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A ML framework for early detecting the likelihood of cardiovascular disease in a patient using multi-attributes

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Abstract: Heart attack is one of the most pressing problems in health care. Heart-related or cardiovascular diseases are the leading cause of many deaths in the world over the past few decades and have emerged as the most life-threatening disease. We need a reliable, accurate, and feasible system for urgently diagnosing such diseases for proper treatment. Nowadays, machine learning is known to play a huge role in the medical industry and the application of machine learning algorithms and techniques on various medical data sets to automate the analysis of large and complex data using various machine learning models for disease diagnosis, classification, or prediction. Results. Several researchers are recently using various machine learning techniques to help the healthcare industry and professionals diagnose heart-related diseases. This research provides an improvement on the factors and triggers that may lead to a heart attack. This research focuses on developing a simplified framework that combines several machine learning techniques such as Naïve Bayes, Support Vector Machine (SVM), K-Nearest Neighbor, Decision tree, and Random Forest to help predict early heart attacks for different age groups using patient data. Both quantitative and qualitative approaches are used, which helped to analyze and evaluate data specifically collected from the Saudi community to conduct this research. The results indicated that the proposed developed framework outperformed the model in the initial stage as it gave SVM greater accuracy in less time to predict with an accuracy of 85.99%. Finally, the framework is evaluated using evaluation criteria, in addition to comparing the work with the previous work.

Keywords: Classification Algorithms, Accuracy, Heart Attack, Machine Learning, Cardiovascular Disease.

I. INTRODUCTION

Information technology has facilitated tremendous applications in the field of health care, one of the most important facilities is the application of information processing that includes both software and computers that deal with the retrieval, storage, sharing, and use of health care information, data, and knowledge for communication and decision-making [1]. Also constantly adding new technologies such as the Internet of Things (IoT), cloud computing and artificial intelligence (AI) have transformed the traditional healthcare system into smart healthcare by integrating key technologies that in turn improve medical services and the performance of the health sector [2]. Heart-related diseases or cardiovascular diseases are the main cause of a large number of deaths in the world over the past few decades and have emerged as the most life-threatening diseases due to their inability to function properly, which leads to the insufficient blood supply to the brain, which It deprives him of oxygen and affects the functions of the whole body, and subsequent epileptic seizures [3], [4]. Heart disease (HD) is one of the most common diseases nowadays, due to several contributing factors, such as high blood pressure, cholesterol fluctuation, diabetes, excretions, and many more. For many years an early diagnosis of such a disease has been sought, and various data analysis tools have been applied to help health care providers identify some of the early signs of HD. Several tests can be performed on potential patients to take additional preventive measures to reduce the impact of developing such a disease [5]. Heart disease can be recognized through medical examinations and the use of early wearable sensors for effective heart disease treatment effectively before a heart attack or stroke, several systems for disease prediction and disease are proposed and distinguished from each other using technologies Extract various data hybrids, artificial intelligence, and internet of things [6]. Medical organizations, all over the world, collect data on various health-related issues, but oftentimes, this data is too large for human brains to understand, data sets can be usefully explored and exploited using machine learning and machine learning algorithms and techniques are applied to various medical data sets to automate large and complex data analysis. Thus, these algorithms have become very useful in recent times, many researchers are using various machine learning techniques to help the healthcare industry and professionals in diagnosing heart-related diseases to accurately predict the presence or absence of heart-related diseases, using various machine learning (ML) algorithms, Such as Naïve Bayes, Stochastic

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Gradient Descents (SGD), Support Vector Machine (SVM), K-Nearest Neighbor (K-NN), Adaboost, Jrip, Decision tree J48, Logistic Regression, Decision Tree, K-Means, and Random forest [5], [7].

The main problem in this research is the increasing mortality of heart disease, in turn, it is considered the main cause of death in the world, and the prediction and detection of heart disease is a critical and difficult task for health care practitioners, especially in the early stages of the patient.

The main motive of this research is the early prediction of the probability of cardiovascular disease in a patient using multiple traits

The expected results of this study will be the possibility of predicting heart disease more efficiently and accurately at an early stage, which reduces the costly treatment and the moment of panic in the final stages so that the appropriate medication can be provided at the right time, which mainly leads to a reduction in the death rate.

II. LITERATURE REVIEW

Heart disease is one of the leading causes of death in the world today [8] A heart attack occurs when the heart muscle does not receive enough blood, and the damage to the heart muscle increases as time passes without treatment to restore blood flow, Various factors can increase the risk of heart failure, Medical scientists have classified these factors into two different categories; One is the risk factors that cannot be changed, and the other is the risk factors that can be changed, Family history, age, and gender are all subject to risk factors that cannot be changed. Blood pressure, cholesterol, smoking, and physical inactivity are all risk factors that can be changed [8], [9]. Common factors that lead to a heart attack:

Among the cardiovascular disease risk factors, high blood pressure (BP) is associated with the strongest evidence of causation and has a high risk of heart attack, as blood pressure is the predominant risk factor for heart disease and heart attack, large studies have demonstrated that high BP is an important risk factor for heart failure, atrial fibrillation, chronic kidney disease, heart valve diseases, aortic syndromes. In addition to microvascular complications and the possibility of seizures due to diabetes and high blood levels, which can exacerbate the injury of the heart muscle and blood vessels [10], [11] In the UK Prospective Diabetes Study, with blood pressure reduced intensively, when diabetes was lowered there was a much stronger benefit of CVD risk reduction, as well as reduced microvascular and vessel complications and heart attacks and a reduced burden of blood pressure-related heart disease, High blood pressure, and high cholesterol are considered independent contributors to cardiovascular disease in patients with diabetes also Obesity can increase rates of cardiovascular disease and mortality or increase cardiovascular disease risk factors such as hyperglycemia, insulin resistance, hypertension, and dyslipidemia, Adipose tissue quality and function (AT) is one of the most relevant aspects of cardiovascular risk as it is associated with all risk factors [10]. The risk of heart disease increases with the number of cigarettes smoked per day [12]. Many types of heart disease can be hereditary. Medical conditions that run in the family are hereditary because of changes in genes that are passed down from generation to generation. Some conditions, such as high blood pressure or coronary artery disease (clogged arteries that supply blood to the heart), run in families but are likely to be caused by several changes Different genes have little effect individually, but act collectively in a complex way cause diseases [13] Ambient temperatures, may be an important risk factor for cardiovascular-related hospitalizations especially in moderate ranges [14]

Heart disease affects the functions of the blood vessels in the body, early and accurate diagnosis and prediction of heart disease are essential to treat heart patients efficiently before heart damage occurs, cardiovascular disease can be identified by medical examinations and the use of wearable sensors for early prediction of heart disease to effectively treat heart patients before a heart attack or stroke occurs, several systems have been proposed to predict cardiovascular disease and differentiate them from each other by using different data mining techniques and hybrid models [6] .the following are some systems for the diagnosis and prediction of heart disease:

In [15] , and optimized swarm convolution neural network, combined with a support vector algorithm, is used for cardiac disease diagnosis, during the implementation process, they examined the deviation present in the test subjects' kidneys using data on chronic diseases such as saliva, ammonia, and urea concentration, details are processed by the SVM using a swarm intelligence training approach, Furthermore, the affected traits were classified using a convolutional network that successfully recognizes heart disease with an accuracy of 98.25%.

Uyar, Ilhan A [16], cardiovascular disease is screened using an optimized genetic algorithm with a fuzzy recursive network, the authors use the University of California Irvine (UCI) database to analyze and evaluate heart disease, patient information is processed using data processing techniques and further scrutinized using the fuzzy rule-based approach, the recurrent network classifies the given input and predicts the output exactly because of the successful training process that is achieved by applying genetic operators, High recognition rate achieved (97.78%).

Rati et al [17] proposed a secure healthcare framework based on a blockchain methodology. The blockchain was used to ensure the transparency and security of access to data and documents, patient records, and the shipping process between service providers and customers. The empirical framework analysis was measured on illegal communications or actions by malicious IoT objects.

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In [18], an IoT-based cardiology recognition system was developed based on a machine learning approach, the system uses the Waikato Knowledge Analysis (WEKA) environment for cardiology data collected from the cloud environment, The developed system collects heart disease details such as body temperature, blood pressure, heartbeat, and humidity level with the help of an IoT device, this system recognizes heart disease in the least time frame.

Anjan Nikhil Repaka, Sai Deepak Ravikanti and Ramya G Franklin, [19] used the Naive Bayesian method to design and implement heart disease prediction. To achieve this SHDP (Smart Heart Disease Prediction) was created via Navies Bayesian to predict various risk factors related to heart disease, the data required in a standardized form to predict the chances of heart disease in a patient, the following attributes are obtained from the medical files, they include These: age, gender, BP, blood sugar, cholesterol, etc... Pooled traits are inputs to the Navies Bayesian classification for predicting heart disease. The data set used is divided into two parts, 80% of the data set is used for training, and the rest 20% for testing. The proposed approach includes the following stages: data set collection, user registration and login, classification via Bayesian Navies, prediction, and secure data transmission using a standard called advanced encryption. Then the result is produced. The research develops and presents various knowledge abstraction techniques by utilizing approved data mining methods to predict the probability of occurrence of heart disease. The results show that the diagnostic system in place helps predict risk factors for heart disease.

Prediction techniques and study techniques using cardiology to extract data were proposed by Chala Beyene et al, [20]. The main objective of the study is to predict the emergence of the chance of heart disease occurring in a limited period to the early spontaneous diagnosis of the disease. In a health system with inexperienced or inexperienced people, the proposed approach is also important. It uses various medical features including blood sugar, age, gender, heart rate, and some features to decide whether a patient has heart disease. WEKA software is used to measure the performance of data sets.

III. METHODOLOGY

A. Research Strategy: The main purpose of research is to predict heart attacks and verify their accuracy using those algorithms based on factors were taken from the already published dataset (a common dataset available on IEEE) and we optimized the variables and added new ones based on clinical research indicating the effect of these factors as well as the approval of participating clinicians. The survey aimed to reach a sample of at least 500 participants. To achieve the goal, the survey targeted several hospitals in different regions in Saudi Arabia. The dataset collected contains 528 participating health practitioners.

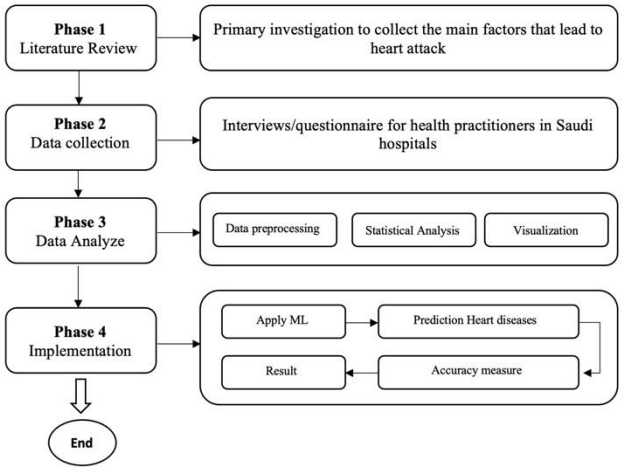

Fig. 1 Research Steps

B. **Data Pre-processing**: Data pre-processing is the most important step before applying ML algorithms. It is not possible to use real-world data directly in the prediction task, as it tends to be incomplete, noisy, inconsistent, and can't be interpreted by machines. Thus, a pre-processing step is applied to the data set to make it into an understandable form to effectively represent it for heart disease prediction. Data pre-processing includes missing data filtering, feature selection, filling the Missing values and feature weighting which improves the data quality and saves time and memory, after which the sorted data will be given to classification algorithms.

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TABLE I Dataset Attribute Description

No.	Attribute	Code given	Unit	Data type
1	age	Age	in years	Numeric
2	sex	Sex	1, 0	Binary
3	chest pain type	chest pain type	1,2,3,4	Nominal
4	resting blood pressure	resting bp s	in mm Hg	Numeric
5	serum cholesterol	cholesterol	in mg/dl	Numeric
6	fasting blood sugar	fasting blood sugar	1,0 > 120 mg/	Binary
7	resting electrocardiogram results	resting ecg	0,1,2	Nominal
8	maximum heart rate achieved	max heart rate	71–202	Numeric
9	exercise induced angina	exercise angina	0,1	Binary
10	oldpeak =ST	oldpeak	depression	Numeric
11	the slope of the peak exercise ST segment	ST slope	0,1,2	Nominal
12	smoking	smoking	0,1	Binary
13	family genetic record	genetic	0,1	Binary
14	weather temperature	name of month	1-12	Open

C. **Evaluation Metrics:** To assess the effectiveness of the proposed method, the evaluation is carried out at this stage in two parts. The first is the evaluation by comparing previous works: by comparing the performance of the research in general with the performance of previous studies. The second part is through evaluation with evaluation criteria:

$$\text{Accuracy} = \frac{[\text{Number of True Positives} + \text{True Negatives}]}{[\text{Total Instances}]}$$

$$\text{Precision} = \frac{\text{Number of True Positives}}{\text{Number of true positives} + \text{False positives}}$$

$$\text{TPR} = \frac{[\text{Number of True Positives}]}{[\text{Number of True Positives} + \text{False Negatives}]}$$

$$\text{FPR} = \frac{[\text{Number of False Positives}]}{[\text{Number of False Positives} + \text{True Negatives}]}$$

$$\text{Recall} = \frac{\text{True positives}}{\text{True positives} + \text{False negative}}$$

IV. Results and Analysis

A. Descriptive Analysis: the factors were taken from the already published dataset (a common dataset available on IEEE) and we optimized the variables and added new ones based on clinical research indicating the effect of these factors as well as the approval of participating clinicians. The following results show the effectiveness of the new factors in the data set created for the Saudi society

Gender: The results showed that 442 of the affected participants were males, while only 83 were females. The results confirm what was mentioned in the literature review chapter that men are more likely to have a heart attack than women, and they have attacks early in life. The rate of heart disease in women increases after menopause but is still lower than that of men.

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TABLE 2 Summary of heart attack dataset

Attribute	Description	Domain value
gender	Sex	84% male, 16% female
Age	In years	19-83 years
blood pressure	resting bp	132 mmHg
Cholesterol	serum cholesterol	235 mg/dl
blood sugar	fasting blood sugar	73% yes, 27% no
heart rate	max heart rate	132.5
Smoking	smoking	78.4% yes, 21.6 no
Genetic	family genetic record	61% yes, 39% no
weather temperature	In month	December
Class	target	60% yes, 40% no

Age: This factor has been improved and the goal gap addressed in the previous research mentioned, as it was directed at the age of 45 and over. the participants were between 19-83 years old. This explains that there are many heart attacks from an early age, and it is not a condition that the injury is associated with advanced stages of life.

Blood pressure: when blood pressure rises and remains high for a period at a rate of 120/180, it harms the body in many ways. Essentially, high blood pressure increases the workload of the heart, resulting in damage to the heart muscle and causing a heart attack. As it is clear, the measurement of blood pressure of the participating ranges from 120-140, as it is considered high in this measurement.

Cholesterol: with high cholesterol, fatty deposits can develop in the blood vessels. Eventually, these deposits grow, making it difficult for adequate blood flow through the arteries. Sometimes, these plaques can rupture suddenly and form a clot that causes a heart attack. It represents an ideal level if the cholesterol level is (100 mg) and a high cholesterol level if the ratio ranges between (160-189 mg). the results show the cholesterol levels of the participants compared to what was mentioned above, the normal and high levels. The percentages are considered very high compared to the normal level.

Blood sugar: over time, high blood sugar can damage the blood vessels that control the heart. People with high diabetes are also more likely to have other conditions that increase the risk of heart disease. About 73% of the participants in this research said they had diabetes.

Family genetic record: the results confirmed that more than 60% of infected people in the Saudi community have a genetic record of cardiovascular disease. the rates of heart disease are shown for those who have heart disease in the family. These results confirm what was mentioned in the Influencing Factors section that many different types of heart diseases can be hereditary, such as high blood pressure or coronary artery disease (blockage of the arteries that supply the heart with blood) that runs in families but is likely to be the result of several genetic changes. Different types have a slight effect individually but act collectively in a complex manner in a way that causes disease [11]

Weather temperature: ambient temperatures are an important risk factor for hospitalization associated with cardiovascular disease [14]. The 'month' variable represents the weather temperature. shows the names of the months when the heart attack occurred for the participants in Saudi society as shown. December, January, and February represent the highest rates of heart attack, which are in the winter in Saudi Arabia, where the minimum temperature reaches -3, shows the statistic of degrees The lowest temperature in winter in the Kingdom in 2021, according to the statistics of the Saudi National Centre of Meteorology

B. Ensemble learning: To improve the accuracy of the results, we used ensemble learning methods to improve the accuracy and stability of algorithms in regression and statistical classification first, bagging to increase model stability, improve accuracy and reduce variance, as it was used on each algorithm individually. Table 4. shows the results of the algorithms after accuracy improvement. Then we used Stacking by making several predictions using the data set and then combine these predictions to produce better accuracy. The benefit of stacking here is that the potential of a set of well-performing models can be harnessed in a classification or regression task and make better-performing predictions than any single model in the ensemble. Accuracy of StackingCVClassifier: 89.52.

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TABLE 3 Accuracy of algorithms before and after development

Classifier	Accuracy before	Accuracy after
Naive Bayes	83.44%	84.08%
K-NN	57.32%	84.71%
SVM	56.69%	85.99%
Random Forest	82.8%	84.08%
Decision Tree	76.43%	82.80%

As shown in Table 3, the accuracy of the algorithms used after developing the accuracy of the results, where about 26% of the two algorithms K-NN and SVM were raised from 57.32%, 56.69% to 84.71%, and 85.99%, respectively. Also, 6% of the decision tree algorithm was raised from 76.43% to 82.80%. SVM constitutes the highest percentage reached by the research compared to the algorithms in the framework, with an accuracy of 85.99%.

C. Evaluation: Five performance measures were selected that have been widely used in the research community and have a proven track record of accuracy and efficiency. The results were evaluated in the first part using Recall, Precision, and Accuracy. Table 4. shows the evaluation results for each algorithm, before and after developing the accuracy. This showed positive results for increasing the prediction accuracy compared to the first model. The results revealed that the proposed developed model outperformed the model in the initial stage by achieving significantly higher ratios.

TABLE 4 Evaluation metrics results

	performance evaluation					
	Accuracy		Precision		Recall	
Classifier	Before	After	before	after	before	after
Naive Bayes	0.83	0.84	0.84	0.84	0.84	0.87
K-NN	0.57	0.84	0.62	0.85	0.55	0.87
SVM	0.56	0.85	0.55	0.84	0.59	0.90
Decision Tree	0.76	0.82	0.76	0.86	0.81	0.81
Random Forest	0.82	0.84	0.81	0.82	0.88	0.90

D. compare results: the results obtained in this study with previous works. Table 5. shows the comparison of the algorithms results we obtained after development with some previous work.

TABLE 5 previous work comparison

Research with Reference	Dataset	K-Nearest Neighbor	Naive Bayes	Decision Tree	Random Forest	SVM
[21]	UCI Cleveland	73.41%	56.19%	66.31%	-	-
[22]	Cleveland and Statlog Database UCI	98.7%	83.12%	93.65%	-	84.19%
[23]	UCI Cleveland	78%	85%	74%	85%	97%
[24]	UCI Cleveland	87%	80%	79%	84%	83%
[25]	UCI Cleveland	-	85.25%	81.97%	90.16%	-
Proposed Work	Saudi dataset	84.71%	84.08%	82.80%	84.08%	85.99%

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The current research has been compared with some previous studies in terms of style, structure, results, and weaknesses of the studies such as ambiguity of the literature review or introduction, or if written, succinctly written. Applying a single, brief, and ambiguous algorithm or methodology to the search, as well as the database as shown in Table 5. The same database was used in all studies for comparison. They used the same database, namely Cleveland and Statlog Database UCI already published in Machine Learning Repository On the other hand, the proposed research provided improvements for all mentioned weaknesses, the most important of these improvements is the creation and collection of new data collection from Saudi Arabia for the Saudi community.

V. CONCLUSION AND FUTURE WORK

The risk of heart disease is that plaque on the walls of the arteries can block blood flow and cause a heart attack or stroke. Exploring the possibility of heart attacks and predicting their occurrence at an early stage will help save human health from any harm and start dealing with counseling and medicines. Advanced computing solutions such as machine learning can be used to help early prediction of heart attacks. This research suggested three main objectives that should be covered, several steps were implemented to cover all objectives comprehensively. Three new factors were added: (1) family genetic history, (2) weather temperature, and (3) smoking. In addition to the current key forecasting factors. The evaluation was done using different evaluation scales. Such as recall, accuracy, ROC, and accuracy. The results indicate that the proposed framework after development outperformed the model in the initial stage by achieving significantly higher percentages, giving SVM more accuracy in less time to predict with an accuracy of 85.99%. in addition to the evaluation by comparing the current research with some previous studies in terms of style, structure, and results, where the comparison was made, and the final analysis showed that the quality of the research The current research has improved and improved weaknesses in the previous research compared to the current research.

VI. LIMITATION OF THE STUDY

This research was presented to help predict the likelihood of developing cardiovascular disease in a patient using multi-attributes some limitations and difficulties were encountered in the stage of data collection, which is first the hospitals do not take research topics seriously, in addition to trying to preserve the information as much as possible because it is considered patient-specific information, as well as the difficulty of accessing the entire sample due to the lack of participants and the accuracy of the required information. Finally, the time specified for collecting the database is considered one of the most important limitations at this stage.

VII. IDEAS FOR FUTURE RESEARCH

Using the limiting factors identified in this study, in the future, the study could be repeated using more case studies. In addition, the proposed framework can find more ways to incorporate other additional factors based on scientific evidence. The search framework can also be applied further to find the different types of disease prediction in Saudi society such as diabetes, respiratory infections, lung diseases, and many more. Whereas non-Saudi organizations could be another future idea to support this field of research and promote the implementation of the framework in different cultures and societies. Also, we can create an android app that the user can download anytime and whenever he wants, he can check his heart condition by entering all the 13 attributes turned on and it will show the condition of the heart, due to this the patient doesn't have to go to the hospital to find his personal details, this will also ensure that his medical data is safe and secure. Therefore, there are many research ideas related to this framework applications.

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