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RESEARCH ARTICLE

A STUDY ON MACHINE LEARNING TECHNIQUES USED FOR HEART DISEASE PREDICTION: A CRITICAL ANALYSIS

Samiah Jan Nasti¹, Kiran Samyal², Sanjay Jamwal² and Mahmood Hussain Mir²

1. Department of Computer Application, Govt. Degree College for Women, Anantnag.
2. Department of Computer Sciences, Baba Ghulam Shah Badshah University, Rajouri, J&K, India-185234.

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Abstract

Among various diseases one of the hazardous diseases that takes uncountable lives every year is heart disease. In today's world, one person is believed to die from heart disease every minute. By WHO report the number of deaths that occur due to heart disease is 1.75 million, which is expected to rise to 75 million by 2030. As a result, an accurate and fast heart disease prognosis is a critical necessity for lowering heart disease-related death rates. Angiography is the easiest and effective clinical test but has drawback of expensive cost and many side effects. So, in order to deal with this difficult issue, a significant role in various disease prognosis is shown by ICT. Machine learning is an emerging technology that performs automation from previous available data and shows promising results, it is a subset of artificial intelligence. In this work different literatures related to heart disease and machine learning techniques used in those literatures are critically analyzed and a review of them is summarized in a systematic manner.

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Introduction:-

Heart is a muscular organ located to the left side of the breastbone. In the human body, the heart is important is a muscular organ located to the left side of the breastbone. The heart is an important component of the circulatory system in the human body, which distributes blood and oxygen throughout the body. It is vital to the body's correct functioning, and even minor heart problems can lead to various diseases and even death [1]. It collects deoxygenated blood from all parts of the body and for oxygenation it sends the impure blood to the lungs. Thus, the blood that is oxygenated in the lungs is transported to all parts of the body. In 24 hours, approximately 7200 litres of blood is pumped by the heart throughout the body and beats about 3 billion in a lifetime. Along with blood, many nutrients and hormones are also transported to all body cells [2]. Large number of diseases can occur due to the disturbance in the blood flow, usually referred to as CVD. According to the WHO, the number of lives taken away by CVD in 2019 is 17.9 million, which is 32% in total, out of which 855 deaths were due to stroke and heart disease. Over the last ten years one of the main cause of the death is due to the diseases related to the heart, and its diagnosis has grown extremely challenging due to the wide range of symptoms [3][4]. Thus, the prediction of heart disease at a very early stage becomes very important so that many lives can be saved from this disease [5]. According to WHO, 175 million global deaths occur due to heart disease [30]. Due to abnormal flow of blood via the heart or due to an

Corresponding Author:- Samiah Jan Nasti

Address:- Department of Computer Applications, Govt. Degree College for Women, Anantnag.

increase or decrease in the number of heartbeats there can be many heart diseases depending upon the situation. On the basis of different situations, heart disease is classified into various types. Coronary Artery Disease (CAD): It is caused when inner walls of the arteries are accumulated by fatty deposits. A heart attack is caused by a constriction or obstruction caused by a plaque. The symptoms of this disease are pain in the chest as well as rapid breath. Cardiomyopathy- It is a condition in which blood is hardly sent to the body by heart. In the early period of this disease symptoms may or may not appear but the situation worsens with the time. Common symptoms of the disease while performing some physical activities and some at rest are inflammation in the legs, feet and ankles, abdomen gets bloated, struggle in reposing and chest burning. Angina-Chest pain comes as a result of decreased blood supply to the heart. Angina pectoris is a sign of coronary artery disease, generally known as angina. Angina is characterized by pressure, aching or burning in the middle of the chest, neck, jaw, and shoulders, as well as a feeling of concern or uneasiness. There are four different types of angina. Angina can be steady or unstable, variant angina, microvascular angina while the heart works harder than usual, stable angina occurs; when the heart is at rest, unstable angina ensues. Microvascular angina occurs when the coronary arteries spasm and variant angina occurs when the coronary arteries spasm. Valvular Heart Disease (VHD) : is an illness that is caused by the failure of the proper functioning of the valves. To direct the blood in the correct direction, four heart valves are responsible. This flow of blood is completely disturbed when one or the other valve does not unlock correctly. This condition may go unnoticed for many years, but symptoms such as whooshing sound, chest pain, abdomen swelling, and shortness of breath become apparent as the disease progresses. There is dizziness, fainting, and an erratic heartbeat. Congenital Heart Disease (CHD): is a congenital abnormality that interferes with the regular functioning of the heart. One of the most prevalent types of birth defects is congenital heart disease. In this condition, a person is born with the disease, which changes how blood flows in adults and in children. Congenital Heart Defects include Septal Defects, Atrial Septal Defects, Ventricular Septal Defects, and Valve Defects. Cerebrovascular Disease is a disorder that impacts the brain's blood flow and blood vessels. It refers to any condition in which ischemia or bleeding affects a part of the brain, either temporarily or permanently. The signs and features of this disease differ depending upon the way how it affects tissues of the brain. A strong and abrupt headache, paralysis of one side of the body or hemiplegic, weakness on one side, disorientation, trouble communicating, including slurred speech, loss of vision on one side, loss of balance, and unconsciousness are all common signs of Cerebrovascular illness. Rheumatic Heart Disease is a life-threatening heart disorder caused by damage to the heart valve as a result of one or more bouts of rheumatic fever. Chest pain or discomfort, shortness of breath, exhaustion, rapid or irregular heartbeat, and irreversible heart damage due to rheumatic heart disease are all symptoms. Heart Attack, a portion of the heart is permanently damaged due to a lack of blood supply. It usually happens when a blood clot prevents blood from reaching the heart. The heart attack symptoms are pain in the chest and tenderness anywhere in the upper portion of the body. Heart failure-it arises when muscles of the heart fails to move blood as they are supposed to. Rapid breath when active or at rest, exhaustion and fragility, swelling in the legs, rapid or irregular heartbeat, limited capacity to exercise, and other symptoms of heart failure are some of the signs and symptoms [29].

Paper organization

This section 1 of this paper contains an introduction to different types of heart disease. The section 2 depicts the earlier work on heart disease prediction. The section 3 discusses the research methodologies and techniques of machine learning in tabular format, section 4 highlights the future scope. Section 5 concludes the article.

Literature Review:-

Among various diseases, the diseases that are related to the heart are the most threatening that occur in any age group and from a few symptoms, condition can worsen and even death of the person can take place. It is steadily rising on daily basis. This condition is caused by a variety of circumstances, some of which are preventable and others that are not. Avoiding smoking, drinking, and keeping a close watch on cholesterol and blood pressure are all avoidable factors. Family history and age are two more unpreventable factors that contribute to the condition. Regular exercise is also important in improving the health of people who have heart disease. Because of its higher death rate all over the world, it has become a tremendous motivation for several researchers to work on this disease to save many lives through effective early detection, and a lot of work has already been done on it.

PRISMA technique is followed to carry out this work. To perform this study, the total number of papers collected from different records was 80. Then 25 papers were removed from the list as they were not important for this work. Among them, 15 papers with irrelevant titles were excluded from the list and only 40 papers were left for further analysis. Then 40 full-text papers were accessed for the study. Among them, 25 concept papers and 10 review papers were analyzed for this study.

Dwivedi, A. Khas et al., applied Artificial Neural Networks, Support Vector Machine, Logistic Regression-Nearest Neighbour, Classification Tree, and Naive Bayes and used 13 attributes from the ML repository named UCI with 270 instances. All of these approaches were evaluated using performance of eight distinct categorization indices. Furthermore, all of these approaches were evaluated using a receiver operating characteristic curve. This study used logistic regression to reach the best accuracy of 85 percent, with sensitivity and specificity of 89 percent and 81 percent, respectively [1]. Patel et al., proposed decision tree classification algorithm and compared with J48 algorithm, Logistic model tree algorithm, and Random Forest algorithm. The data used to forecast heart disease in this study was gathered from patients of the UCI repository's Cleveland database, which was used to explain the performance of decision tree methods. The dataset contains 76 attributes and 303 cases. In this study logistic regression was used to reach the best accuracy level [3]. A. Singh et al., employed machine learning techniques to predict heart disease and collected data from the UCI machine learning repository, with 73 percent of the data being used as a training dataset and 37 percent being used as a testing dataset. K-Nearest Neighbor, Linear Regression, Support Vector Machine, and Decision Tree are the machine learning approaches employed in this study, and it was shown that the k-nearest neighbor algorithm has the greatest accuracy rate of 87 percent for heart disease prediction [6]. S. Mohan et al., proposed an article in which they researched on heart disease prediction utilizing hybrid machine learning techniques. The authors of this paper have not only focused on data collection. Still, they have also carefully selected features that are more contributing to this disease. The dataset is Cleveland, which is collected from the UCI machine learning repository and consists of 13 attributes and 297 instances, and has selected only 11 attributes that are likely more contributing for the heart disease, and has proposed a heart detection model using seven machine learning techniques [7]. Shah, D. et al., proposed a model for detecting heart disease at early stage. The dataset was gathered from the UCI Machine Learning Repository and consists of 77 attributes and 303 occurrences, of which the authors only used 14 attributes in this publication. When pre-processed data was utilized in the model, K-nearest neighbor, Naive Bayes, and Random Forest produced the best results, while the k-nearest neighbor algorithm produced the highest rate of accuracy [8]. Jyoti Soni et al. used Naive Bayes, Decision Trees, and Artificial Neural Networks to predict heart illness. They used a dataset of 909 occurrences from the Cleveland Heart Disease Database, which had 14 attributes. The results show that Decision Tree outperforms and that Bayesian Classification sometimes has equal accuracy to Decision Tree, but other methods such as KNN, Neural Networks, and classification based on clustering does not achieved the higher rate of accuracy. They also discovered that adopting a genetic algorithm to minimize the real data quantity to obtain the ideal subset of attributes required for heart disease prediction enhances the accuracy of Decision Tree and Bayesian Classification [9]. Vikas Chourasia et al., have worked on predicting heart disease with a smaller number of variables. They tested three alternative classifiers for heart disease prediction, including Naive Bayes, J48 Decision Tree, and Bagging algorithm, and found the same level of accuracy as before the attributes were reduced. 10-cross validation was utilized to determine the unbiased estimate of the prediction model [10]. Mohammad Waqar et al., worked on the prediction of the heart disease and have acquired a dataset from UCI, they performed their work by using several machine learning algorithms without the use of feature engineering. The synthetic minority oversampling technique (Smote) was utilised to manage the imbalance data in this study, and it was shown that the Smote-based artificial neural network outperformed all other models and existing systems. The data for this study was gathered from the UCI Cleveland dataset [11]. Khusboo Verma et al., used Random Forest, Logistic Regression, Decision Tree, and Support Vector Machine. The dataset used in this study comes from UCI machine learning, and it has 909 occurrences and 54 attributes. The proposed model outperformed other existing models such as random forest, logistic regression, support vector machine, and decision tree, as all of these models required a significant amount of time and provided lower levels of accuracy than the proposed hybrid deep-learning-based approach [12]. M. Kavitha et al., proposed a hybrid model for the prediction of the disease. Both decision tree and random forest were combined together to propose a model. The hybrid model outperformed the results and showed high level of result rather than produced by a single technique [13]. Poornima Singh et al., using a neural network, presented an effective model for the prediction of the heart disease to lower the risk rate. A multilayer perceptual NN and back propagation were applied as the training algorithm. The illness prediction dataset is a publicly available dataset with 15 features that were used in this study. The system was developed using a multilayer perceptual neural network and the BP algorithm, with the conclusion that the MLPNN model outperforms the Bp Algorithm [14]. Viren Viraj Shankar et al., have

improved the accuracy of their results by using real-world hospital data. Making use of patients they proposed using a convolution neural network approach for both organized and unstructured data. They gathered real-world hospital data, sanitized it, and then fed it into ML algorithms like Naive Bayes, KNN, and CNN. The developed model had an accuracy range of 85 to 88 percent [15]. Safial Islam Ayon et al., investigated computational algorithms and compared seven of them: SVM, logistic regression, deep neural network, NB, RF, and KNN. The Cleveland and statlog heart disease datasets was considered to carry out the study on the prediction of the disease, and it was shown that the Deep neural network had the highest accuracy rate among the seven algorithms [16]. Nidhi Balta et al., have analysed various ML techniques that have been introduced in recent years for the prediction of heart disease and concluded that ML technique when applied over 15 attributes outperformed the result and with the combination of selection of best features genetic combination has also showed the good accuracy [31].

Summary of the Existing Literature related to Heart Disease

Table 1:- ML techniques with Datasets used in prediction of Heart Disease.

Author	Year	Paper Title	ML Techniques Used	Dataset Used	Number of Attributes	Number of Instances
Purushottam et al. [17]	2015	Efficient Heart Disease Prediction System	Knowledge Extraction based on Evolutionary Learning	Cleveland. Data	13	303
SABA BASHIR et al. [18]	2015	A multicriteria weighted vote-based classifier ensemble for heart disease prediction	NB, Decision Tree based on Gini Index, Information Gain, SVM and Instance based Learner	UCI Machine Learning Repository	14	303
Jaymin Patel et al.[3]	2016	Heart Disease Prediction Using Machine learning and Data Mining Technique	J48 algorithm Logistic Model Tree and Random Forest Algorithm:	UCI Machine Learning Repository	13	303
Marjia Sultana et al.[19]	2016	Analysis of Data Mining Techniques for Heart Disease Prediction	Bayes Net, Kstar, Smo, MLP and J48	Collected and UCI	13	270
Abhishek Rairikar et al.[20]	2017	Heart Disease Prediction Using Data Mining Techniques	KNN, Decision Tree and NB	Cleveland Database	13	909
Amita Malav et al.[21]	2017	Prediction Of Heart Disease Using K-Means and Artificial Neural Network as Hybrid Approach to Improve Accuracy	KNN,NB,ANN and Hybrid combination of k mean clustering algorithm and ANN.	UCI	14	–
Sellappa Palaniappan et al. [22]	2018	Intelligent Heart Disease Prediction System Using Data Mining	Neural Network, Decision Tree, Naïve Bayes	Cleveland Heart Disease Dataset	15	–

		Techniques				
Aakash Chauhan et al. [23]	2018	Heart Disease Prediction using Evolutionary Rule Learning	Weighted Association rule, Rule mining algorithm	Cleveland Database	13	–
Shadman Nashif et al. [1]	2018	Heart Disease Detection by Using Machine Learning Algorithms and a Real-Time Cardiovascular Health Monitoring System	Naive Bayes, Artificial Neural Networks, Support Vector Machine, Random Forest and Simple Logistic Regression	Cleveland Heart Disease and Stat log Heart Disease dataset	13	303 and 270
R. Venkatesh et al.[24]	2019	Development of Big Data Predictive Analytics Model for Disease Prediction using Machine learning Technique	Naïve Bayes, Clustering and Statistical classification.	UCI Machine learning repository	14	–
Anjan Nikhil Repaka et al.[25]	2019	Design And Implementing Heart Disease Prediction Using Naives Bayesian	Naïve Bayesian	UCI Dataset	25	–
Devansh Shah et al.[8]	2020	Heart Disease Prediction using Machine Learning Techniques	Naïve Bayes, Decision tree, K-nearest neighbor, and random forest algorithm	UCI Machine Learning Repository	14	300
Archana Singh and Rakesh Kumar [6]	2020	Heart Disease Prediction Using Machine Learning Algorithms	k-nearest neighbor, decision tree, linear regression and support vector machine(SVM)	UCI Machine Learning Repository	14	303
NajmuNissa et al. [29]	2021	Heart Disease Prediction Using Machine Learning Techniques	Support Vector Machine, Decision Tree, Random Forest	UCI Machine Learning Repository	14	1026 and 303
Dr. M. Kavitha et al. [13]	2021	I. HEART DISEASE PREDICTION USING HYBRID MACHINE LEARNING MODEL	Random forest, Decision tree, hybrid model of random and decision tree	Cleveland Heart Disease Dataset	14	–
Ibrahim M. El. Hasnony et al. [26]	2022	II. MULTI-LABEL ACTIVE LEARNING-BASED MACHINE LEARNING MODEL	MMC, Random, Adaptive, QUIRE, and AUDI) selection strategies for multi-label	Cleveland Heart Disease dataset	13	303

		FOR HEART DISEASE PREDICTION II.	active learning were applied			
Raj Kumar GangappaNadakinamani et al. [27]	2022	V. CLINICAL DATA ANALYSIS FOR PREDICTION OF CARDIOVASCULAR DISEASE USING MACHINE LEARNING TECHNIQUES.	REP Tree, M5P Tree, Random Tree, Linear Regression, Naive Bayes, J48, and JRIP	Hungarian and Stat log (heart) Dataset	14	294 and 304

Research Findings

Data is inadequate so a proper dataset is not available for this disease prediction. In the future, an adequate dataset can be collected from the authorized source which can contribute to the effective prediction of the disease. Supervised ML algorithms are widely used for the prediction of the disease. The ensembled [hybrid/combination of two or more methods] models proposed for the prediction of the disease shows promising results.

Machine Learning Techniques for Heart Disease Prediction

To predict the heart disease various ML techniques are utilised in different studies. Supervised learning, unsupervised learning, and reinforcement learning are the distinct types of ML techniques. Supervised Machine Learning is a technique that is based on data which is provided with the labels. In unsupervised learning, data is provided without labels and in reinforcement learning, a machine learns itself based on hit and trial method [6]. ML is a branch of AI that develops algorithms which are able to learn from the previous data and make predictions based on that data. Using a training dataset, a model is created that trains machine learning algorithms. The model based on previous data can make predictions [8]. In supervised learning, the dataset is provided with labels to train the model and in the future make the predictions [6]. Machine learning constructs models by discovering hidden patterns in the input dataset. Supervised learning is a machine learning technology in which data is provided with labels, and it predicts the result for fresh data based on that provided data. The data that is labeled (training data) acts as a supervisor/teacher in Supervised Computer Learning, teaching the machine to predict the proper output for fresh data [6]. Unsupervised Learning: The data presented to the machine in unsupervised learning is not labeled. There is no instructor in this learning to teach the machine to anticipate the output; instead, the computer finds the pattern and relationships among the data and predicts the output for new data based on that pattern [6]. Reinforcement Learning: it takes suitable action in a particular situation to maximize rewards. The most often used machine learning technique for predicting cardiac disease is supervised learning, namely classification. In this paper much focus is given to the most widely used classification technique for heart disease prediction [8].

A substantial amount of work has been performed by different authors on the prediction of heart disease. SVM, Naïve Bayes, Random Forest and Decision Tree are the most frequently used ML techniques applied by different authors in their work. Many algorithms in some cases have shown accurate results and in other cases have shown poor results.

Support Vector Machine:

The support vector machine is an algorithm that works with the concept of a hyperplane. It's a classification type of machine learning technique that divides data into categories by drawing a hyperplane between them. In SVM, a line that divides the input variable and space is called as Hyperplane. It can be used to segregate input variable space having classes that are either 0 or 1 [1][6] [28].

Naïve Bayes:

It is a supervised machine learning technique in which Bayes theorem is applied for the classification. Because it relies on assumptions, a lack of available probability data, and class conditional independence, this method can lose accuracy. It is a basic, straightforward, and efficient classification technique that solves non-linear, complex problems [1][8] [28].

Decision Tree:

It is one of the most important tools for classification and prediction. Tree like nodes are used by decision tree. It is a type of Supervised ML algorithm. The ease with which the decision-making process may be visualized and understood is one of the advantages of employing decision trees in machine learning. This is a supervised machine learning algorithm of the type. These trees are built quickly and easily using a top-down recursive divide-and-conquer strategy [6][7] [13].

Random Tree:

Ensemble classifier generates several decision trees, which are then combined to provide the best result. The output of the classes is represented by each tree. The bootstrap aggregation algorithm is another name for the random forest algorithm [7][3][1] [13] [28].

K-Nearest Algorithm:

It is a supervised classification technique in which objects are classified on the basis of their closest neighbors. It assumes that new data and existing data are comparable and assigns new data to the category that is most similar to the existing categories. It operates by calculating the distance between data points. KNN algorithm is simple for implementation without making assumptions or generating models. Using noisy and irrelevant features can reduce the accuracy of KNN. For regression, search, and classification, KNN is employed [6][8].

Artificial Neural Network:

It grasp the processing of human brain and generate algorithms that are utilized to solve various challenges related to the prediction. It can be trained to model any number of database outputs and can generate a distinct method for each one. ANN is a fantastic tool for finding complicated and ambiguous patterns [1].

Future Scope

The more efficient work can be carried out in this domain which will help medical science in the efficient prediction of the disease and an appropriate and tested hybrid models for heart disease prediction can be proposed using a mix of machine learning techniques, it is possible to predict cardiac disease with high accuracy. Data is inadequate so a proper dataset is not available for this disease prediction, an adequate dataset can be collected from the authorized source which can contribute to the effective prediction of this disease. Large primary dataset can be collected from various organizations and repositories to achieve a higher accuracy rate of the disease prediction. In addition to primary supervised ML techniques like decision tree, random forest and SVM, the advanced techniques like boosting, gradient boosting and XGBoost are available which can be used to propose and ensemble model.

Conclusion:-

The heart is crucial to the body's efficient functioning. Any disruption in the proper functioning of the body can lead to various diseases related to the heart and it is one of the biggest challenges in the modern era that takes away millions of lives every year. In the early stage, if the symptoms are ignored, they can worsen the condition with time and even lead the person to death in a short time. To lower the number of people who die from heart disease, early detection is essential. To avoid unhealthy habits and to have regular exercise to some extent can control heart disease. Most researchers have already used various ML techniques in their work for heart disease prediction. Each algorithm has outperformed the result in some cases and has shown poor performance in some other cases.

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