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Significant Analysis of Heart Disease Detection Using Artificial Intelligence Algorithms

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ABSTRACT

Lifestyle changes affect human health significantly, leading to heart disease and Sudden death in patients. The Healthcare Industry faces multiple challenges in managing and treating the increasing number of patients according to their disease severity level. The challenges for medical experts include early identification of symptoms & timely treatment to save them. The non-availability of efficient, effective, and automatic screening methods and limited medical data analytics augment these challenges. Some current medical applications have stated that Artificial intelligence algorithms provide efficient outcomes in predicting heart diseases. This paper conducted a detailed survey on various artificial intelligence algorithms used for heart disease prediction from various related datasets. The survey aims to identify the limitations and factual problem statements and identify solutions.

Keywords: *Heart Disease Detection, ECG Analysis, AI Algorithms, Machine Learning Algorithms, Healthcare Analysis.*

1. INTRODUCTION

Heart Diseases (HD) like myocardial infarction, ischemic chest pain, and congestive heart failure are the major causes leading to death. Nearly 12 million people die due to HD every year. The US government reported more heart disease-related deaths than other developed countries. Heart diseases occur due to excessive BMI, sedentary lifestyle, alcohol abuse, and smoking tobacco. Early diagnosis is essential to prevent death due to heart disease. Conventionally, doctors use diagnosis techniques like collecting the patient's history, doing physical examinations, and understanding the symptoms experienced. The issues with conventional practices are the lack of accuracy and more time consumption. AI is an advanced technology that simulates human intelligence and helps doctors predict who is at high risk of heart disease. AI can automatically collect and analyze data to show correlations, patterns, and predictions. It makes a machine simulate human intelligence to solve problems. The main goal of AI is to create an intelligent model that can perform complex tasks.

Artificial Intelligence (AI) incorporates human intelligence into computing machines using a protocol (algorithm) focusing on three aspects, such as learning, reasoning, and self-correction, to obtain maximum efficiency. Machine learning is a subset of AI used to develop algorithms for learning data and improving their performance concerning time and without coding. Deep learning is a subset of machine learning used to develop deep neural network models for learning and extracting features automatically from the data. Based on the functional activities, machine learning algorithms are categorized into supervised, unsupervised, semi-supervised, and reinforced learning. Recently, machine learning and deep learning algorithms (DL) have been used to solve challenges in emerging applications, particularly medical data analytics [45–49]. Compared to machine learning algorithms, deep learning algorithms are constructed based on neural networks, mimicking human brain function and automatically analyzing the data. It is scalable, robust, reliable, and efficient for analyzing medical images, medical data, and time series data. This paper aims to carry out a detailed study of various AI algorithms used in diagnosing medical data related to heart diseases to understand the challenges and research gap.

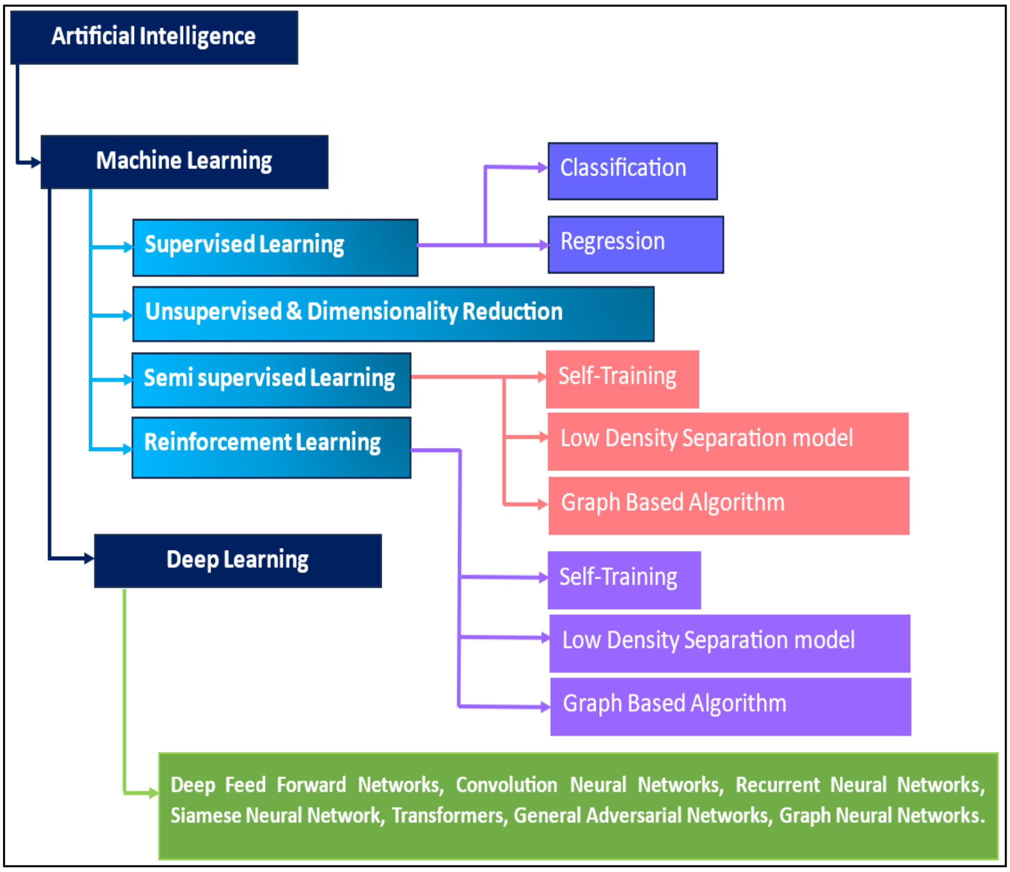

Figure-1. Artificial Intelligence Algorithm And Classes

The medical industry of developing countries has found that the ratio of cardiac specialists to the number of heart disease patients is very low. With a limited number of doctors, the diagnosis and efficiency are slow. In case of doctors' unavailability, the clinical management should promptly perform earlier diagnosis, checking patient records, and screening tests for heart diseases. However, the existing methods are not prompt and affect the timely treatment, leading to heart attacks [1] or increasing the severity level of other related heart diseases. This problem is considered a major problem, and several research works have been motivated to provide an automatic diagnosis system for heart diseases. In contrast, the prediction accuracy is less, leading to ineffective diagnosis.

This research work has aimed to design and implement an efficient automatic diagnosis of heart diseases using deep learning algorithms. So, in the initial stage, the aim is to understand the issues and challenges of the earlier research works that provide a new pathway in designing a proposed deep learning model. This paper contributes the following:

1. A study is made on recent research on heart disease prediction through AI algorithms.

2. It understands the issues and challenges involved in heart prediction regarding datasets, software, hardware, and algorithms.

3. The effectiveness of the models is evaluated, and the models with high accuracy are found.

Below is a detailed study of various earlier methods to help readers understand the issues and challenges of the earlier research.

Heart Diseases Diagnosis Using Artificial Intelligence Algorithms

The authors [2-3] seek to give a complete overview of the advanced applications of AI algorithms in clinical diagnosis and cardiovascular disease treatment. They review the effectiveness of AI algorithms in processing electronic health record (EHR) data [4]. They highlight the AI techniques utilized for diagnosing and predicting DR and AMD from EHR data to understand the risks of proceeding with the right treatment of ocular disease.

Artificial intelligence-based Diagnosis systems can be designed using Machine Learning (ML) models for heart disease detection. Various research works [1, 9, 10] have emphasized data processing in handling and appropriately converting the input data into features. One of the efficient machine learning algorithms is Random Forest (RF) [1, 11, 20, 19], which has a collection of decision trees to decide, predict, and classify heart diseases. The authors [1] have aimed to enhance the classification accuracy concerning heart disease identification, emphasizing data analysis; 83% accuracy was achieved with the training data. The RF algorithm combines the linear model [11] to predict heart diseases and improve prediction accuracy. The RF and Linear model obtained 88.7% accuracy while experimenting with the heart disease dataset. The authors [20] used the Chi-Square method to extract the features from the Cleveland Heart Disease dataset and several machine learning models for classification. All the proposed machine learning models were experimented with 303 instances, and 13 Cleaveland heart disease dataset features were selected. The RF model obtained better results with 88.5% accuracy than the regression and clustering-based ML models. The authors [19] used several supervised classifiers for heart disease prediction and compared their output with other models. From the comparison, it was found that the RF model gained 100% accuracy for a Kaggle dataset in heart disease prediction.

Internet of Medical Things (IoMT) gathers patient health information to diagnose heart diseases [5, 8]. The author proposed a custom method (specially designed for a particular protocol) for predicting and classifying heart diseases by analyzing the data obtained from IoT devices. The input ECG signals are captured through wearable IoT devices and stored in the cloud database. The entire process involves data generation, collection, analysis, and prediction; this method obtained a better prediction of 99.15% accuracy [5]. Medical IoT sensors generate heart-related data optimized using AI algorithms to predict heart diseases.

Artificial Intelligence integrated Internet of Things (AIoT) was used for analyzing ECG data and detecting cardiac diseases [8]. The whole process of an AIoT system involves IoT-based Harward, smart device applications, a cloud database, and a Convolution Neural Network for integrating all. From the experimental results, it is identified that AIoT obtained 94.96% accuracy.

The author [8] has deployed an AI-based model to detect and classify heart diseases observed through various IoT sensors and obtained 94.96% accuracy in classification. An ANN model was proposed [6] to detect heart diseases from PCG heart signals, and the classification performance was evaluated. 94 PCG signals were experimented with by ANN to classify the normal and heart disease signals. The final classification result is extracted using the Radial Basis Function (RBF) and Back Propagation Network (BPN) model. The simulation result shows that the RBF model obtained 98% accuracy, and the BPN model obtained 90.8% accuracy. Fetal heart diseases can be identified by analyzing DNA cytosine methylation. DNA methylation is crucial in biological processes like development, differentiation, and gene expression. The level of methylation can determine the health condition of the human body. The irregular level of DNA cytosine methylation changes the gene and causes diseases. AI models are developed to analyze DNA cytosine methylation to detect fetal heart diseases Bahado-Singh et al. [7]. 12 case reports with 59187 cytosine samples were used in the experiment, and the proposed AI model obtained 98% and 94% sensitivity and specificity, respectively, regarding heart disease detection.

1.1 Herat Diseases Diagnosis Using Machine Learning Algorithms

Considering the applications of machine learning algorithms, many AI applications are developed using machine learning algorithms that are implemented with the basic ideas of AI [33]. Machine learning algorithms have obtained better output in speech recognition [34] and emotions [35]. Many machine-learning algorithms are used in manufacturing control [36] and economic planning [37]. The authors [38] stated that machine learning is a powerful data analytics tool [39] used in several expert systems [40]. Some research [41,42] uses machine learning algorithms in robotic design and control.

They are often used to provide solutions for applied scientific problems. For example, machine learning algorithms used for applicability conditions [43] and deep learning algorithms promise better results for solving problems in the field of chemistry [44]. A high number of researchers have applied machine learning algorithms in the fields of medicine [45, 46], particularly in diagnosing medical images [47], computational biology [48, 49], astronomy [50], agriculture [51], corporation economy [52], industry [53], construction [54], environmental modelling [55], and geo-ecological processes [56], exploration [57], petrographic studies [58-59], and forecasting of data mining [60].

Machine learning algorithms are the core of contemporary investigations in Natural Language Processing (NLP) [61-63]. Machine learning algorithms are categorized into various classes based on their process and purpose of the algorithms [64] and include supervised learning [65], unsupervised learning [66], dimensionality reduction, semi-supervised learning, reinforcement learning [67], and deep learning [68].

Regarding heart disease prediction, classification algorithms perform on a tabular form of data to predict heart disease. Among the classification algorithms, the Random Forest algorithm is one of the supervised learning models used in both classification and regression applications [1, 11, 19, 20]. The classification model's efficiency varies based on the application and the available data. A comparative study [12] shows an efficient framework for predicting HD using the UCI repository dataset and healthcare sensors. While comparing different classifiers, the simulation results demonstrate that the J48 classifier outperforms other classification models regarding prediction accuracy.

Computational Intelligence (CI) methods are called Effective Computation since they reduce computational and time complexity. Some of the efficient classifiers like decision tree (DT) and K-Nearest Neighbor models (KNN) models [14] behave as computational intelligence models; their performance was evaluated by experimenting with HD datasets obtained from the NHS database, and the accuracy of detection efficiency was compared with the existing methods. The author [18] used an online UCI dataset including 303 rows and 76 properties. The Isolation Forest (IF) method normalizes the data based on the dataset's key attributes and metrics, aiming to enhance the accuracy. It also employed all the supervised learning methods, emphasizing its experimental results. Finally, it was concluded that the efficacy of K-Nearest Neighbor (8 neighbours) outperforms the other methods regarding sensitivity, precision, accuracy, and F1-score.

In addition to the classification models, ensemble learning models are also considered for heart disease prediction. A neural network algorithm [13] is used to build the prediction model, followed by the Genetic Algorithm and PSO algorithm for extracting important features from an ECG dataset. The analysis employs the Cleveland heart disease dataset and ECG images. These ensemble models combine two or three algorithms to provide effective results. Such hybrid models provide better accuracy in the prediction process.

Similarly, the authors [15] have developed a two-stage stacking model containing base and meta-level classifiers. The predictions from the base classifiers are fed as input to the Meta-level classifier. An enumeration algorithm is then utilized to choose the optimal mixture of classifiers, producing the best results, showing that the suggested model reaches a high accuracy of 95.43%, sensitivity of 95.84%, and specificity of 94.44% for congenital heart disease detection. This approach is an effective tool for clinicians to determine individuals with normal coronary arteries from those with congenital heart disease. The author [16] used the data mining method for heart disease prediction. The LR and Neural Network models are utilized as data mining algorithms. The dataset was taken from the UCI. The results demonstrate that the LR algorithm performs better than the Neural Network model, achieving a precision of 95.45% and an accuracy of 91.65%.

Different methods are integrated to create hybrid learning models concentrating on specific parameters to improve overall performance and accuracy. The models learn features in the datasets to obtain the weights that help predict heart diseases. For example, improving the weights obtained by the algorithm improves the prediction accuracy. Some of the hybrid models [17] like that are, (Inf-FSs) to detect the essential elements, Improved Weighted RF (IWRF) for predicting heart disease (HD), and the Bayesian model to enhance the new hyper-parameters for IWRF. Two publicly available datasets, namely Statlog and HD clinical records, were utilized for model development and validation. Compared with the previous algorithm, hybrid models showed the superiority of the suggested Inf-FSs-IWRF model, reaching higher accuracy and F-measure on both datasets. Also, a comparison to prior studies revealed that the new method performed better by obtaining 2.4% and 4.6% increased accuracy on the respective datasets.

1.2 Herat Diseases Diagnosis Using Deep Learning Algorithms

In this sub-section, various pieces of literature are reviewed and discussed to illustrate the efficiency of deep learning algorithms. Most researchers have suggested that DL-based disease diagnosis is the most powerful and accurate result prediction method. It also discusses the merits and demerits of the existing DL-based approach to HD diagnosis. The neural network-based classification models were proposed [21] to improve the efficiency of HD detection and accurately detect the early symptoms of HD. For this, the input data are collected from the MIT-BIH AF database, which contains the reports of the 10 patients. To analyze the efficiency of the proposed approach, the authors have analyzed the model's error rate using different points. Compared to the existing models, the current model performed with a lower error rate (below 9%). A Deep Neural Network (DNN) model **[26]** is proposed to detect normal and abnormal HD data from the input data collected from the Cleveland Clinic Foundation. The simulation result of the model shows that it has classified the input data with 83.67%, 93.51%, 72.85%, 79.12%, and 0.8571 accuracy, sensitivity, specificity, precision, and F1-score, respectively. A modified deep convolutional neural network (MDCNN) model has been implemented [28] to classify normal and abnormal HD data from the input data containing 303 records collected from various resources (UCI machine learning repository, public healthcare datasets, and Framingham) through IoT sensors. The experiment result shows that, compared to other models, the proposed model classifies with 98.2% accuracy. This model required an advanced feature selection model and optimization technique to classify the data gathered from the wearable device available in the market.

Several deep learning models [27, 29] were used in earlier research to diagnose and classify heart diseases at home using heart sounds. The input HD data are gathered from two sources: first, data observed from the locally available data gathered from the mobile applications, which included 704 data; second, the data observed from clinical trials, which consists of 1636 data. The simulation result of the model indicates that it has achieved 100% accuracy in diagnosing HD. This model required additional features to more accurately classify the large data gathered from various hardware sensors and integrated computing devices. Deep learning approaches, like KNN, ANN, SVM, and DNN [23], were used to detect heart diseases from the input dataset. The input data are collected from different medical industries based on 14 attributes like age, sex, Chol-level, and chest pain range. The authors have applied the Talos optimization technique to classify the input data accurately. The combination of Talo optimization and the DL model has produced a 90.76% accuracy.

The LSTM and GAN ensembled models **[24]** are used to detect heart diseases from ECG samples. The input ECG samples are collected from two different datasets, MIT-BIH and PTB-ECG. The MIT-BIH and PTB-ECG datasets contain 214 and 54 normal data, 146, 346 and abnormal HD data. The proposed model classifies dataset-1 with 99.2% and dataset-2 with 99.4% accuracy. Both ML and DL models have been used to improve the accuracy of HD prediction in diagnosis [25]. The UCI machine learning HD datasets are experimented with the DL models to prove the efficiency. It contains 14 attributes based on patient personal and health data. The irrelevant input data are isolated using the Isolation Forest algorithm, and it has achieved 94.2% accuracy [25].

A detailed study was presented to understand the efficiency of the deep learning models in heart disease prediction [30] based on the analysis of the two clinical factors. Two sets of hybrid deep learning models (CNN-LSTM and CNN-GRU) are implemented to accurately classify the input data [22]. The efficiency of these methods is evaluated by implementing them with two HD datasets. The first dataset contains 27,373 HD reports and 30000 health reports. The second dataset is collected from the Cleveland database, which contains 526 abnormal and 499 normal heart patient data. Both datasets are classified using the proposed approaches. The simulation result of the model shows that the proposed hybrid model performs better than the existing ML-based model with 98.41% accuracy. However, this hybrid model required additional features to classify the large ECG and image data set.

1.3 Comparison of survey

Most of the research discussed in the above section has used ECG signals as input samples to diagnose HD. The main objective of this research is to prove the efficiency of AI-based models in diagnosing HD. Table-1 discusses some of the recent AI-based HD prediction research works. It summarizes the methodology, dataset used, and obtained results with comments about the method.

Table-1 Survey comparison

Author	**Method**	**Dataset**	**Performance**				**Remark**
			ACC	**PRE**	**REC**	**F1**	
Y.J. Lin et al. (2019)	AI-based CNN model	ECG samples were taken from wearable devices from patients at Tainan Hospital.	Clinical Trails- Dataset 1				We need to extract more features to classify various kinds of arrhythmia.
			94.46%	-	-	-	
			MIT-BIH Dataset 2				
			95.73%	-	-	-	
R.Bahado-singh et al. (2023)	AI-based approaches include SVM, GLM, PAM, RF, LDA, DL, and Logistic regression models.	12 HD case reports of fetal, with 59187 cytosine samples	-	98%	94%	-	The major strength of this approach is that it can classify the CHD from the fetus with minimum invasive.
S. Manimurug	AI-based hybrid	Patients' information	Hybrid Faster R-CNN				The proposed approaches are more

an et al. (2022)	faster R-CNN model and hybrid LDA-MALO technique.	with 76 characteristics and 303 records were obtained from the UCI repository and UCI echocardiogram image datasets containing 66 normal and 66 abnormal images of 30 patients.	99.15%	-	-	-	efficient in diagnosing normal and abnormal HD data and images.
			Hybrid LDA-MALO				
			96.85%	-	-	-	
T.R. Ramesh et al. (2022)	DT, SV, NB, RF, KNN, and LR	The online UCI dataset has 303 rows and 76 properties collected from 4 different healthcare institutions.	94.1%	91.7%	94.8%	90.8%	The proposed ML-based approach is the best model for predicting and classifying HD data.
J. Premsmith and H. Ketmaneechairat. (2021)	LR and Neural Network models are utilized.	The UCI dataset contains 303 patients' cardiac reports with 75 attributes obtained from the Cleveland Clinic Foundation (CCF) in Cleveland, Ohio, in the US.	Logistic Regression				The proposed LR model performs better and improves the web application's prediction accuracy with less error rate.
			91.65%	-	-	_	
			Neural Network				
			95.45%	-	-	-	
M.M. Ali et al. (2021)	KNN, DT, and RF	An open-source Kaggle HD dataset contains 1025 patient records, 713 males and 312 females, 499 normal HD reports, and 526 abnormal HD reports.	Random Forest (RF)				The supervised ML-based algorithm is more suitable for producing high accuracy with high potentiality.
			100%	100%	100%	-	

K.H. Miao and J.H. Miao (2018)	DNN	HD reports from the Cleveland Clinic Foundation include 91 female and 212 male patients.	83.67%	79.12%	93.51%	0.8571	This model is more useful to healthcare professionals and patients in all countries.
M.A. Khan (2020) DATASET :	Modified Deep Convolutional Neural Network (MDCNN)	Through IoT sensors, 303 records were collected from various resources (UCI machine learning respiratory, public healthcare datasets, and Framingham).	98.2%	-	-	-	Classifying the data gathered from the wearable devices available on the market required an advanced feature selection model and optimization technique.
Mainajjar and S.S. Abu-Naser (2022)	The proposed deep learning-based approach.	(1) mobile App, which included 704 data. (2) clinical trials, which include 1636 data.	100%	-	-	-	This model is the best model for classifying HD from the audio spectrogram.
A. Rath et al. (2021)	LSTM and GAN model	MIT-BIH (contains 214 normal and 146 abnormal data) and PTB-ECG (54 normal and 346 abnormal data).	MIT-BIH dataset-1				This model is also more suitable for diagnosing other health problems and diseases.
			99.2%	-	-	-	
			PTB-ECG dataset-2				
			99.4%	-	-	-	

2. CONCLUSION

The main objective of this paper is to present a detailed analysis of various Artificial Intelligence algorithms used to diagnose heart diseases. It explains AI, machine learning, and deep learning with their sub-classes. Different AI, ML, and DL algorithms are used for heart disease prediction on various datasets, like ECG, heart sound, Cleveland HD, and healthcare records, and the results they obtain are explained. The overall analysis shows that the ECG dataset is predominantly used for heart disease prediction. The study identified that Random Forest and KNN algorithms are highly used for heart disease prediction. Deep learning models, like the DCNN model, are considered for ECG image-based heart disease prediction. The deep learning models obtained higher prediction accuracy than AI and ML. It has also been noticed that very few methods have tried to predict the earlier symptoms of heart diseases. Still, they have not performed better, consumed more time, and had programming complexity. Hence, it is essential to develop a hybrid deep learning model for examining, diagnosing, and predicting earlier symptoms of heart diseases from multi-modality data for heart disease prediction.

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