Prediction of heart diseases utilising support vector machine and artificial neural network

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ABSTRACT

The heart, like a pump, is an organ about the size of a fist, mainly composed of muscle and connective tissue that functions to distribute blood to tissues. The heart is located under the rib cage, above the diaphragm between the lungs, slightly closer to the left. Sometimes a small, unexpected problem with the veins or the valves that supply the heart affects a person's life and can lead to death. Early diagnosis is essential to predict diseases that affect the human heart and lead people to live another period of life. In this context, the authors introduce two methods for early diagnosis of heart disease, the support vector machine and artificial neural network (ANN). The medical data is taken from the University of California Irvine (UCI) Machine Learning Repository database, and it contains reports of 170 people. The investigation results confirm that the optimal execution is the support vector machine technique. It gives high-accuracy prediction results. As for the performance of the forward propagation artificial neural networks technique is acceptable.

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1. INTRODUCTION

The heart is the first organ formed in a child's body and is in the mother's womb [1]-[5]. The heart of the foetus begins to beat for the first time in the sixth week of pregnancy, and the other organs in the formation are created around the heart and blood vessels in the body of the foetus [6]. The heart beats more robust and faster in situations that require significant effort, such as running, climbing, or playing sports such as football. In other words, the heart is the source of life and vitality for people and living things, and perhaps, for this reason, it is believed that the soul is stored inside the heart [7]. This organ contracts an average of 70 times a minute, 104,000 times a day, and 38 million times a year, pumping its blood into our body. The size of the heart is the size of our fist and it weighs between 280-340 grams in a body [8]. It is a pump consisting of a very durable muscle group that moves the blood that gives our body vital nutrients and oxygen through the circulatory system [9]. Also, it is positioned in the middle of the chest, just below the breastbone. A pericardium covers the outer face of the heart [10]. There is a tiny amount of lubricating fluid between the pericardium layer and the heart so that the heart can move easily while running. Like a pump system, it receives blood from the body through the vascular system [11]-[13], conveys it to the lungs for oxygenation, and elevates oxygen-enriched blood back into the body. Figure 1 shows a set of images of heart surgeries.

In general, heart disease [14], [15] happens when there is a hardening process inside the coronary blood vessels, meaning in other words, the accumulation of a layer of a mixture of calcium and fats happens, or when a constriction happens in these blood vessels, it is possible that a narrowing happens in the stomach, which hinders the delivery of blood to the muscle heart, this matter is serious. Furthermore, as the heart's ability to contract is enfeeble, there is a decrease in the pumping of blood to vital organs in the body. This process of narrowing the blood vessels causes Angina Pectoris [16], and if permanent loss to the heart muscle occurs, then Myocardial Infarction [17] is made. In addition, the spread of the SARS-CoV-2 [18]-[22] also has a significant impact on heart health because this virus infects the human respiratory system and acts to reduce the level of oxygen in the lung and thus affects the heart rate and may lead to destruction.

Figure 1. Heart surgeries images

Today, artificial intelligence [23]-[29] is moving from the computer world to the real world of healthcare, and it does some tasks better than doctors can do on their own. Artificial intelligence can more accurately predict the probability of death of a patient within a year compared to a doctor. In the recent period, studies have appeared in which machine learning has proven the ability of machine learning to predict whether heart patients are at risk of death [30], [31], which we will talk about in the third section, in addition to the success of this study in analysing the data of heart patients.

The main contribution of this article is the utilisation of machine learning techniques (support vector machine and forward propagation artificial neural network (ANN)) in analysing Heart Disease patient’s data. The selection of these techniques is based on their high ability to predict and classify disease types. All data are collected from the University of California Irvine (UCI) machine learning repository database, as for the information of the 170 patients, it is taken from one of the laboratories for the period between 2017-2020.

The rest of the article is organised as follows. Section 2 gives a simple survey of studies that have applied machine learning techniques in predicting heart disease. The data collected and the techniques utilised in this study are illustrated in section 3. The experimental outcomes of the implemented case study are presented in section 4. Finally, the article is concluded in section 5.

2. LITERATURE SURVEY

In recent years, a group of researchers have conducted many studies in the use of artificial intelligence techniques in the field of predicting heart diseases and classifying diseases. In this section, five papers that applied machine learning techniques to investigate heart diseases data published in 2020-2021 are selected. In the opening, it is a study [32] in which four techniques of machine learning (k-nearest neighbours, naive bayes, random forest, support vector machine) are applied in predicting heart disease. Furthermore, an enhancement has been made to these techniques to be more effective in extracting results. This study shows that the most effective strategy in giving accurate results is the random forest method, with more than 88% accuracy. Sahoo and Jeripothula proposes in their paper [33] the application of a set of techniques, namely, naïve bayes, support vector machine, decision tree, k-nearest neighbours, and logistic regression to analyse coronary artery disease data collected from the UCI repository and having 13 essential attributes. This study has discovered that the optimal accuracy is given to the support vector machine technique, as it managed to reach a result of more than 85% in data analysis. In another article written by Rajdhan *et al.* [34], have suggested applying machine learning techniques (random forest, naive bayes, logistic regression and decision tree) to diagnose heart diseases. The database for this study is collected from the UCI machine learning repository. This study confirms that the highest achievement is the Random Forest technique, as it has achieved an accuracy of more than 90% compared to other machine learning techniques performed. In 2021, a study conducted by Salhi *et al.* from Algeria [35], has applied three data analytics techniques, namely k-nearest neighbours, neural networks, and support vector machine, to analyse data for people with heart disease. Their study observes that the good technique in terms of accuracy is the neural networks technique, as it reaches an accuracy of 93%. In another study conducted by Jindal *et al.* [36], they suggest the use of machine-learning techniques (logistic regression and k-nearest neighbours) to predict and classify patients with heart disease. This study has confirmed that the best performance is the k-nearest neighbours’ algorithm, with more than 88% accuracy.

3. MATERIALS AND METHODS

In this section, the techniques utilised in this paper are briefly covered, as well as the data collected and arranged in tables. The specifications of the computer that is used to execute this work are as follows: Hardware: Intel® Core™ i5 processor, 1-TB HDD storage, with memory 8 GB, Software: Windows 10 Home 64 with last updated (March 2021), and Python 3.7. The datasets have been taken from the UCI machine learning repository database that including the Statlog heart dataset [37], [38]. Besides, the Cleveland database is employed to classify individuals, where they are classified into two classes are Normal (Healthy) =0 and patient (cardiac)=1. The information reports of 170 cases are taken from a laboratory and kept in Excel file (heart_diseases.xlsx), and also the dataset includes 13 features for each report. These features are exhibited in Table 1. Table 2 exhibits the classification set with their numerical value. The primary role of Machine learning techniques in this work is to predict only four diseases, namely arrhythmia [39], cardiomyopathy [40], congenital heart defects (CHD) [41], and coronary artery disease (CAD) [42]. These techniques will be briefly covered, and their importance is going to be explained.

Table 1. A medical dataset on heart disease

Attribute	Limit
Age	Endless
Gender	Male =0 Female=1
Chest pain type	1 to 4
blood pressure	Endless
Serum cholesterol (mg / dl)	Endless
Satiety sugar level> 120 mg / dl	1 = True 0 = False
Electrocardiograph level at rest (0,1,2)	1 to 2
Maximum heart rate	Endless
Chest pain caused by exercise	1 = Yes 0 = No
ST value at rest	Endless
The inclination of the ST segment in the peak exercise state	1 to 2
Number of major vessels (0-3)	Endless
Damage Ratio: 3 = normal; 6 = permanent damage; 7 = reversible damage	3,6, and 7

Table 2. Classification set

Class type	Numerical value
Class 1: Normal	1
Class 2: Patient	2

3.1. Support vector machine

Support vector machine [43]-[47] is marked by its superior ability to take a set of input data and build a prediction for each entry based on its characteristics. This technique is a non-probabilistic linear binary classification process. Moreover, each of these output classes belongs to or depend on a specific category. Thanks to these, the automated training algorithms build a model that assigns the new or incoming data to the predetermined categories. Sometimes support vector machines (SVM) produces the hyperplane [48], but the desired characteristics will not achieve a perfect separation spectrum. It results within the model that cannot be generalized to other data; this process is known as overfitting. To allow a certain level of flexibility to compensate for this type of training error, a minimum gap is formed to capture the mistakes and penalties of the model data. It is what is known as soft margin. Table 3 exhibits the SVM technique parameters adopted in this work, with the value of each parameter. In addition, SVM is a class of learning techniques initially specified for discrimination, meaning predicting a binary qualitative variable. Then it is generalised to quantitative variable prediction. It considers a dichotomous variable is discrimination. In that case, it is based on a search for the optimal level of the hyperplane that perfectly classifies or separates the data, when possible, while being as far away as possible from all observations. Therefore, the principle is to locate a classifier, or discriminant function, whose ability to generalise (prediction quality) is the most significant likely.

Table 3. SVM parameter

Parameter	Value
Kernel	Linear
Method	SOM
Population No.	190

*SMO is sequential minimal optimisation

3.2. Artificial neural network

Artificial neural networks [49]-[51] are part of the set of technologies that we know as artificial intelligence and that, today, are used in countless applications and also have great potential for the future. They are based on mathematical models that try to resemble biological neurons, hence their name. Besides, artificial neural networks (ANNs) are illustrated by their power to solve the most challenging problems that are very complex in many areas, such as prediction, optimisation, and pattern recognitions and other. As a computational model, artificial neural networks use graphs and functions, made up of process elements (nodes) and connections (links). They process inputs and generate outputs that help solve problems. In some models local memory is used in the nodes or process elements. The nodes and connections of the neural network are organised in layers. Forward propagation [52] has been practised in this work, as it is the first round in datasets training. In addition, the principal worth of this technique is to compute and keep all intermediate variables with the output in order from the input layer to the output layer. That is, the movement between the layers will be in one path. This technique begins by randomly configuring the weights of all datasets. After that, all datasets are analysed to give high accuracy in prediction. Table 4 exhibits the forward propagation ANN (FP-ANN) technique parameters adopted in this work, with the value of each parameter. The effects (final results) of predictions made in the hidden layer are organised in the output layer.

Table 4. Forward propagation ANN

Parameter	Value
Iterations	1000
Population No.	190
Learning Time	7s

4. EXPERIMENTAL OUTCOMES

In this section, the results of the forecasts received from the techniques applied will be disclosed. Figure 2 explains the mechanism of action in this article from the process of entering and processing and showing the results. Table 5 shows the results of the techniques' accuracy in predicting each disease with implementation time for each prediction process. Table 6 exhibits the optimal and acceptable execution of each technique in diagnosing heart patients through accuracy.

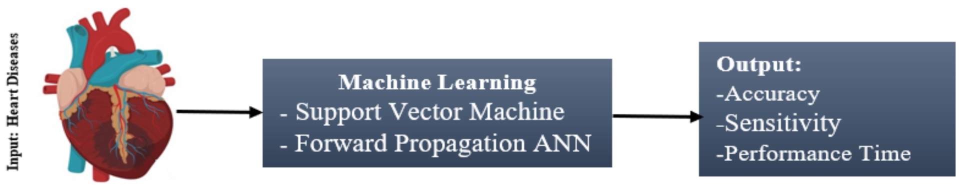

Figure 2. Mechanism of work in this paper

The following scientific formulas are used to calculate the accuracy and the sensitivity of each technique:

$$Accuracy = \frac{TP+FP+FN+TN}{TP+TN} \quad (1)$$

$$Sensitivity = \frac{TP}{TP+FN} \quad (2)$$

where:
True positive (TP): They are truly patients and defined as patients according to the diagnostic test result.
False positive (FP): The cases that the test incorrectly described the patient even though they are truly intact.
False negative (FN): They are cases that are truly suffering and defined as healthy according to the diagnostic test result.
True negative (TN): According to the real diagnostic result, they are true negative states that are described as healthy on the test.

Table 5. Experimental results

Diseases	SVM			FP-ANN		
	Accuracy	Sensitivity	P.T	Accuracy	Sensitivity	P.T
Arrhythmia	89.1%	89.1%	0.079120	85.8%	85.4%	0.024425
Cardiomyopathy	80.2%	77.1%	0.024425	85.6%	85.6%	0.078130
CHD	83.1%	81.2%	0.079120	72.7%	68.9%	0.065125
CAD	71.2%	68.1%	0.078130	69.6%	61.5%	0.012525

Note: P.T indicates the performance time and is in seconds.

Table 6. The performance execution of each technique

Diseases	Optimal Execution	Acceptable Execution
Arrhythmia	SVM	FP-ANN
Cardiomyopathy	FP-ANN	SVM
CHD	SVM	FP-ANN
CAD	SVM	FP-ANN

5. CONCLUSION AND FUTURE DIRECTION

In this paper, two techniques are utilised in predicting whether or not individuals have heart disease. Four diseases are predicted using 13 medical data of 170 individuals taken from the Cleveland database. Data of the 170 individuals are classified into 90 learning datasets and 80 testing datasets. The accuracy and the sensitivity are measured for both techniques in predicting each disease. From the experimental effects, it is clear that the best technique for achieving and giving high-accuracy results is support vector machine, as it can be relied upon in predicting and diagnosing heart diseases and helping physicians make the right decision in determining the patient's condition. In the future, other techniques will be applied to predict other heart diseases using the same data.

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