, with the support of early diagnosis. Healthcare expenses are rising above, both company budgets and the average cost of medical treatment nationally, due to asymptomatic conditions like cardiovascular disorders. Early detection and treatment of these illnesses are essential. Utilizing the data that is accessible in healthcare systems has been significantly impacted by recent technological advancements. As part of this, patients' Heart Disease (HD) may be predicted using the massive amount of data. However, due to concerns with prediction and diagnosis performance and accuracy, projecting HD has emerged as one of the main obstacles facing the healthcare sector. The main challenges were to apply homogeneous data mining techniques to define the most significant causes of heart disease and to accurately predict the overall risk. Using Data Analytics (DA) to speed up the prediction process is one way to make use of massive amounts of health care data. Selecting the optimal analytical methods, however, is the most crucial step as it will impact the final result of the diagnostic and forecasting. In order to assess the effectiveness of the methods for HD forecasting, this study intends to implement DA approach in collecting of databases. In this research work, Best First Search (BFS) has been used to identify the most important attributes for HD prediction. This study employs a range of ML approaches based on AI to predict HD. The Random Forest (RF) method, which uses specific characteristics, has the highest accuracy rate (98.63%) in this experiment. The BFS extracted 14 relevant features and then compared them using AI approaches. Based on the analysis, feature selection has enhanced the DA technique by improving the efficiency and precision of the classification model's prediction.**

Keywords: ***Heart Disease (HD), Data Analytics (DA), diagnosis, prediction, Artificial Intelligence (AI), Machine Learning (ML)***

I. INTRODUCTION

Healthcare encompasses a diverse range of fields. Its main objectives are to prevent, identify, treat and care for diseases and conditions that have an influence on the general health and welfare of individuals and communities [1]. The range of services is broad and include things like medical examinations, initiatives, counselling, and campaigns to promote public health. Healthcare providers, includes a wide variety of people like doctors, nurses, therapists, and researchers, who work together to protect patients' overall health, that includes their emotional, physical, and mental health. Healthcare entails more than just a clinical care; it also includes preventive medicine, medical advancement, and medical information, all of which enhance people's overall standard of living [2]. The human heart is one of the most important organs. Its function is to pump the blood throughout the body. HD refers to any condition that may cause disruptions in the heart's normal functioning. Heart Failure (HF) and Coronary Artery Disease (CAD) are the two most common types of HD in the world, while there are numerous others as well. The main reason for coronary HD is obstruction or shrinking of the coronary arteries [3]. Moreover, the coronary arteries deliver blood to the heart. The leading cause of mortality worldwide is the Coronary Heart Disease (CHD) that impacts over 26 million individuals and accounts for 2% of annual fatalities. Worldwide, about 17.5 million died in 2005[4]. 10% of the population in the developing world is over 65 years old, and 2% of the global population has CAD. Only about 2% of the yearly healthcare expenditure is allocated to the treatment of CAD. The US government funded $35 billion in 2018 on CAD [5]. Heart failure risk can be increased by a number of circumstances. Medical experts split these risk variables into two groups: modifiable risk factors and unchangeable risk factors. The risk variables that are unchangeable are age, gender, and family history. Risk variables also include things like high blood pressure, smoking, sedentary lifestyle, and high cholesterol [6]. HD is a serious condition, hence a diagnosis or prognosis is required. There are several ways to achieve it. Angiography is a widely used method utilized by most doctors globally. Nevertheless, there are certain disadvantages to the angiography method. The process of diagnosing a patient is costly and requires a great deal of analysis, which makes the task of a physician extremely challenging. These drawbacks serve as motivation for the development of a less invasive approach for HD prediction. These traditional approaches deal with patient medical records; also, because they are carried out by humans, they are labour-intensive and may produce inaccurate results [6].

Utilizing recent developments in healthcare data, a health prediction system can be created to enhance HD monitoring and diagnosis. Using DA to help with early diagnosis of cardiac problems is one way to make use of massive amounts of healthcare data. Using state-of-the-art techniques, the DA approach analyses enormous volumes of information in order to find hidden trends and improve the understanding of a particular data set, to create an analytical model, that can be applied for better diagnosis, predict outcomes, and analyse symptoms. The most crucial step in a DA approach is selecting the optimal analytic methods. Without a thorough conceptual understanding of every algorithm and input choice, the approach is unable to effectively identify the best suitable model for diagnosis execution. In order to address the problems, this study intends to use a DA strategy to gather HD data from various databases and examine how well the strategies work to predict HD in patients.

Our research's main objective was to advance both current and novel AI-based cardiac preventive medicine techniques, with a focus on HD prevention. This is a result of the rise of lifestyle diseases, particularly cardiovascular diseases, being halted but not reversed; as a result, AI-based automatically supervised prevention appears to be a significant chance to advance the aforementioned fields. This could have significant repercussions on the social, medical, and scientific domains as well as the economy. The purpose of this work is to create and evaluate an AI tool for preventative medicine that can forecast the likelihood of developing a heart condition. In order to calculate a HD likelihood based on a variety of patient variables and, from a computational perspective, identify the minimal set of characteristics required to do so, it combined and compared a number of AI approaches. When implemented to a particular patient, this signifies advancements in this area of study, leading to enhancements in preclinical treatment and diagnostics, along with increased prediction precision in preventative medicine.

The goal of ML, a subfield of AI, is to empower machines to solve problems intelligently by leveraging data and algorithms. With more amount and higher quality data, ML can learn more accurately than humans would be able to, all without the need for explicit programming for every task. Making predictions, classifying data, gaining insights from data mining, and identifying patterns using data mining are the most popular applications of ML. ML is applied in many different contexts in the real world, such as recommendation engines, prediction models, spam filtering, and malware detection. Because there are so many distinct use cases, selecting the best ML algorithm is essential because each model has unique applications and strengths, and model success depends on the quantity and quality of data. To improve accuracy, a strong ML model continuously learns from new data. ML applications are causing a significant revolution in the healthcare industry.

The healthcare sector is undergoing a dramatic transformation because of ML applications. ML is an aspect of AI software, striving to increase the efficiency and reliability of work carried out by medical practitioners. ML holds significant promise for countries struggling with shortage of physicians and an overloaded healthcare system. The ability to identify patterns in large data sets and speed up the process of identifying diagnostic indicators linked to disease or risk makes it essential to medicine. Clinical therapy is currently using ML categorization algorithms. Classification techniques can be applied to acquire knowledge. Reliable HD prediction can help clinicians make accurate choices and improve the outcome of patients. ML-based techniques, such as Decision Tree (DT), Fuzzy Logic (FL), Logistic Regression (LR), Random Forest (RF), and Naïve Bayes (NB) have been widely used in the early diagnosis of HD. The percentage of HD deaths has decreased thanks to these professional medical decision-making systems powered by ML.

The results of the several approaches demonstrate that different elements can influence the study's conclusions. The accuracy of each classifier's performance was evaluated in this study using a subset of characteristics. The study makes recommendations on which classifier to use with particular dataset when building a high-level intelligent system for HD. The suggested system will help medical professionals diagnose patients with HD more correctly. This paper presents a way for applying DA tool to evaluate the data. To monitor their performance in HD data, five algorithms based on the DA approach are put into practice. Based on how well each model performs on the training set, an evaluation will be conducted to determine how each model may impact the outcome. Numerous variables, including physical examination results, early symptoms, and patient indicators that may impact the prognosis of heart health, were studied.

II. LITERATURE REVIEW

A prediction model that makes use of numerous established categorization algorithms and different combinations of information is presented by Al Alshaikh et al. [7]. Its thorough evaluation indicates that the suggested ML-based HD prediction method (ML-HDPM) performs exceptionally well over a wide range of critical evaluation parameters. The study findings show promise in terms of performance indicators, including high rates of accuracy. The method also demonstrates gains in the rates of false positive and true positive, suggesting that it has the ability to predict accurately while reducing false alarms. Rojek et al. [8] created an AI – based method that can forecast the likelihood of a cardiac arrest. From a computational standpoint, it determined the lowest set of parameters needed to accomplish that goal by combining and comparing multiple AI algorithms and techniques to determine the likelihood of a specific cardiac arrest depending on a range of patient factors. When the study's models are compared, it becomes clear that the LR models are far more precise. Their moderate value of prediction is nevertheless suitable for making a preliminary diagnosis and patients' selection who require precise screening. By utilizing ML and data visualization technologies, Leonardo et al. [9] provides an instructional and early warning detection system that is accessible to the general public, describing a case of CAD. According to research, although adopting a better lifestyle might reduce the likelihood of developing CAD, age and natural degeneration of the health system still play a role.

According to Chang, et al. [10], analysis of data is required for this kind of tool, which is noteworthy because of its accuracy rate of about 83% over training data. Next, address the RF classifier algorithm, its experiments and outcomes, which improves research diagnosis accuracy. In order to develop an easy technique to forecast HD, Kanrar et al. [11] utilized ML algorithms, choosing the best one, based on its classification report. For the benefit of humanity, it aids in the development of affordable software to forecast HD. The primary areas of limitation for these efforts pertain to the algorithms and classification methodologies used in HD prediction. In this field, researchers want to use a variety of data cleansing techniques to create a database that is suitable for their planned algorithms.

Maarten et al.'s [12] focused on the AI required to address the specific medical issue of HD. This paper has shown that different linear regression models offer ideal circumstances for estimating the likelihood of HD. In comparison to other algorithms, the regression algorithm has a good classification accuracy. The recommended approach by Chowdary et al. [13] used sampling processes and methods for feature selection to identify the more valuable attributes in the imbalanced database. When models of classifiers were finally used, an ensemble classifier produced very accurate results. The suggested method proved to be successful in predicting HD in two datasets. According to Jindal et al. [14] proposes ML methods like LR and K-NN can be used for predicting and categorizing patients with HD. The accuracy rate of exceeding 88% in this study shows that the K-NN technique operates at peak efficiency. Sahoo, et al. [15] have proposed numerous methods for assessing CAD data that contains 13 crucial features, including LR, NB, SVM, DT, K-NN, and UCI repository data. According to this study, the method of SVM provides the best precision in data analysis, with an 85% success rate. Uyar et al. [16] created the Genetic Algorithm (GA) that utilized the programmed Recurrent Fuzzy Neural Networks (RFNN) to assess HDs. In that study, the UCI HD database was used. The findings showed that the evaluation's efficiency percentage was 97.78%. An accurate combination of techniques for diagnosing CHD was developed by Arabasadi et al. [17]. To diagnose HD, P.K. Anooj [18] used a customized fuzzy rule-based algorithm that collected information from the patient's medical record in a methodical manner. A fuzzy rule-driven guidance system and automatic creation of balanced fuzzy rules are the two phases of the proposed HD prediction technique. The data mining approach, selection of attributes, and attribute weightage methodology are used in the first step to produce the balanced fuzzy rules.

III. DATASET DESCRIPTION

The HD directory from the UCI ML Repository, gathered on the Kaggle website, served as the study's data set [19]. It includes 76 features from 1025 patients that characterize the various health variables and HD diagnosis. As seen, only 19 attributes in total have been chosen for the dataset in this investigation, with the target field referring to the patient's existence of HD. The dataset description reveals patients belonging to both gender, under the age group of 26-90. Inclusion of patients based on normal and abnormal variables like diet, stress, ECG with heart rate of 60-120 were done. Complaints of obesity, diabetes, smoking, physical activity, edema, history of chest pain –typical, atypical and non-angina type were analysed. Both class 1(patients having HD) and class 0 (patients with no HD) were the targets. The systolic (80-180) and diastolic (60-120) blood pressure of these patients and their troponin levels were monitored.

IV. DATA PREPROCESSING

To enhance the raw data's quality, a pre-processing procedure will be employed. Processing of the raw data will minimize noise and missing information that affect the study's outcome. Following pre-processing, the results will be utilized in the stages to come. Normalization of the data is necessary because the study shows discrepancies in the ranges of the variables. The following equation (1) describes how normalization is carried out:

$$X \text{ normalized} = \frac{x - min(x)}{max(x) - min(x)} \quad (1)$$

Here the, most recent standardised value is denoted by X normalized. The least value of each feature is assigned the number "0," its highest score value is assigned the number "1," and all additional values are converted to integers between "0" and "1."

Using a DA method, descriptive statistics of the dataset

This research work predicts heart illness using a variety of ML-based methods. Prior to moving on to the section on technique evaluation, the data is examined, and the results are shown in the next section. Table 1 includes 59 values for age, 49 values for diastolic and systolic blood pressure, 44 values for Heart Rate (HR), and 56 values for target. A portion of the 59 patients HR, bp_diastolic, and bp_systolic variables are missing. As a result, before building the model, this study employed a number of techniques to fill in the missing variables. The majority of the patients are elderly, as evidenced by the research's observation that the mean age is 59. The age ranges that applied were minimum (26 years) and maximum (90 years). The data is insufficient, as demonstrated by a standard deviation of 17.97 for the 56-to-75-year-old age group, which likewise visits the doctor more often. The majority of individuals have normal bp/sys values, as indicated by the bp/sys mean of 128. The bp_diastolic value ranges from 50 Hgmm to 125 Hgmm, with 77 being the mean value. The bp_systolic value ranges from 75 Hgmm to 185 Hgmm at its minimum and highest, respectively. It is evident that some data are missing given the 48 HRs, and the median is used to fill up those gaps. The mean HR is 84 beats per minute(bpm), with the maximum HR is 166 bpm.

Table 1 descriptive statistics of the numeric value

	Age	HR	bp_systolic	bp_diastolic	Target
count	59.0	44.00	49.00	49.00	56.00
mean	17.97	84.75	128.00	77.5	0.60
Std	17.67	24.60	24.00	17.44	0.50
Min	27.00	55.00	75.00	50.00	0.00
25%	60.00	75.50	115.00	68.15	0.00
50%	65.00	79.00	145.00	79.00	1.00
75%	70.00	95.00	160.75	95.00	1.00
Max	95.00	175.00	195.00	120.00	1.00

Figure 1 shows the association between all attributes and the desired value. The graph demonstrates the different correlations that exist between different qualities and the end point.

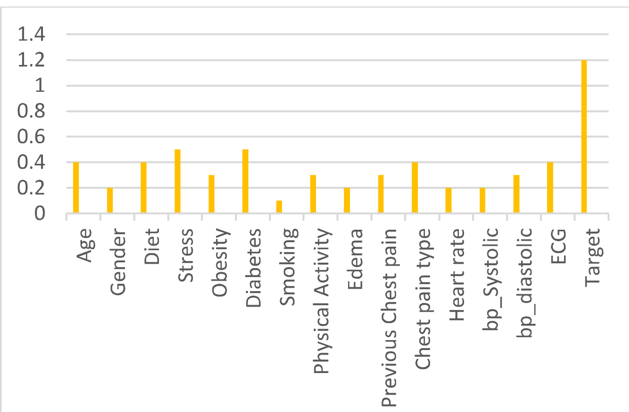

Figure 1 correlation of attributes with the target value

The data are categorized as follows: male and female, normal and abnormal diet, normal and abnormal stress, tobacco use and tobacco free, being obese and non-obese, physical and sedentary activity, positive and negative troponin levels, diabetic and non-diabetic and typical and abnormal electrocardiograms (ECGs), as illustrated in Figure 2. According to the American Heart Association (AHA), the risk of CVD in men and women in the USA is 40% between the age of 40 and 59, 75% between the age of 60 and 79, and 86% in those over the age of 80 [20]. Figure 2 shows that men and women are afflicted at rates of 77.5% and 22.5%, respectively. It is apparent that there are on average more men than women with HD. Type 2 diabetes hypertension, dyslipidemia, insomnia, and other HD risk factors are all directly impacted by obesity. Obesity raises the risk of HD and associated death without regard to other HD risk factors. The incidence of HD is impacted by obesity by 62.5%. An elevated risk of diabetes is linked to major adverse cardiac events such as heart attack, death and stroke. Individuals without diabetes and those with diabetes have diagnostic rates of 27.5% and 72.5%, respectively. Patients with diabetes have a higher incidence of HD than non-diabetics. Smokers and non-smokers have diagnostic rates of 65% and 35%, respectively. Compared to non-smokers, smokers have a higher prevalence of HD. A person's diet consists of the total amount of food they eat. It's also best to steer clear of trans fats and choose unsaturated fats over saturated fats. The incidence of HD is impacted diet by 67.5%. Any skeletal muscle-driven bodily action requiring a net consumption of energy is considered physical exercise. Lack of exercise, or physical inactivity, is one of the four major causes for fatality globally (6% of death) [21]. HD incidence is 60% higher in those who do not exercise. The body's reaction to risky situations is stress. The incidence of HD is impacted by stress to a 70% degree. A form of chest pain or discomfort known as angina is caused by a lack of oxygen-rich blood flow to the heart muscle. There could be a tightness or pressure on the chest region. Usually, one or more restricted or occluded coronary arteries are the cause. The spread of HD-related chest discomfort. One crucial component in the occurrence of HD is the history of chest discomfort. Of those who had previously experienced chest pain, 65% had an HD diagnosis. Proteins called troponins are found in the heart and skeletal muscles. Troponin is discharged into the bloodstream upon damage to the heart. Doctors look for elevated blood troponin levels to diagnose a heart attack. This test can also help medical professionals decide on the best course of action immediately. Troponins impact the prevalence of HD by 62.5%. An ECG measures the electrical activity in the heart by placing sensors across the skin of the chest. This quick and simple test can be finished at a physician's office. These tests, which are most effective when performed during exercise (e.g., treadmill walking), can detect cardiac problems, including CHD. The likelihood of HD incidence is impacted ECG patterns by 62.5%.

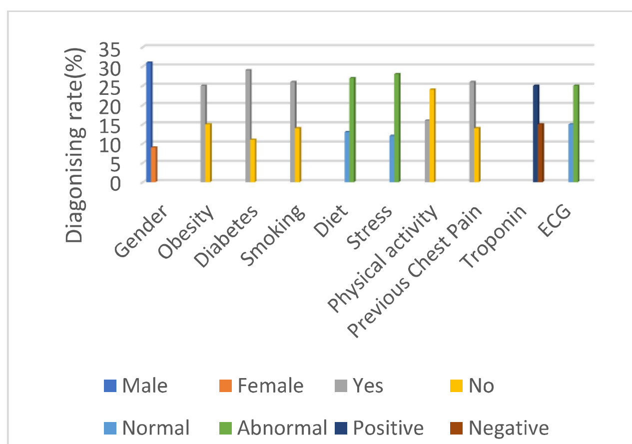

Figure 2: Relationships between features and HD

Feature selection

The process of feature selection is selecting a particular group of important attributes, for use in ML and statistical algorithms. Reducing the amount of input expedites the ML and generalization procedures and helps the machine create the model, more quickly. The data we have collected does not indicate that every attribute is equally important. There are 14 pertinent features, which was extracted by the BFS from 19 properties of cardiac patient records in this experiment. The 14 features are as follows: age, gender, physical activity, stress, diet, ECG, diabetes, smoking, kind of chest pain, diastolic blood pressure, obesity, troponin, prior chest pain and target.

Classification based on the prediction of HD

Using ML techniques, classifying analysis is an analytical process that detects and assigns a target to a set of data in order to facilitate more precise evaluation. The classification can be utilized with a technique to forecast a pattern or to assist in decision-making. Five distinct techniques for classification were chosen for data analysis in this study. We tried a number of ML algorithms, including DT, RF, NB, and FL and LR in order to determine the optimum method.

V. RESULT AND DISCUSSION

The collected data was classified by utilizing a confusion matrix in the research using Python software. The comparative results of the classifiers selected are shown in Table 2. It is clear from the analysis that the RF approach, having a maximum accuracy of 98.53 percent, is preferable to the DT, LR, NB, and FL methods. Based on the investigation, it is clear from figures 3 and 4 that RF outperforms all other algorithms of classification with regard to precision, sensitivity and specificity.

Table 2: Comparative Analysis of Different Classifiers and their Performance Metrics

Performance measures	FL	NB	DT	RF	LR
accuracy (%)	95.61	93.03	97.65	98.63	93
precision	0.630	0.566	0.614	0.823	0.57
recall	0.760	0.507	0.876	0.952	0.56
sensitivity	0.770	0.507	0.864	0.961	0.65
specificity	0.957	0.950	0.973	0.98	0.94

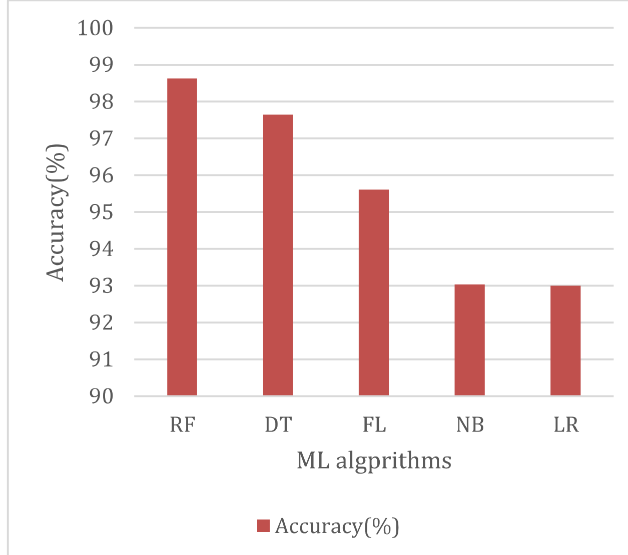

Figure 3 - comparison of accuracy for different ML algorithms

In contrast to different methods of classifying like LR,FL,NB and DT which have accuracy performance of 97.65%, 95.61%, 93.033%, and 93%, respectively, the RF method has produced a greater accuracy performance of 98.63% in Figure 3, which depicts the efficacy of the classification model used to accurately determine the HD status.

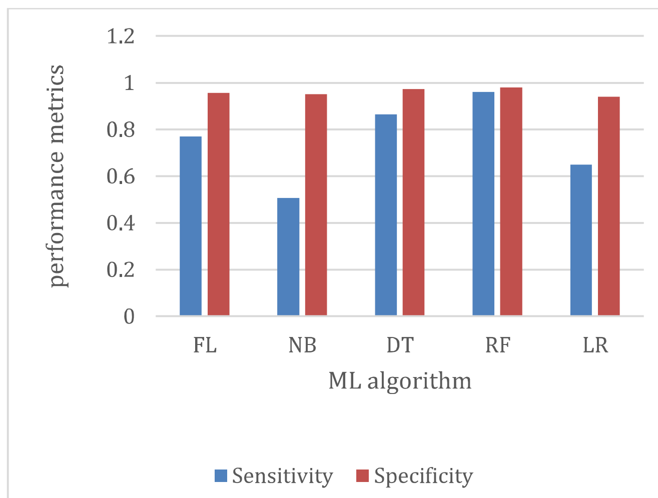

Figure 4: Comparison of Sensitivity and Specificity for various ML algorithms

The five-classification model's sensitivity and specificity are displayed in Figure 4 using the given database. After analyzing the specificity scores of each five-classification model, it was found that RF had a high specificity value of 0.98 compared to 0.973, 0.957, 0.95, and 0.94 for DT, FL, NB, and LR, respectively. In the same manner, the sensitivity value of the RF model has outperformed the other classifier models, with a 0.961 value, as opposed to 0.86, 0.77, 0.507, and 0.65 for the DT, FL, NB, and LR. According to the RF model's classification report, 95.2% of recall values indicate that the HD prediction was made correctly. These outcomes demonstrate that the RF is appropriate for analyzing the HD dataset and that the 14 features chosen have the power to affect the RF model's performance.

VI. CONCLUSION

The DA method for HD prediction was introduced in this work. With the potential to completely change patient care, individualized preventive intervention, early detection of healthcare delivery, AI-based HD prevention solutions provide a revolutionary approach to healthcare. The study of the data required five fundamental steps: feature selection, classification analysis and evaluation, data pre-processing, data collection and preparation. In order to use the analytics methodology, 14 features that impact the HD diagnosis were used. When compared to other model, the RF technique performs better, with the maximum accuracy of 98.63%. The performances of LR model has been significantly reduced by the absence of additional datasets and discriminatory feature sets. The majority of the dataset's features have been shown to be highly correlated with one another. By methodically examining the effectiveness of the various elements, the medical professionals will be helped to archive the records. In light of the analysis, feature selection has improved the accuracy and performance of the classification model's predictions, hence improving the DA method.

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