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A Systematic Review of Machine Learning Approaches for Cardiovascular Disease Diagnosis

Noor-Ul-Ain
Department of Computer Science and Information Technology,Superior University Lahore, Pakistan
Shahid Ameer (Corresponding Author)
Department of Computer Science and Information Technology, Superior University Lahore, Pakistan
Amina Aslam
Department of Computer Science and Information Technology, Superior University Lahore, Pakistan
Muhammad Ayaz
Department of Computer Science, University of Management and Technology Lahore, Pakistan
Hafiza Sana Fatima
Department of Computer Science and IT, The University of Lahore, Sargodha Campus, Pakistan
Kishwar Shahzadi
Department of Computer Science and Information Technology,Superior University Lahore, Pakistan
Muhammad Suleman Shahzad
Department of Computer Science and Information TechnologySuperior University Lahore, Pakistan
Ramesha Jamil
Department of Radiology and Imaging Technology, Dr. Sulaiman Al Habib Hospital Riyadh, Saudi Arabia

Author Details

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Corresponding E-mail & Author*:
Shahid Ameer
Department of Computer Science and Information Technology, Superior University Lahore, Pakistan

Abstract

Diseases (CVD) are the world's biggest health issue and the leading cause of mortality, after cancer and diabetes. Early detection and prediction of CVDs are crucial for addressing the issue because they can drastically lower rates of morbidity and mortality. Physicians can diagnose a variety of cardiac conditions, including heart failure and valve dysfunction, with the use of computer-aided procedures. We live in the "information age," when millions of bytes of data are created daily. By employing the data mining technique, we can transform this data into knowledge for clinical research. Based on various risk factors, machine learning algorithms have demonstrated encouraging outcomes in the prediction of heart disease. Our goal in this study is to evaluate and analyze the results produced by machine learning methods, such as support vector machines, artificial neural networks, logistic regression, random forests, and decision trees, in order to predict CVDs. The accuracy of several machine learning algorithms in predicting cardiac

issues is highlighted in this literature review, which can also serve as a foundation for developing a clinical decision-making tool to identify and stop heart illness early.

Introduction

A regular occurrence of the modern lifestyle is stress and trauma. Cardiovascular issues are also caused by additional risk factors, including high blood pressure, high cholesterol, obesity, smoking, type 1 or type 2 diabetes, and a history of predisposing conditions. Heart disease, another name for cardiovascular problems, is a condition that impacts both the heart and blood arteries. These days, heart problems are the leading cause of death. According to the 2019 WHO data, CVD accounts for 32% of all deaths worldwide. Even if they have no past history of heart disease, those who have contracted COVID-19 are more likely to experience cardiovascular problems, such as heart attacks, according to studies. This is believed to be caused by the direct impact of the virus on the heart as well as the systemic inflammation that COVID-19 causes.

To avoid complications and enhance patient outcomes, early identification and diagnosis of cardiac issues are essential. Algorithms that use machine learning have demonstrated significant promise in correctly identifying high-risk patients and forecasting heart disease. Neural networks, SVM, logistic regression, decision trees, and random forests are the machine learning techniques most commonly used for the identification and prediction of cardiac problems. Machine learning algorithms make it simple to investigate datasets that are too complex for humans to comprehend. These algorithms are used to analyze and assess a sizable, intricate dataset in order to pinpoint the necessary patterns with perfect precision.

These algorithms are used to analyze and assess a sizable, intricate dataset in order to pinpoint the necessary patterns with perfect precision. Datasets including details on patient demographics, medical histories, and the outcomes of various diagnostic tests are used in the evaluation of heart disease incidence using a variety of machine learning techniques. The machine learning algorithms receive the pre-processed three data as input, learn from the data, and produce a predictive model.

Table-1: Signs and Vulnerability factors of different types of CVD

S. No.	CVD Type	Characterization	Signs/Symptoms	Vulnerability Factors
I	Stroke	• Various forms of stroke • Includes TIA, Ischemic, and Hemorrhagic stroke	• Sudden physical impairment • Brain hemorrhage • Weakness • Transient ischemic attacks (TIA)	• High blood cholesterol (BC) • Diabetes • Old age • Tobacco use • Unhygienic diet
II	Coronary Heart Disease (IHD)	• Ischemic Heart Disease (IHD) • Blockage of coronary arteries	• Breathing difficulty • Chest tightness • Nausea, tiredness	• High cholesterol and BP • Diabetes • Old age • Smoking • Hereditary factors
III	Congenital	• Malfunction	• Breathlessness	• Maternal

	Heart Disease	of the heart from birth • Issues in central blood vessels	• Growth and developmental deviations	infections (e.g., Rubella) • Poor maternal nutrition • Close blood relation between parents • Alcohol use
IV	Rheumatic Heart Disease & Fever	• Inflammation of heart valves or muscles • Often after strep throat/tonsillitis	• Shortness of breath • Fatigue • Irregular heartbeat • Chest pain • Joint swelling • Nausea, vomiting	• High BC and BP • Diabetes • Childhood infections (e.g., strep throat)
V	Pulmonary Embolism (PE) & Deep Vein Thrombosis (DVT)	• Blood clot in lungs or deep veins	• Chest tightness • Sudden breathlessness • Palpitations • Joint swelling • Nausea, stomach pain, vomiting	• Obesity • Cancer • Hormone therapy • Contraceptive use
VI	Peripheral Vascular Disease	• Includes Functional PAD & Critical Limb Ischemia (CLI)	• Nausea • Stomach cramps • Vomiting	• Obesity • Family history • High cholesterol • Diabetes • Smoking • Inflammatory disorders
VII	Other Cardiovascular Diseases	• Includes heart tumors, brain tumors, muscle and valve disorders	• Nausea • Stomach cramps • Vomiting	• High BC and BP • Diabetes

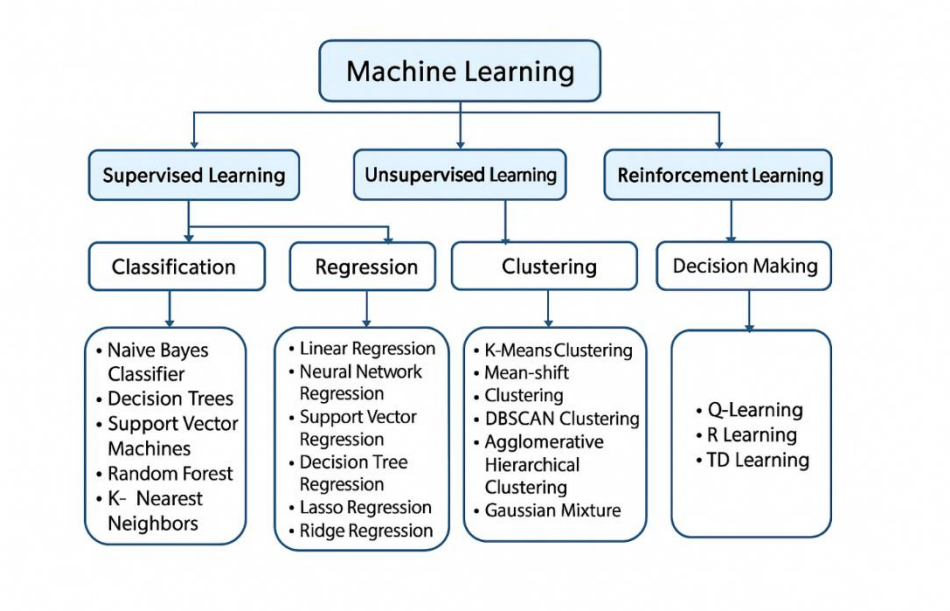

Fig 1: Types and Classification of Machine Learning Algorithm 1.1

KNN, or K-Nearest Neighbors

One popular supervised learning technique for classification and regression problems is the K-Nearest Neighbors algorithm (KNN). The data are first categorized using similarity indices. Regarding fundamental facts, the KNN algorithm doesn't require any assumptions. This approach is ineffective for handling noisy data.

Support Vector Machines Algorithm

One supervised learning model for handling regression and classification problems is the Support Vector Machine. Finding the hyper-plane that can produce the biggest margin of separation between data points of different classes is the aim of SVM.

The hyper-plane (optimal hyper-plane) optimizes the distance or gap between it and the closest data points in each class.

Random Forest Algorithm

The Random Forest technique is a widely used ensemble method based on decision trees that is applied for classification and regression. Each tree is built by selecting a subset of characteristics and data samples from the training set.

K- Means Clustering

K-Means clustering is a well-known unsupervised machine learning technique that effectively groups related data points into clusters according to similarity indices. The fields of pattern recognition, data mining, and picture segmentation are where this approach is most frequently used**.**

Decision Trees Algorithm

Similar and regression analysis.to Random Forest (RF), a non-parametric algorithm that creates a decision pattern that resembles a tree with potential outcomes, the Decision Tree algorithm is widely used in supervised machine learning for both classification

Logistic Regression

A popular statistical technique for figuring out the relationship between a binary dependent variable and one or more independent variables is logistic regression analysis. When predicting a binary outcome is the goal of a classification task, this approach is frequently used.

Literature Review

Ali et al. [1] evolved a model with two SVM to diagnose heart disease effectively. Elimination of the unnecessary features was done with the first SVM and prediction was done with the help of the second SVM. 3.3% more exactness was accomplished by using hybrid gird search algorithm (HGSA) than the traditional SVM model.

Javeed et al. [2] promoted a prototype for both training and testing data which contains two algorithms i.e Random Search algorithm (RSA) and random forest algorithm (RFA). It was seen that RSA-RF system performance was 3.3% more than a random forest model.

Santhana Krishnan. J[3] used decision trees and Nave Bayes machine learning algorithms, to predict heart attacks. The Decision Tree Model achieved a precision rate of 91% and Nave Bayes' accuracy level was 87%. They presumed that the best algorithm was a decision tree for handling data sets.

Aditi Gavhane et al. [4] worked on machine learning applications by using certain parameters like lifespan, gender, heart rate, etc. to foresee the vulnerability of heart problem. To train and test the dataset, they used neural network supervised algorithms, that is MLP (multilayer perceptron), which gives reliable outcomes from the user's input. Machine learning algorithm using neural network is the most accurate and reliable algorithm.

Devansh Shah et al. [5] developed a system using some supervised classification techniques such as Random Forest, Decision Tree, KNN, and Naïve Bayes. To identify heart problems, the Cleveland database from the UCI repository was employed. Out of 76 attributes, only 14 attributes such as age, pain in the chest, gender, etc. are taken and found a K nearest neighbor, which gives the most noteworthy precision.

Archana Singh et al. [6] developed a system using LR, SVM, decision tree and KNN machine learning algorithms. For training and testing, UCI repository dataset was used. They found that KNN is more precise and effective in contrast to different algorithms.

Apurb Rajdhan et al. [7] carried out various approaches such as LR, RF, Decision tree and Naive Bayes algorithms to predict heart problems over UCI repository dataset. They found that 90.16% accuracy was achieved by the RF algorithm to forecast heart problem.

Rati Goel [8] worked on SVM, LR, RF, Decision tree, Naive Bayes and KNN algorithms of ML and compare their efficiency based on basic parameters like chest pain (CP), gender, blood pressure (BP), and cholesterol to predict heart disease. He concludes that the SVM has better performance in comparison to other machine learning algorithms.

Ekta Maini et al. [9] used different types of ML algorithms [RF], Logistic Regression, Naıve Bayes, k-Nearest Neighbors and AdaBoost, using Python to do the prediction. Utilizing a sample of 1670 patients from the UCI dataset who presented to a private tertiary care facility in southern India and considered 13 clinical parameters, such as anxiety, ancestry, nicotine consumption, indulging in alcoholic beverages etc. They developed a model using ensemble techniques (RF and AB), which excelled in

comparison to LR. RF is the best to do the prediction, accomplishing 3.8% accuracy, 92.8% sensitivity, and 94.6% particularity.

Apurv Garg et al. [10] worked on KNN and Random Forest ML supervised Algorithms to separate CVD patients. from normal persons. They used Kaggle's data set for his experimental analysis using the Python programming language. They concluded that K-Nearest Neighbors (KNN) provides better performance (86.885% accuracy) in comparison to the Random Forest algorithm (81.967% accuracy).

Md. Mahbubur Rahman, et al. [11] used KNN, Ada Boost, LR, XGBoost, SVM, DT, Naive Bayes, and RF various ML algorithms considering the basic parameters like lifespan, gender, angina, arterial pressure, electrocardiogram, etc. to predict heart disease accurately. A dataset of 1026 patients was taken. They have statistical measurement parameters. criteria like sensitivity, exactness, selectivity, F-measure, precision, and classification errors. They determined that the decision tree demonstrated the greatest precision (99%) and responsiveness (98%) in contrast to alternative techniques, with the lowest classifications errors for the identical dataset.

Manjula P et al. [12] used various ML techniques like SVM, Decision Tree, LR, RF, Navie Bayes and KNN in their model with Vulnerability factors like age, gender, arterial pressure, cholesterol levels, and family background of heart problem to train and test their models of machine learning. The random forest algorithm achieved exceptional precision in their model.

Pavan Kumar Tadiparthi et al. [13] reviewed several types of machine learning algorithms for predicting heart issues. They determined that the precision of the machine learning algorithms for disease prediction can be enhanced with proper feature selection and ensemble methods. Python environment was used for experiment. Logistic Regression gives 81.9% accuracy and better performance given by the classification model on the data set, which uses 14 features.

Joloudari et al. [14] used SVM, CHAID and RTs ML algorithm for artery disease identification. 303 patients' information from Z-Alizadeh Sani dataset was used, out of which 216 CAD patients and 88 normal patients. According to the study, random tree model outperforms other classification models with an accuracy rate of 91.47%.

Padmanabhan et al. [15] evaluated AutoML performance. UCI data repository and the CDD (Cardiovascular Disease Dataset) were both used as cardiovascular datasets in the experiments. The experiments yielded a 74% correct prediction rate with 70,000 cardiovascular disease results and an 85% correct prediction rate with the Heart UCI dataset.

Chen et al. [16] stated that the XGBoost algorithm created decision trees in sequential order. Independent variables were given weights, which were employed by the decision tree to generate prediction. If a wrong prediction is made by the tree, then variables are used in the next decision tree as its importance is increased. Each predictor's output is then merged to form a accurate and reliable model.

Reldean Williams et al. [17] used a set of eight machine learning methods, including Artificial Neural Networks, RF, LR, SVM , Decision Trees, XG Boost and Naive Bayes for heart problem prediction with elements like Systolic and diastolic pressure, cholesterol level and Chest tightness. UCI data repository is used. They found that out

of the machine learning methods utilized, Random Forest demonstrated the highest accuracy for forecasting the incidence of the illness.

Weng et al. [18] employed Four deep learning techniques, namely Neural Networks (NN), Gradient Boosting, RF and LR to forecast the likelihood of heart disease. The CPRD (Clinical Practice Research Datalink) dataset encompasses a comprehensive medical record, comprising information on population, medical history, medication use, health outcomes, and hospital admission particulars. Several vulnerable factors like Nicotine addiction, Arterial pressure, High blood sugar, cholesterol level etc. were taken and found that for the ML model, diabetes was not the top gamble factor. It was found that neural networks were best, with 3.6% more accuracy for predicting heart disease.

Kishore et al. [19] Demonstrated that in comparison to other methods like CNN, NB, and SVM, Recurrent Neural Networks (RNNs) exhibit decent precision. Furthermore, neural networks perform effectively in detecting heart disease.

Avinash Golande [20] used Machine Learning Techniques to predict Heart Attack effectively. Experts used a few data mining policies to predict heart attacks. Naive Bayes, decision trees, k-Nearest Neighbors are prevalent machine learning techniques used for classification tasks. However, the precision of each technique may differ based on specific problem and dataset being analysed. In some cases, decision trees may achieve higher accuracy than other algorithms.

V.V. Ramalingamet et al. [21] applied various computational learning methods to analyse complex datasets. The researchers discovered that combining multiple algorithms, such as with Random Forest and Ensemble models, has successfully addressed the problem of overfitting. Random Forest, in particular, achieves this by utilizing multiple Decision Trees. On the other hand, Naïve Bayes' model was observed to be highly computationally efficient while still achieving good performance. SVM performed very well in maximum cases.

Mohan et al. [22] employed a range of machine learning models, such as RF, LR, SVM, Decision Tree, KNN, J48, Naïve Bayes and Neural Networks, to forecast the occurrence of heart problem. Prediction exactness increases with the use of a larger number of attributes. Their findings indicated that the Naïve Bayes classifier outperformed all other machine learning algorithms.

Himanshu st al. [23] briefly examined a large data set and a small data set of heart diseases prediction. Deep learning showed higher accuracy for medical diagnosis. They shared that small data sets take minimal time for training as well as testing and performed prediction using SVM and KNN algorithms.

S. Bashir et al. [24, 25] Various feature selection techniques, including decision tree (DT), logistic regression (LR), random forest (RF), Naïve Bayes (NB), and Support Vector machine (SVM), have demonstrated comparable efficacy in predicting the occurrence of the disease.

Arsalan Khan et al. [26] studied the results of a predictive ML algorithm for CVD patients. The researchers utilized patient information gathered from two hospitals located in Pakistan, specifically Khyber Teaching Hospital and Lady Reading Hospital. The RF algorithm is the most effective for predicting and classifying CVD.

M. Kavitha et al. [27] employed RF, decision trees, and hybrid algorithms to forecast illness with great precision. The hybrid algorithms exhibited a high degree of accuracy, approximately 88.7%, in disease prediction compared to other models.

Chintan M. Bhatt et al. [28] used different ML models to find their effectiveness. Experiments were conducted on Google COLAB using Python. More than 86.5% accuracy for all ML classifiers was achieved. Through hyperparameter tuning, the accuracy of RF was raised from 86.48% to 86.90%, and XGBoost algorithm accuracy was raised from 86.4% to 87.02%.

Hasan and Bao et al. [29] conducted a study to find out the best feature selection approach, i.e. filter, wrapper, and embedding, for identifying heart disease. Various ML algorithms including RF, SVM, k-Nearest Neighbors, Naive Bayes, and XGBoost, were employed to identify the optimal

Discussion & Future Scope

It is discovered that all research papers aimed at illness detection and prediction use a conventional silo method following a thorough and systematic examination of the literature on various machine learning algorithms for cardiovascular disease projection and detection. The majority of machine learning approaches have only used a small number of datasets and specific parameters, and they have not been able to forecast diseases with 100% accuracy. In order to increase the accuracy of ML models, additional algorithms, feature engineering approaches, or data pretreatment strategies can be investigated as an extension of this literature study. To accomplish the aforementioned objective, it is also suggested that extensive, varied datasets comprising information from various people, demographics, and geographic areas be employed. Therefore, the current paper's future study could concentrate on ML model implementation and validation in actual clinical situations.

Conclusion

This literature study aims to develop accurate and effective machine learning techniques for predicting cardiac disease, which doctors can use to identify high-risk patients and create individualized treatment regimens. Machine learning techniques can help lower mortality rates and improve patients' overall health outcomes by improving the accuracy of cardiac issue prognosis.

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