## CHAPTER ONE

## 1.0 Introduction

Cardiovascular diseases are conditions that influence the constructions or capacity of your heart, for example, Abnormal heart rhythms/arrhythmias, Aorta infection, and Marfan disorder, Congenital coronary illness, Heart assault, Heart disappointment, Heart muscle sickness (cardiomyopathy) and Stroke, and so on (Steinbaum, 2019). Cardiovascular diseases are Non-Communicable Diseases (NCD) like cancers, chronic respiratory diseases, diabetes, and Mental Health Disorders. CVD is seen as “a silent epidemic” because they are at the forefront of diseases leading to death. These diseases share common risk factors namely; age, unhealthy diet sexual orientation, hypertension, diabetes mellitus, tobacco smoking, processed meat utilization, unnecessary liquor consumption, sugar consumption, family ancestry, weight, absence of exercise, psychosocial factors, and air contamination (Emakhu et al., 2020; WHO, 2019).

Over 36 million people die annually from Noncommunicable Diseases accounting for about 63% of all global deaths. More than threequarters of the global deaths from CVDs occur in developing nations. Low- and middle-income countries are known to bear 86% of the number of these premature deaths giving rise to estimated cumulative economic losses of US$7 trillion over the next 15 years (WHO, 2019).

According to the Federal Ministry of Health (FMoH), “cardiovascular disease is a major public health concern, accounting for 11% of the over 2 million NCD deaths in Nigeria each year.” People with Cardiovascular Disease are often unaware of their condition until a disaster such as a stroke, heart attack, or death occurs. (WHO, 2019).

The increase in the amount of health data gathered through the electronic health record (EHR) systems makes the use of strong analysis tools are necessary. Data Mining has proved itself to be very effective in data analysis and forecasting diverse scenarios for numerous fields (Sai Shekhar et al., 2021). Paring data mining with deep learning had led to the formation of many models to forecast specific scenarios for us to operate on them. The need of making accurate predictions of heart disease made the use of machine learning algorithms to point out predictions based on many factors. In the occurrences of many factors, the human mind cannot process that much and come up with estimation and can therefore provide incorrect feedback several times, leading to vital risk to the patient.

## 1.1 Background of the Study

Several research have been done in relation to heart disease in machine learning, some have work on predicting the early stage of heart disease (Almustafa, 2020; Gao et al., 2021; Usha Sri, 2020), increasing the efficiency of diagnosis and reduce the misclassification cost (Dandona et al., 2017) and on the relationship between certain factors and to the presence of heart disease (Muibideen & Prasad, 2020) as well as enhancing the selection of features(attributes) that are in causal relationship with presence of heart disease(Jothi Prakash & Karthikeyan, 2021).

Research have been done on the area of heart disease prediction using different machine learning techniques like logistic regression, Support Vector Classifier, Random Forest, Decision trees and with deep learning models e.g. Convolutional Neural Network (CNN). Muibideen & Prasad, (2020) in their research builds a probabilistic graphical model to understand the causal relationship among attributes of the Cleveland heart disease dataset from University of California Irvine (UCI) to predict heart disease. Emakhu et al., (2020) in their research used AdaBoost, Bagging, Random Forest, and Voting Ensemble (Decision Trees, Logistic Regression and Support Vector Machines) to analyze different heart disease prediction system models for designing an automated medical diagnosis.

Many factors or input features even to machine learning often make a predictive modeling task more challenging to model. This is more generally referred to as the curse of dimensionality. Feature engineering is important in increasing the efficiency and correctness of prediction on machine learning models. It entails changing raw data into characteristics that better describe the underlying problem to prediction models, resulting in enhanced model accuracy on previously unseen data. Feature engineering includes determining attributes that are relevant for your modeling assignment, estimating the utility of a feature, and extracting features. The automatic creation of new features from raw data, Feature Selection; the selection of features from a large number of features to a few that are helpful. (Shekhar, 2018). Also in all the above researches, 14 features(attributes) where used which brings the need for dimensionality reduction for computational efficiency and improvement on the accuracy of the analysis(Lidy & Rauber, 2008).

Bayesian networks (BNs) have received increasing research attention as it possesses potential significant benefit to the healthcare system(McLachlan et al., 2020). A Bayesian network represents the causal probabilistic relationship among a set of random variables, their conditional dependencies, and it provides a compact representation of a joint probability distribution. It is made up of two major components: a directed acyclic graph and a collection of conditional probability distributions. The directed acyclic graph is made up of nodes that represent random variables. A node might be a health domain in terms of health assessment, and the states of the node could be the possible reactions to that domain(Cheng et al., 2002).

The proposed method in this study is the use of wrapper feature selection technique as a dimension reduction technique for extracting important features and the use of Naïve Bayes, Bayesian Network, KNN, and Logistic Regression to make predictions. The performance of all the models is also measured to make a comparison.

## 1.2 Problem Statement

Medical dictation has traditionally been a high-maintenance sector in terms of time, accuracy, and cost. Human beings are prone to and capable of making mistakes. Cases of cardiovascular diseases are rising at an exponential pace, and that is very troubling and early detection is crucial in preventing the progression of the disease. Patients usually visits a hospital when the disease reaches an advanced stage. This leads to increase in the cost of treatment and also weakens the chances of recovery and often leads to loss of life. Cardiac disorders can be avoided if they are detected early. The importance of developing a constraint-free, reliable and timely prediction system has long been recognized by the health sector. Machine learning based prediction system can prove to be an effective tool in detecting the heart diseases in an early stage.

## 1.4 Aim and Objectives of the Study

The main aim of the study is to develop an accurate method for prediction of heart disease. To achieve these, the work considered the following specific objectives:

* Study the best performing models in heart disease prediction.
* Use Wrapper method on Bayesian network to extract those feature dependency that affects the performance of the classifier
* To compare results obtained from the ensemble model and that of the individual models.

## 1.5 Significance of the study

As heart disease has become is a silent epidemic, accurate and timely prediction of heart disease is important. This will help in reduction in the cost of treatment, loss of life and also increases the chances of recovery.

## 1.6 Scope and Limitation of The Study

**Scope**

This study covers the use of structured tabular data on supervised machine learning algorithms to accurately predict the risk of the presence of heart disease in a person.

**Limitation**

The Study does not include the use of heart image data to make prediction on the presence of heart disease in a person

# CHAPTER TWO: LITERATURE REVIEW

## Introduction

The chapter explain heart disease, its type and causes. It also explains the various symptoms and ways of manually diagnosing heart disease. An over view of machine learning as well as different tool and algorithms predominantly used in heart disease prediction is given. This chapter reviews the prominent prediction system in relation to this research. The Cleaveland dataset as well as features are also explained. Various related works are also briefly outlined; the algorithm used and evaluation metrics used.

## Cardiovascular Diseases

Cardiovascular diseases (CVDs) include any disorder, abnormality, or failure to function well, relating to the heart and blood vessels or the circulation.(Ike & Onyema, 2020). Cardiovascular diseases includes Abnormal heart rhythms/arrhythmias, Aorta infection, and Marfan disorder, Congenital coronary illness, Heart assault, Heart muscle sickness (cardiomyopathy) and Stroke, and so on (Steinbaum, 2019).

Cardiovascular diseases (CVDs) is not in itself an actual disease; it is rather refers to wide range of disorders affecting not only the heart but also blood vessels(Adedoyin & Adesoye, 2005). CVD is a cluster of injuries that affect the cardiovascular system (the heart and blood vessels). These are most commonly diseases of the heart and of the blood vessels of the heart and brain(Nason, 2007).

## Types Cardiovascular Diseases

CVD comprises many different types of condition. Some of these might develop at the same time or lead to other conditions or diseases within the group. Diseases and conditions that affect the heart include:

**Coronary heart disease**

Coronary heart disease (CHD), also called coronary artery disease (CAD) and atherosclerotic heart disease, is the end result of the accumulation of atheromatous plaques within the walls of the arteries that supply the myocardium (the muscle of the heart). In other words, CHD affects the arteries that feed the heart muscle. The disease is the most common cause of sudden death.

**Angina**

The pain associated with very advanced CHD is known as angina, and usually presents as a sensation of pressure in the chest, arm pain, jaw pain, and other forms of discomfort. The word discomfort is preferred over the word pain for describing the sensation of angina, because it varies considerably among individuals in character and intensity and most people do not perceive angina as painful, unless it is severe. Angina is essentially a cramp in the heart muscle. Angina is a type of chest pain that occurs due to decreased blood flow into the heart

**Stroke**

A stroke is an acute neurological injury whereby the blood supply to a part of the brain is interrupted, either by arterial blockage or rupture (haemorrhage). The part of the brain perfused by a blocked or burst artery can no longer receive oxygen carried by the blood; brain cells are therefore damaged or die (become necrotic), impairing the function of that part of the brain. Stroke can cause permanent neurological damage or death if not promptly diagnosed and treated.

Strokes can be classified into two major categories: ischemic and hemorrhagic. Ischemia can be due to thrombosis (clotting), embolism (clot or obstruction from elsewhere in the body), or systemic hypoperfusion (reduction of the blood flow to all parts of the body). Haemorrhage can be due to intracerebral haemorrhage or subarachnoid haemorrhage. About 80% of strokes are due to ischemia.

**Rheumatic heart disease**

Rheumatic heart disease is a condition in which the heart valves are damaged by rheumatic fever caused by streptococcal infection. Rheumatic fever is an inflammatory disease that can affect many of the body's connective tissues — especially those of the heart, joints, brain or skin. Anyone can get acute rheumatic fever, but it usually occurs in children five to 15 years old. The rheumatic heart disease that results can last for life. About half of these babies have a minor defect and will not need any treatment but the rest will need either medical treatment or surgery. Rheumatic heart disease is complication of strep throat that causes inflammation in the heart and which can affect the function of heart valves

**Congenital heart disease**

Congenital heart disease is a broad term that can describe a number of different abnormalities affecting the heart, all of which are abnormalities of the heart's structure and function caused by abnormal or disordered heart development before birth. In some cases, such as coarctation of the aorta, it may not present itself for many years and a few lesions such as a small ventricular septal defect (VSD) may never cause any problems and are compatible with normal physical activity and a normal life span. Some congenital heart diseases can be treated with medication alone, while others require one or more surgeries. Congenital heart disease is a problem with heart function or structure present from birth

**Peripheral arterial disease**

In peripheral arterial disease, the arteries that supply the blood to the legs become narrowed or completely blocked off. The narrowing of the artery usually occurs in the upper part of the leg. The disease is caused by a gradual build-up of fatty material within the walls of the artery (atherosclerosis). The presence of atheroma can also cause a blood clot (or thrombus) to form, blocking off the artery completely. People with peripheral arterial disease are also likely to have narrowing of other arteries in the body. If there is narrowing in the arteries that supply blood to the heart, it can cause angina or a heart attack. If the arteries to the neck are affected, it can interfere with the flow of blood to the brain and may cause a stroke.

**Aortic aneurysm and dissection**

An aortic aneurysm is a balloon-like swelling of the aorta that can rupture causing large internal bleeding (dissection).

**Deep vein thrombosis**

A deep vein thrombosis (DVT) is a blood clot (thrombus) that develops in a deep vein, usually in the lower leg. Deep vein thrombosis can cause pain in the leg and can potentially lead to complications. About 1-3 people in 1000 develop a DVT each year in the UK. A DVT usually develops in a deep vein in the leg but it can occur elsewhere, such as the arm. Deep veins pass through the centre of the leg and are surrounded by the muscles. A DVT is different to blood clots that form in a separate set of veins (called superficial veins) that lie under the skin. These clots are called superficial thrombophlebitis and are less serious.

It is uncommon for DVT to cause any further problems but potential complications include Pulmonary Embolism (PE) and post-thrombotic syndrome. PE happens when a piece of the blood clot breaks off and travels in the bloodstream to become lodged in the lungs and block blood flow. This can happen hours or even days after the formation of a clot in the calf veins. It may cause chest pain and shortness of breath. Post-thrombotic syndrome happens if a DVT damages the valves in the vein, so that instead of flowing upwards, the blood pools in the lower leg. This can result in pain, swelling and ulcers on the leg.

**Other cardiovascular diseases**

These could include tumours of the heart, vascular tumours of the brain, disorders of the heart muscle (cardiomyopathy), heart valve diseases and disorders of the lining of the heart(Nason, 2007).

### Symptoms

Symptoms will vary depending on the specific condition. Some conditions, such as type 2 diabetes or hypertension, may initially cause no symptoms at all(Felman, 2019).However, typical symptoms of an underlying cardiovascular issue include:

* pain or pressure in the chest, which may indicate angina
* pain or discomfort in the arms, left shoulder, elbows, jaw, or back
* shortness of breath
* nausea and fatigue
* lightheadedness or dizziness
* cold sweats

Although these are the most common ones, CVD can cause symptoms anywhere in the body.

## Risk factors

These can be classified as modifiable risk factors, nonmodifiable risk factors, and emerging risk factors. Worldwide, CVDs are largely driven by modifiable risk factors. In Nigeria, these modifiable risk factors were listed by the WHO (in 2016) in the order of occurrence. These lists include the harmful use of alcohol (22%), physical inactivity (22%), tobacco use (11%), hypertension/raised blood pressure (18%), salt/sodium intake (8%), diabetes mellitus and dyslipidemia (4%), obesity (4%), ambient air pollution (1%), and household pollution (<1%).

On the other hand, the nonmodifiable risk factors include advancing age, male sex, family history of premature cardiovascular events, and race.

Emerging risk factors include elevated homocysteine, small, dense lipoprotein (Lpa), plasminogen activator inhibitor, inflammatory markers such as C‑reactive protein and infectious agents‑like chlamydia.(Ike & Onyema, 2020).

Lifestyle factors such as alcohol consumption, smoking, and malnutrition(Gallagher et al., 2018; Ike & Onyema, 2020) may influence the burden of CVDs in the country, and these modifiable risk factors can be better managed to reduce CVD prevalence(Udeh et al., 2020). World Health Organization/International Society of Hypertension (WHO/ISH) has made a prediction charts which is cost-effective and assess the total cardiovascular risk through the integration of risk factors (age, sex, presence or absence of diabetes, smoking status, systolic blood pressure, total serum cholesterol)(Babatunde et al., 2020; Hamid et al., 2019).

However, in the global south, there is a significant rise in the incidence of CVDs resulting from epidemiological transition, increased urbanization(Gallagher et al., 2018; Hamid et al., 2019), adoption of the Western diet and lifestyle(Ike & Onyema, 2020) and poor knowledge of risk factors for CVDs(Babatunde et al., 2020; Olayinka Akinwusi et al., 2013). This has resulted in an increased mortalities among the working populations(Babatunde et al., 2020).

### People can take the following steps to prevent some of the conditions within CVD:

Manage body weight: The National Institute of Diabetes and Digestive and Kidney Disorders advise that if a person loses 5–10%Trusted Source of their body weight, they may reduce their risk of developing CVD.

Get regular exercise: The American Heart Association (AHA) recommend doing 150 minutes Trusted Source of moderate-to-intense physical activity every week.

Follow a heart-healthy diet: Eating foods that contain polyunsaturated fats and omega-3, such as oily fish, alongside fruits and vegetables can support heart health and reduce the risk of CVD. Reducing the intake of processed food, salt, saturated fat, and added sugar has a similar effect.

Quit smoking: Smoking is a key risk factor for almost all forms of CVD. Although quitting can be difficult, taking steps to do so can drastically reduce its damaging effects on the heart(Felman, 2019).

Dietary changes and reduction in smoking, reduction of population blood pressure to reduction of salt intake have proven to reduce prevalence of CVD in men(Beaglehole & Panico, 2001)

## Cardiovascular Disease in sub-Saharan Africa

CVD deaths in sub-Saharan Africa occur at younger ages on average than in the rest of the world(Moran et al., 2013). The most common underlying cause of heart disease in high-income countries is coronary artery disease while in sub-Saharan Africa (SSA), the predominant causes have traditionally been ascribed to rheumatic heart disease, hypertensive heart disease and cardiomyopathy(Gallagher et al., 2018). In Nigeria, hypertension and rheumatic heart disease are high on the list of causes of heart failure(Gallagher et al., 2018; Onwuchekwa & Asekomeh, 2009).

Poor health system response due to lack of funding have led to the increasing risk of CVDs in sub-Saharan Africa (SSA)(Hamid et al., 2019; Ike & Onyema, 2020). Also Nigeria’s high focus on communicable diseases leaves little room for addressing this rapidly increasing public health burden(Udeh et al., 2020).

The inability of people to describe the symptoms of the disease as most people in various communities are only aware of malaria to be a major cause of death has be problematic to the increase in death due to heart disease(Udeh et al., 2020). Other people have the belief that some types of disease like stroke and heart attack can be sent paranormally through occult incantations and charms from an enemy or an evil person (witch/wizard)(Udeh et al., 2020). Thus, exploring the knowledge, their risk factors, and predicting its presence from early symptoms may play an important role in the prevention and control of Death through CVDs in Nigeria. The purpose of this study is to develop a prediction system will few numbers of symptoms that will promptly predict the presence of CVD in a person.

Overall, the knowledge of CVDs in the setting was found to be related to the psychosocial nature of the participants; the effectiveness of any intervention needs to take these factors into consideration. For example, health policies for CVD health education and awareness should be tailored to address some of the issues of belief, values, and religion, as mentioned in the study(Udeh et al., 2020).

Advances in drug development had also yielded major benefits on both acute and chronic outcomes. The widespread use of an “old” drug, aspirin, had by this period been shown to reduce the risk of dying of acute or secondary coronary events(Ike & Onyema, 2020).

## Related Works

Research has been done in this field and people have produced methods to predict cardiovascular disease using supervised machine learning algorithms. Several research papers have been written on this topic. A short survey has been in which analyzes performance of various models based on machine learning algorithms and techniques is shown below:

In one of the works by (Prasad, 2020) , Bayesan network was used to predict heart disease. Bayesian networks apply Bayes’ Theorem (also known as Bayes’ rule or Bayes’ law). In Bayes’ theorem, a prior (unconditional) probability represents the likelihood that an input parameter will be in a particular state; the conditional probability calculates the likelihood of the state of a parameter given the states of input parameters affecting it; and the posterior probability is the likelihood that parameter will be in a particular state, given the input parameters, the conditional probabilities, and the rules governing how the probabilities combine. The network is solved when nodes have been updated using Bayes’ Rule:

P(A|B) =

Where P(A) is the prior distribution of parameter A; P(A|B) is the posterior distribution, the probability of A given new data B; and P(B|A) the likelihood function, the probability of B given existing data.

Although Bayesian Network are “white box” models( i.e their reasoning process can be understood by humans and their answers always come with probabilities attached) (Loyola-Gonzalez, 2019). Bayesian networks (BN) have been used to build medical diagnostic systems as doesn't produce a range outcome but rather a probability for each potential predicted event. Baysian network have some drawbacks ranging from being Computationally expensive. Eg: Approximate structure learning is too NP-Complete tending to perform poorly on high dimensional data, quality of the results of the network depends on the quality of the prior beliefs or model i.e A variable is only a part of a Bayesian network if you believe that the system depends on it.

In another paper by (Aniruddha Dutta, 2020) , Convolutional Neural Network (CNN) was used to make heart disease prediction. Convolutional Network is very useful in the field of image recognition. A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm which can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image and be able to differentiate one from the other. Convolutional Neural Network (CNN) is known to provide better outcomes than other machine learning algorithms if tuned better and feeded a good amount of data, it also poses some drawbacks ranging from being significantly slower due to an operation such as maxpool thereby making training process take a lot of time if the computer doesn’t consist of a good GPU, to the fact that it requires a large Dataset to process and train the neural network

In a work by (Mursal Furqan, 2020), algorithms like Logistic Regression Classifier, K-Nearest Neighbors Classifier, and Random Forest Classifier were individually used to predict heart disease with each resulted in its percentage accuracy. The accuracy gotten from all the models ranges from 72 -84 percent with logistic regression having the highest accuracy of 84%. Using method of running different algorithms is useful to know the performance of each model on a dataset for the major decision of which model prediction to be expected more accurate. Logistic regression which was the best performing model is one of the supervised Machine Learning algorithms used for classification i.e. to predict discrete valued outcome. Although logistic regression being **one of the simplest machine learning algorithms** and is easy to implement yet provides great training efficiency in some cases. It also possesses some drawbacks including model overfitting the training set on high dimensional datasets,it can best perform well when only important and relevant features are used to build the model otherwise the probabilistic predictions made by the model may be incorrect and the model's predictive value may degrade.

The table below shows comparative analysis with previous studies

## Literature Review

The table below shows some of the related literature and their weaknesses

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S/N** | **Title** | **Year** | **Author** | **Method Used** | **Evaluation Metrics** | **Weakness** |
|  | A fast algorithm for heart disease prediction using Bayesian network model | 2020 | Mistura Muibideen and Rajesh Prasad | Bayesian network (BN) | Accuracy, Precision, Recall, F1 Score | Bayesian Network requires a comparatively large amount of effort to be able to learn patterns in data. Bayesian learning is extremely **computationally expensive** |
|  | An Efficient Convolutional Neural Network for Coronary Heart Disease Prediction | 2020 | Aniruddha Dutta, Tamal Batabyal, Meheli Basu, Scott T. Acton | Convolutional Neural Network (CNN) | AUC | The training process takes a lot of time on non-GPU systems. It also requires a large Dataset to process and train the **neural network** |
|  | Heart Disease Prediction using Machine Learning Algorithms | 2020 | Mursal Furqan, Hiba Rajput,Sanam Narejo | Logistic Regression Classifier, K-Nearest Neighbours  Classifier, and Random Forest Classifier | Accuracy | The models used can easily overfits data that are particularly noisy |
|  | A Novel Approach to the Diagnosis of Heart Disease using Machine Learning and Deep Neural Networks | 2020 | Sahithi Ankireddy | K-Nearest  Neighbors (KNN), Support Vector Machine (SVM), Random  Forest Classifier (RF), Naive-Bayes (NB) and Deep Neural  Network (DNN) | ROC-AUC | It requires very large amount of data in order to perform better than other techniques. It is also extremely expensive to train due to complex data models. |
|  | Improving the performance of heart disease prediction system using ensembling techniques | 2021 | Ekta Maini, and Bondu Venkateswarlu | Ensembling techniques (Naïve Bayes, SVM, Logistic Regression and and Multilayer Perceptron) | Accuracy | The merged ensemble method can be extremely **computationally expensive** due to Neural network used |
|  | Coronary Artery Disease Diagnosis; Ranking the Significant Features Using Random Trees Model | 2020 | Javad Hassannataj Joloudari , et al. | Random Trees, Decision Trees, support vector machine (SVM) | Accuracy, ROC curve, Gini, Gain and Confidence | The model used (Decision Tree) is easily leads to overfitting of the data that are particularly noisy |
|  | Early Prediction of Heart Disease Using PCA and Hybrid Genetic Algorithm with k-Means | 2021 | Md. Touhidul Islam, Sanjida Reza Rafa, Md. Golam Kibria | K-Means with PCA and  Hybrid Genetic Algorithm | Accuracy, Clustering Error, Recall, Precision,  F1 Score | K-Means has a tendency of been trapped at the local optimum and GAs has a tendency to converge towards local optima or even arbitrary points rather than the global optimum of the problem |
|  | Heart Disease Prediction Using Hybrid Machine Learning Algorithms | 2020 | S.Raguvaran  R.Anandhi  A.Anbarasi  T.Megala | Logistic  Regression, Random Forests Classifier Algorithm, Neural network, KNN (K-Nearest Neighbour) | Accuracy |  |
|  | Heart disease prediction using machine learning techniques | 2021 | Apurv Garg, Bhartendu Sharma and Rijwan Khan | K-Nearest Neighbor (K-NN) and Random  Forest | Accuracy |  |
|  | Prediction System for Heart Disease Based on Ensemble  Classifiers | 2020 | Joshua Emakhu, Sujeet Shrestha and  Suzan Arslanturk | AdaBoost, Bagging, Random Forest, and Voting Ensemble (Decision Trees, Logistic Regression and Support Vector Machines) | Accuracy  Recall  Specificity |  |

**TECHNIQUES USED**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S/N** | **Author and Year** | **LR** | **KNN** | **NB** | **SVM** | **BN** | **CNN** | **MLP** | **RF** | **DNN** | **RT** | **DT** | **Ada Boost** | **Bagging** | **Boosting** | **K-Means** | **Accuracy** |
|  | Mistura Muibideen and Rajesh Prasad **-2020** | √ | √ | √ |  | √ |  |  |  |  |  |  |  |  |  |  | **85%** |
|  | Aniruddha Dutta, Tamal Batabyal, Meheli Basu, Scott T. Acton **-2020** | √ |  |  | √ |  | √ | √ | √ |  |  |  |  |  |  |  | **85.7%** |
|  | Mursal Furqan, Hiba Rajput, Sanam Narejo **-2020** | √ | √ |  |  |  |  |  | √ |  |  |  |  |  |  |  | **87%** |
|  | Sahithi Ankireddy **-2020** |  | √ | √ | √ |  |  |  | √ | √ |  |  |  |  |  |  | **92%** |
|  | Ekta Maini, and Bondu Venkateswarlu **-2021** | √ |  | √ | √ |  |  | √ |  |  |  |  |  | √ | √ |  | **87.5%** |
|  | Javad Hassannataj Joloudari , et al. **-2020** |  |  |  | √ |  |  |  |  |  | √ | √ |  |  |  |  | **93.4%** |
|  | Md. Touhidul Islam, Sanjida Reza Rafa, Md. Golam Kibria  **-2021** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | √ | **94.06 %** |
|  | Apurv Garg, Bhartendu Sharma & Rijwan Khan -**2021** |  | √ |  |  |  |  |  | √ |  |  |  |  |  |  |  | **86.9%** |
|  | Joshua Emakhu and Sujeet Shrestha **-2020** | √ |  |  | √ |  |  |  | √ |  |  | √ | √ | √ |  |  | **87.04%** |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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**EVALUATION METRICES USED**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S/N** | **Author and Year** | **Accuracy** | **Precision** | **Recall** | **F1- Score** | **AUC/ROC** | **Gini** | **Gain** | **Confidence** | **Cluster Error** | **Probability Mean Error** | **MCC** | **Kappa Statistic** | **Specificity** |
|  | Mistura Muibideen and Rajesh Prasad **-2020** | √ | √ | √ | √ |  |  |  |  |  |  |  |  |  |
|  | Aniruddha Dutta, Tamal Batabyal, Meheli Basu, Scott T. Acton **-2020** |  |  |  |  | √ |  |  |  |  |  |  |  |  |
|  | Mursal Furqan, Hiba Rajput, Sanam Narejo -**2020** | √ |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Sahithi Ankireddy **-2020** |  |  |  |  | √ |  |  |  |  |  |  |  |  |
|  | Ekta Maini, and Bondu Venkateswarlu **-2021** | √ |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Javad Hassannataj Joloudari , et al **-2020** | √ |  |  |  | √ | √ | √ | √ |  |  |  |  |  |
|  | Md. Touhidul Islam, Sanjida Reza Rafa, Md. Golam Kibria -**2021** | √ | √ | √ | √ |  |  |  |  | √ |  |  |  |  |
|  | Apurv Garg, Bhartendu Sharma & Rijwan Khan -**2021** | √ |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Joshua Emakhu and Sujeet Shrestha **-2020** | √ |  | √ |  |  |  |  |  |  |  |  |  | √ |
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# CHAPTER THREE: SYSTEM ANALYSIS AND DESIGN

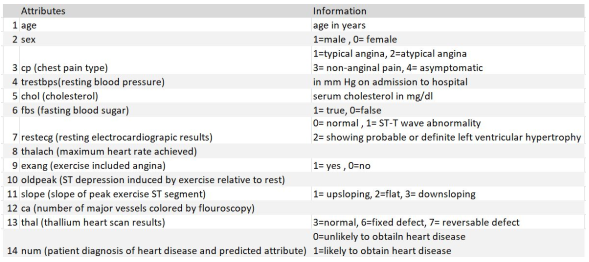
## Methodology

Cognitive Project Management for AI (CPMAI) The primary research method for this study is literature review and conceptual modeling. This study will first review various research done under cardiovascular disease prediction and their characteristics. Based on this understanding, a classification method will be developed resolve the limitations of those research.

In order to accurately, easily and effectively make prediction for cardiovascular disease, the research plan to the proposed method is developing an effective model to predicting heart disease. To achieve this, the following has to be considered:

1. The dataset to be used
2. Data Retrieval
3. Data preprocessing
4. Feature Selection
5. Target Class Transformation and
6. the model to be used for the study.
7. **Dataset**

This research is proposed to use the heart disease dataset from the UCI machine learning repository called Cleveland Heart Disease Data set. Cleveland Heart Disease Dataset is a publicly available supervised dataset provided by the Cleveland Clinic Foundation was used for the ML model. This data set contains 14 total attributes of patient medical information for 303 patients. The figure below shows the chosen attributes, and its information. These attributes have been selected by other researchers and healthcare professionals because they are known to be the best determining factors of heart disease.



1. **Data Retrieval**

Data retrieval is usually the first step. Data can be gotten from various sources. It can be as easy as someone handing over a file on a drive for you to analyze them directly. Or you need to download it. Our dataset is to be downloaded from the UCI machine repository.

1. **Data Preprocessing**

Data preprocessing is also known as cleaning data. It is one of the most important steps to achieve the best from the dataset. This is a process whereby data inconsistencies such as missing values, out of range values, unformatted data, and noise are removed from the data. The process is usually time-consuming because it involves a lot of experimentation trying out various data analysis tools. Our preprocessing would involve data retrieval, handling missing values, target class transformation and data discretization

Handling Missing Values

Missing data values is a common problem faced by analysts. This occurs due to different reasons such as incomplete extraction, corrupt data, failure to load the information, etc. This is a great challenge that must be fixed because good models are generated when you make the right decisions on how to fix it. These are 5 ways of handling missing data:

* 1. Deleting Rows
  2. Replacing with mean/median/mode
  3. Assigning a unique category
  4. Predicting the missing values
  5. Using algorithms which supports missing values

We would adopt the method of handling missing values that proves best.

1. **Feature Selection**

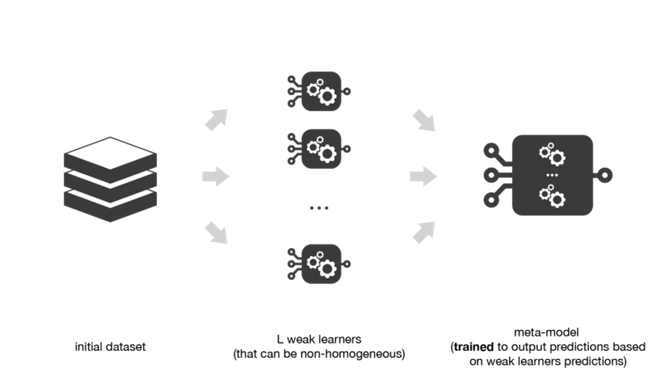
In order to select the best features for our model. Recursive feature elimination is proposed. RFE is a feature selection method that fits a model and removes the weakest feature (or features) until the specified number of features is reached.

1. **Target Class Transformation**

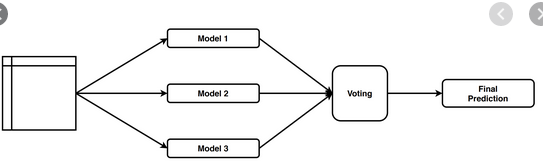
As stated in the data set description, the target class contains values (0, 1, 2, 3, 4). Where 0 means healthy (no heart disease) and (1, 2, 3, 4) means the presence of sickness of varying degrees. Interest is in the absence or presence of heart disease, so the need to limit the class to (0, 1). Level (1, 2, 3, 4) was converted to 1.

1. **Proposed Model**

An ensemble model made from different algorithms is proposed. This work proposed the use of Stacking and voting ensemble (both hard and soft voting). The idea of stacking is to learn from several different weak learners and combine them by training a meta-model to output predictions based on the multiple predictions returned by these weak models

Stacking consists in training a meta-model to produce outputs based on the outputs returned by some lower layer weak learners.

Voting ensemble involves summing the votes for class labels from other models and predicting the class with the most votes or summing the predicted probabilities for class labels and predicting the class label with the largest sum probability.



***Proposed Models to use***

The proposed models comprise of Bayesian Network, Random Forest Classifier, Multilayer perceptron (MLP) and Naïve Bayes and Logistic Regression. This is because the models proved to have high performance on predicting heart disease from previous studies.

Although ensemble machine learning techniques are difficult to interpret and have longer training and prediction time than single models, since you need the predictions of many models, they proved beyond doubt to provide better accuracy

1. **Performance Metrics**

Performance metrics are used to evaluate how different algorithms perform based on various criteria such as accuracy, precision, recall etc. They are discussed below.

***Confusion Matrix***

The confusion matrix shows the performance of the algorithm. It depicts how the classifier is confused while predicting. True positive value signifies that the positive value is correctly predicted, false positive means the positive value is falsely classified, false negative means the negative value is falsely predicted while the true negative means the negative value is correctly classified.

***Accuracy***

Accuracy is the ratio of the number of correctly classified instances to all the cases. It is the sum of TP and TN divided by the total number of instances.

***Precision***

Precision is the proportion of true positive instances that are classified as positive. It reflects the closeness of predicted values is to one another.

***Recall***

Recall is the proportion of positive instances that correctly classified as positive. Recall is known as sensitivity.

***F1 Score***

F1 score combines both precision and recall and finds a balance between both.

# CHAPTER FOUR: RESULTS AND DISCUSSION

In total for machine learning classifiers, 303 records were used each with 9 total attributes. 8 out of the 9 features played a part in determining the last feature or the heart disease diagnosis. The evaluation involved different classification methods, i.e., Naïve Bayes, Bayesian Network, KNN, and Logistic Regression. In this study, WEKA was used to classify the Cleveland dataset. This is done using different proportions of the dataset for training and testing and the accuracy measure is taken as shown in Table 1. In Table 1, Splitting the training and testing data into 80:20 ration has the highest accuracy.

Table 1. Test proportion to determine the best ration for highest model accuracy (rounded to 4 digits)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ALGORITHMS** | **TRAINING/TESTING ACCURACY RATIO** | | | | | | | | |
| 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| Naïve Bayes | 82.4176 | 83.8843 | 85.3774 | 84.0659 | 86.0927 | 87.6033 | 86.8132 | 86.8852 | 86.6667 |
| Bayesian Network | 81.685 | 83.4711 | 86.3208 | 85.1648 | 87.4172 | 87.6033 | 86.8132 | 88.5246 | 86.6667 |
| KNN | 79.8535 | 79.3388 | 79.717 | 80.2198 | 82.1192 | 80.1653 | 82.4176 | 80.3279 | 86.6667 |
| Logistic Regression | 68.8645 | 65.2893 | 75.000 | 82.4176 | 86.0927 | 83.4711 | 81.3187 | 85.2459 | 83.3333 |

In determining which ML algorithm to use, accuracy scores were produced for each of the common machine learning algorithms. Figure 1 shows the accuracy scores of the K-Nearest Neighbors, Logistic regression Bayesian network, and Naïve Bayes algorithm Algorithms, and proves how the Bayesian Network had the highest accuracy score on 80:20 training/testing split.

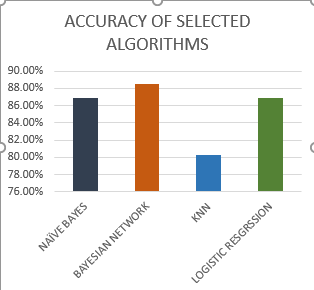


Figure : Accuracy Comparison of the models

ROC graphs were also established for the Bayesian Network (Fig 4.), Naïve Bayes (Fig 5), Logistic Regression (Fig 6), and KNN (Fig 7). Bayesian network and Naïve Bayes had the highest a score of approximately 92%. Logistic regression had a score of approximately 91% with KNN having a Score of 87.3%

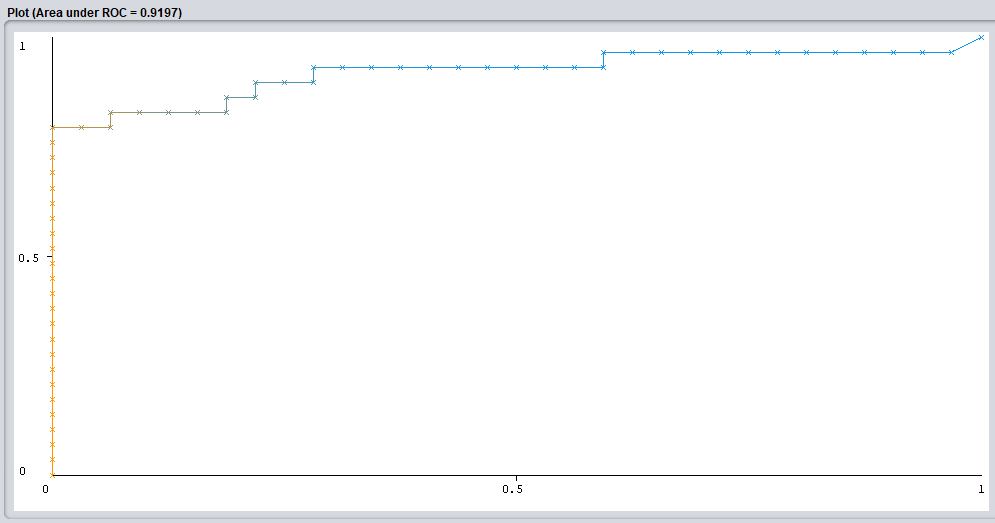
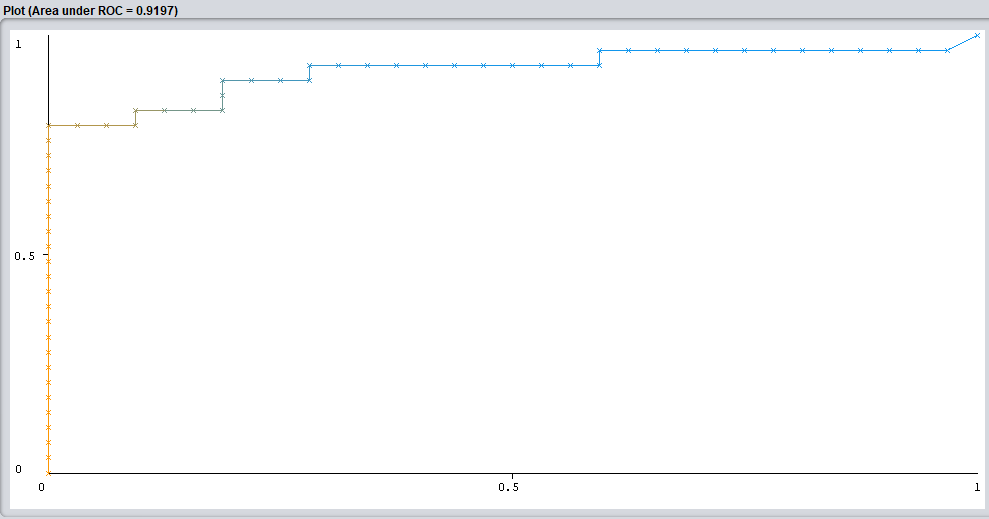
 

Figure : Bayesian Network Figure : Naive Bayes

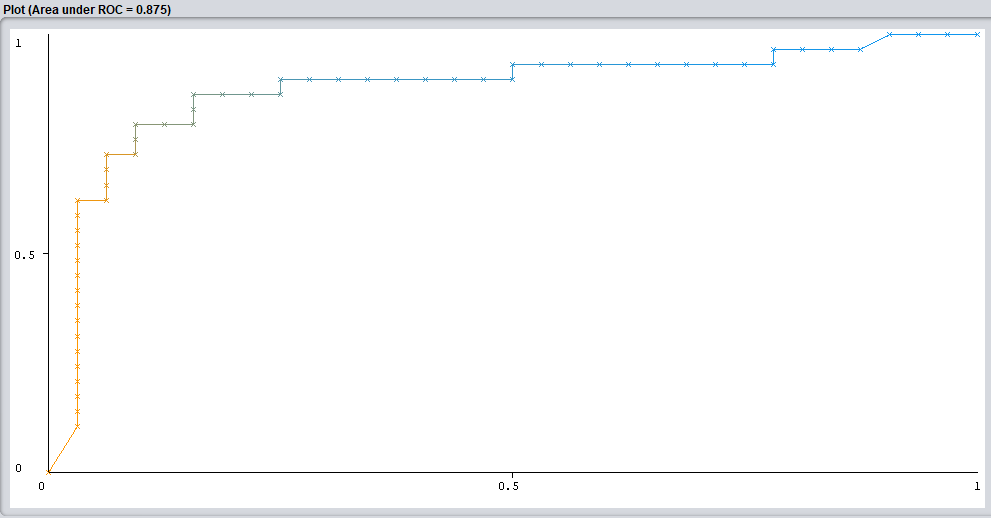
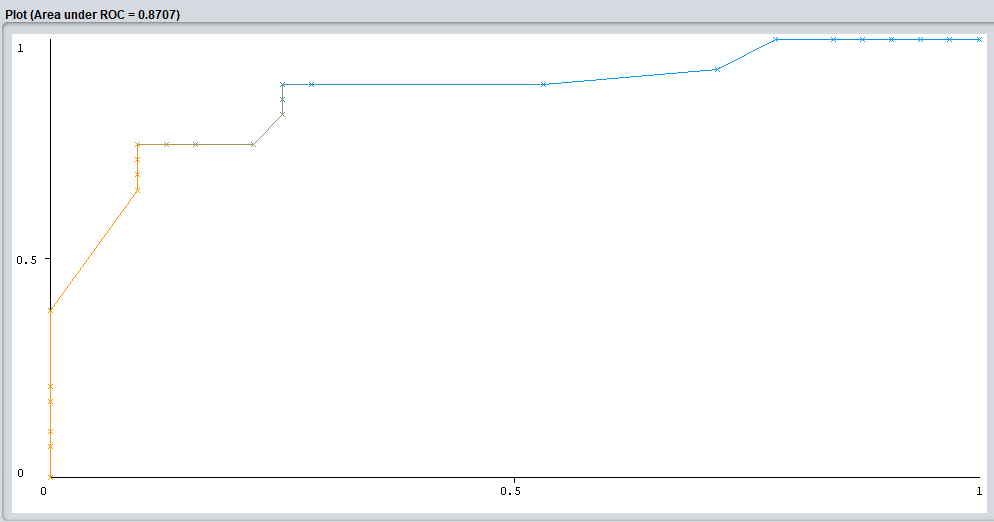
 

Figure : Logistic Regression Figure : KNN

Comparison of the models in relation to Matthews Correlation Coefficient (MCC) chart is shown in Figure 8 below. The Chart shows Bayesian network having the highest score of 77% followed by Naïve Bayes and Logistic regression with similar score of about 74%.KNN has the least MCC score of about 61%.

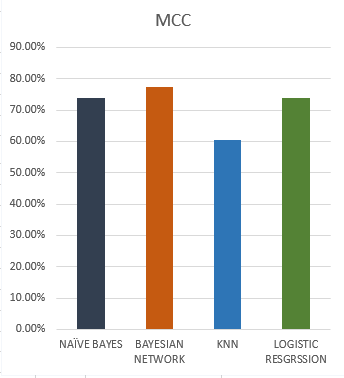


Figure : MCC chart of the Models

Table 2: Metrices Comparison between Naive Bayes, Bayesian Network, Logistic Regression and KNN

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Accuracy** | **Precision** | **Recall** | **F-Measure** | **MCC** | **ROC Area** | **Kappa statistic** |
| **Naïve Bayes** | 86.8852 | 0.870 | 0.869 | 0.868 | 0.738 | 0.920 | 0.7362 |
| **Bayesian Network** | 88.5246 | 0.888 | 0.885 | 0.885 | 0.773 | 0.920 | 0.7688 |
| **Logistic Regression** | 86.8852 | 0.870 | 0.869 | 0.868 | 0.738 | 0.908 | 0.7362 |
| **KNN** | 80.3279 | 0.804 | 0.803 | 0.803 | 0.606 | 0.873 | 0.6043 |

Looking at the performance of the various models, each model had proved to have a good predictive power to heart disease However, looking at the MCC score and accuracy score Bayesian Network, despite having a similar AUC score with Naive Bayes was the overall winner. Bayesian Network proved to be the better overall model as seen by its much higher performance when looking at accuracy score and Matthews Correlation Coefficient. Thus, it can be deemed that it was the best algorithm out of the 4 tested.

Table 3: Comparison Various Approaches with our Proposed Approach

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S/N | Author and Year | Method | Dataset | Metrics |
|  | Mistura Muibideen & Rajesh Prasad, 2020 | Bayesian Network | Cleveland dataset: 14 Attributes | Accuracy: 85%  Precision: 86%  Recall: 85%  F1- Score: 85% |
|  | Aniruddha Dutta, Tamal Batabyal, Meheli Basu, Scott T. Acton **-**2020 | 2-layer CNN | NHANES dataset:  7 attributes | Accuracy: 81.78%  Recall: 77.3%  Specificity: 81.8 %  AUC: 76.78 % |
|  | Sahithi Ankireddy -2020 | Deep Neural  Network (DNN) | Cleveland dataset: 14 Attributes | Accuracy: 85.60% |
|  | Ekta Maini, and Bondu Venkateswarlu **-**2021(Maini and Venkateswarlu 2021) | Ensembling techniques (Naïve Bayes, SVM, Logistic Regression and and Multilayer Perceptron) | Cleveland dataset: 14 Attributes | Accuracy: 87.5% |
|  | **Our proposed approach** | Bayesian Network with Wrapper subset evaluation (For feature selection) | Cleveland dataset: 8 Attributes. Namely: age, sex, cp, exang, oldpeak, slope, ca, thal | Accuracy: **88.53%**  Precision: **88.8** %  Recall: **88.5**%  F1- Score: **88.5** %  ROC Area**: 92.0%** |

# CHAPTER FIVE: SUMMARY, CONCLUTION AND RECOMMENDATION

Conclusion

It is worth researching much of what is required to forecast and diagnose any disease using machine learning effectively. Heart disease is considered one of the major threats to life and now it is a critical challenge to predict heart disease at an early stage in the area of clinical data analysis in order to minimize the death rate. Our method reduces the dimensionality of the dataset using WEKA wrapper method of data selection to select the best subset on Cleveland dataset features for better accuracy and efficiency predicting heart disease. The selected features are 8 in numbers and they include: age, sex, cp, exang, oldpeak, slope, ca, thal . The proposed method in the study has been evaluated with various metrics, and its performance results are compared with explores different machine learning algorithms.

A very detailed, useful, and highly preferable Machine Learning based model in this paper that helps medical practitioners diagnose heart diseases at an early stage to enable patients to take precautionary measures in a rectification window. The paper used Naïve Bayes, Bayesian Network, KNN, and Logistic Regression on the reduced features. The same features are used to both train and test the dataset. The outcome reveals that these data mining techniques can predict heart disease early with an accuracy of approximately 89%.

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