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Research Article

PREDICTION OF CARDIOVASCULAR DISEASE USING MODIFIED EXTREME LEARNING MACHINE

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ABSTRACT

Heart disease is the main reason for death in the world over the last decade. The World Health Organization reported that heart disease is the first leading cause of death in high and low income countries. Clinical diagnosis is done by doctor's expertise but still some cases are reported of wrong prediction and diagnosis. Today, numerous doctors manage healthcare data utilizing medicinal services data framework it contains huge measure of information, used to extract hidden information for prediction of cardiovascular disease. The main objective of this research is to develop a Heart Disease Prediction System to predict the presence of heart disease using machine learning algorithms. Extreme Learning Machine (ELM) is a new class of Single-Hidden Layer Feed Forward Neural Network (SLFN), which is simple in theory and fast in implementation and it reported that it suffer from over fitting. It can be overcome by incorpoted a structural risk minimization principle into the (weighted) ELM and proposed a Modified Weighted Extreme Learning Machine (M-WELM). The experimental results shows that proposed method outperforms well and provides better classification accuracy to predict the presence of cardiovascular disease.

INTRODUCTION

Heart disease is the main source of death for the two men and women in the world over recent years, with the greater part of the death happening in men [13]. One in every four people is afflicted with and dies of heart disease, and in the United States, over 610,000 afflicted Americans lose their lives annually. It is known that heart is essential organ in human body part if that organ gets affected then it also affects the other vital parts of the body. It is just a pump, which pumps blood through the body. In the event that circulation of blood in body is wasteful the organs like brain endure and if heart quits working inside and out, death happens within minutes. Life is totally subject to effective working of the heart. The term Heart disease alludes to ailment of heart and blood vessel system inside it. The factors have been shown that increases the risk of Heart disease such as Family history, Smoking, Poor diet, High blood pressure, High blood cholesterol, Obesity, physical inactivity and Hyper tension. Factors like these are utilized to examine the Heart disease [11]. Much of the time, diagnosis is for the most part in view of patient's present test outcomes and doctor's experience. Accordingly the diagnosis is a complex task that requires much experience and high expertise.

The heart circulatory system is composed of the heart and blood vessels, including arteries, veins, and capillaries. The term 'cardiovascular ailment' that speaks to a category of heart disease includes a wide assortment of conditions that furious the heart and the blood vessels and the route in which blood is pumped and flowed in the body. Cardio vascular disease affects the heart circulatory system and damages the system also damages the valves resulting in heart attack or heart failure [8]. To keep away from such a circumstance a clinical expert system is produced to expert system the heart disease and to diminish the level heart failure and death. Therefore it is very important for people predict the heart disease by an automated method of classification techniques.

Classification techniques of Machine Learning Algorithms [4] play a significant role in Prediction. Machine learning algorithm [17] can altogether help in tackling the medicinal services issues by creating classifier frameworks that can help

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doctors in expecting sicknesses in beginning times. In any case, extracting information from huge data it might be heterogeneous, unorganized and high dimensional and may contain noise and outliers. Most appropriate Extreme Learning Machine has been chosen and validating their performances in terms of accuracy and precision.

Problem Statement

In present world there are many scientific technologies which help doctors in taking clinical decisions but they might not be accurate. Heart disease prediction system can help therapeutic experts in predicting condition of heart, in light of the clinical data of patients fed into the system. Doctors may in some cases neglect to take accurate decisions while diagnosing the heart disease of a patient, consequently heart disease prediction systems which utilize machine learning algorithms aid such cases to get accurate outcomes. There are many tools available which use prediction algorithms but they have some flaws. The vast majority of the devices can't deal with enormous information and most are not incorporated, not sent on cloud and subsequently not open on the web. There are many hospitals and healthcare industries which collect huge amounts of patient data which becomes difficult to handle with currently existing systems. The objective of this work is to predict more accurately the presence of heart disease with reduced number of attributes and deploying the algorithms to overcome the existing limitations.

The rest of the paper is organized as follows. Section II deals the related works about the cardio vascular system and their prediction issues and the existing methods. Section III deals with the Extreme Learning Machine and proposed method Modified Weighted Extreme Learning. Section IV, gives the result and performance analysis. Finally, the overall proposed method concludes in section V

Related Work

Heart disease is the main source of death in the world over recent years. Researchers have been utilizing a few data mining systems in the diagnosis of heart disease. Support vector machine are a cutting edge method in the field of machine learning and have been effectively utilized as a part of various fields of use. Parthiban*et.al* (2012) [4] uses classification algorithm like Naive Bayesian and Support vector machine used for prediction utilizing attributes from diabetic's diagnosis to discover whether diabetic patient is experiencing heart disease with showing levels. From the experimental results obtained, it can be seen that the classifier displays a high classification accuracy i.e. 94.60% generally speaking. Subsequently this SVM model can be prescribed for the classification of the diabetic dataset.

Patel *et.al* (2015) [5] presents new model that improves the Decision Tree accuracy in distinguishing heart disease patients. It thinks about various algorithms of Decision Tree classification looking for better execution in heart disease analysis utilizing WEKA. The algorithms which are tried by J48 algorithm, Logistic model tree algorithm and Random Forest algorithm. The objective of this investigation is to extract hidden patterns by applying data mining strategies, which are imperative to heart diseases and to anticipate the nearness of heart disease in patients. The current datasets of heart disease patients from Cleveland database of UCI vault is utilized to test and justify the performance of decision tree algorithms.

Cardio vascular disease influences the heart circulatory system and damages the system valves bringing about heart attack or heart failure. To stay away from such a circumstance a clinical expert system is produced to distinguish CVD ahead of time and to decrease the level heart failure and death. Kumar *et.al* (2014) built up a programmed framework for the classification of ICU patients utilizing ANN techniques for decision-making is executed. The basic leadership was performed utilizing highlights extricated from ECGs. This expert system implements the neural network to diagnose the heart diseases. The back propagation algorithm is utilized to prepare the neural network for diagnosing the cardio vascular illness and to take preparatory activities. The result of training process will be the error level related with the original data. In view of the error level a choice will be taken that a patient has this specific level of risk related with him. The proposed approach exhibited a superior performance in terms of classification accuracy and also simple to implement and use, as it only requires the ECG signal to determine the patients' states.

ELM and its enhanced variant are just in view of the empirical risk minimization principle, which may experience the ill effects of over fitting. Mao *et.al* (2014) [6] consolidated the basic risk minimization standard into the (weighted) ELM, and proposed a Modified (weighted) Extreme Learning Machine (M-WELM). The M-WELM can be summed up to cost sensitive learning and can likewise manage information with imbalanced class circulation as the WELM. Then again, it's over fitting risk can be diminished by considering both the observational and structural risks simultaneously. From the experimental results, M-WELM algorithm demonstrates the best execution against the other revealed ELM calculation and SVR algorithm, especially when using less training samples. Prerana *et.al* (2015) designed an algorithm for accurate prediction of heart disease risk level. PAC algorithm is built utilizing existing machine learning algorithms. Popular machine learning algorithms to decide the heart disease risk level and to help the specialists effectively anticipate the same. Hadoop single node cluster is utilized to process Big Data. Map Reduce code is actualized for the composed algorithms. At long last the comparisons between the algorithms is done which encourages the users to figure out which algorithm demonstrates the highest accuracy. The interface is easy to use and the application is all inclusive open on cloud. Depending on the increasing requirement multi nodes can be added to the cluster to decrease the execution time and process more data.

A binary classification technique, Probabilistic Extreme Learning Machine (called P-ELM) is proposed by Zhao *et.al* (2011) to improve the reliability of the classification of an unknown object. The P-ELM algorithm may restrain vulnerability of the extreme learning machine prediction in the different trials of simulation because of the introduction of input weights and bias, which would damage the reliability of the classification for the new object. ELM is coordinated with thickness techniques and Bayesian decision theory so as to consider the uncertainty of the predictions in ELM. Huang et al

(2012) [2] shows that both LS-SVM and PSVM can be simplified further and a unified learning framework of LS-SVM, PSVM, and other regularization algorithms referred to Extreme Learning Machine (ELM) can be built.

Zhang *et.al* [3] proposed a fast and efficient classification technique as ELM algorithm. The ELM randomly identify the all hidden node parameters and then analytically make a decision on the output weights. It has good simplification process and it can be executed naturally. In ELM the nonlinear activation functions are used such as sigmoid, sine, hard limit, radial basis functions and complex activation functions.

METHODOLOGY

Classification is one of the most important decision making techniques for selecting data. In this paper, the main aim of research is to build Intelligent Heart Disease Prediction System [8] to predict the data as presence of heart disease for improving the classification accuracy. This section comprises of existing Extreme Learning Machine (ELM) and proposed Modified Weighted Extreme Learning Machine (M-WELM) method used for prediction of cardio vascular system by various classifiers are briefly explained. They are briefly explained below.

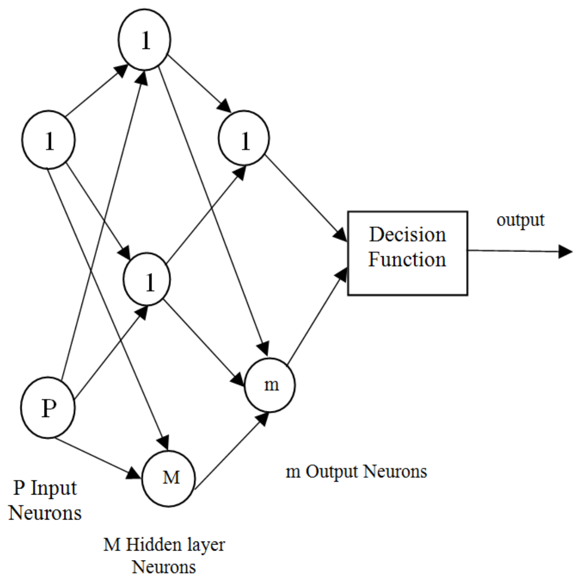

Figure 1 ELM Structure

Extreme Learning Machine

Extreme learning machine (ELM) mainly applied for Single Hidden Layer Feed forward Neural Networks (SLFNs) it is the process of randomly selecting the input weights and systematically determines the output weights of SLFNs. This algorithm tends to the best generalization performance at extremely fast learning speed [14]. ELM contains the three layers they are input layer, hidden layer and an output layer are shown in figure 1.

ELM has several significant features which are differ from traditional learning algorithms applied for feed forward neural networks. The learning speed of ELM could be completed in seconds or less than seconds for many traditional applications. In traditional algorithm there exists a virtual speed barrier in which the algorithms cannot process and it is not unusual way to take long time for train a feed-forward network using classic learning algorithms for uncomplicated applications [6]. The ELM has better simplification performance compared with gradient based learning algorithms such as back propagation. The gradient based learning algorithms and some other learning algorithms may face many issues such as local minima, improper learning rate and over fitting, etc. The methods are implemented to overcome the above issues such as weight decay and stopping methods.

In real applications, the number of hidden N nodes will always be less than the number of training samples N and the training error cannot be made exactly zero but can be a nonzero training error ϵ. The hidden node parameters $a_i$and (input weights and biases or centers and impact factors) of ELM need not be tuned during training and may simply assigned with random values according to continuous sampling distribution. If the number of neurons in the hidden layer is equal to the number of samples, then H is square and invertible. Otherwise, the system of equations needs to be solved by numerical methods, concretely by solving

$$\|H(w_1, \dots, w_M, b_1, \dots, b_M)\hat{\beta} - T\| = min_{\beta}\|\beta - T\| \quad \text{---------(1)}$$

The result that minimizes the norm of this least squares equation is

$$\hat{\beta} = H^{\dagger}T \quad \text{--------- (2)}$$

Where $H^{\dagger}$was theMoore-Penrose generalized inverse of matrix H.

The three important properties are
Minimum training error.
Smallest norm of weights and best generalization performance.
The minimum norm least-square solution of Hβ = T is unique,$\hat{\beta} = H^{\dagger}T$
The ELM learning algorithm looks much simpler and it gives accurate result when compared to other algorithms. Extreme Learning Machines provides better solutions and possesses a unique features to deal with issues such as regression, uncertainty and (multi-class) classification tasks [3].

Weighted Extreme Learning Machine (WELM)

Weighted extreme learning machine for imbalance learning, which defined aN x diagonal matrix W associated with every training sample x_i. Usually if training data xicomes from a minority class (assumed to be positive class), the associated weightWiiwill be set relatively larger than other [6]. To maximize the marginal distance and to minimize the weighted cumulative error with respect to each sample, an optimization problem mathematically are written as

Minimize$\|H\beta - T\|^2$,$\|\beta\|$ --------- (3)
Where$T = [t_{1,\dots\dots} t_N]$

Minimize $L_{P_{ELM}} = \frac{1}{2}\|\beta\|^2 + \frac{1}{2}\ CW\ \sum_{i=1}^{N}\|\xi_i\|^2$ --------- (4)

Subject to h(xi) β = $t_i^T - \xi_i^T$ i=1,…N

Where h(xi) is the feature mapping vector in the hidden layer with respect to xi, βrepresents the output weight vector connecting the hidden layer and output layer, and C is the regularization parameter to represent the trade-off between the minimization of training errors and the maximization of the marginal distance. ξi, the training error of sample xi, is caused by the difference of the desired output $ti$and the actual output h(xi).

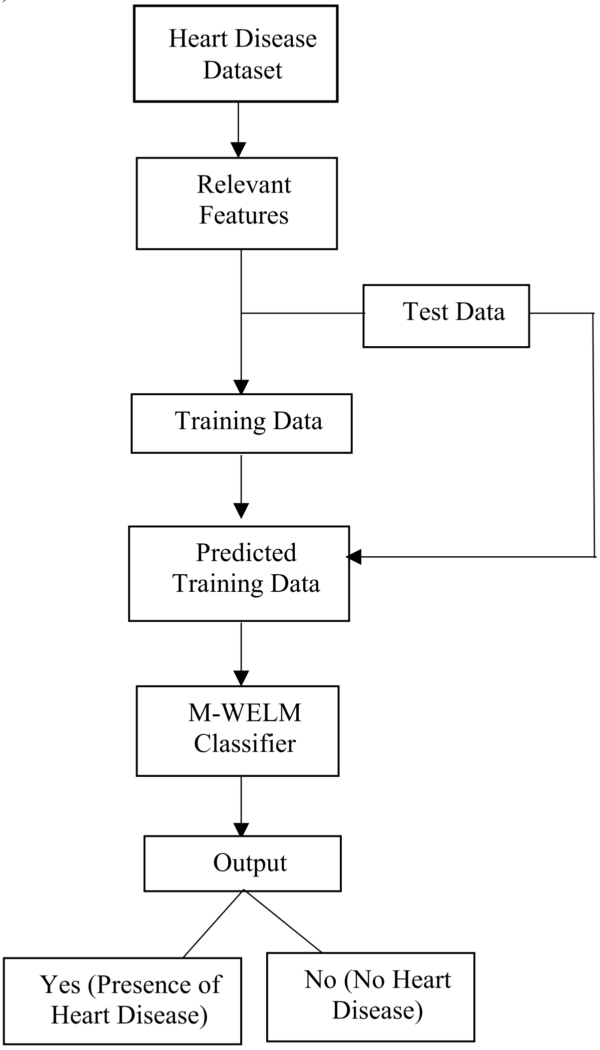

Figure 2 Flowchart for Proposed M-WELM

Modified Weighted Extreme Learning Machine Algorithm (M-WELM)

It is reported that ELM and weighted ELM algorithms are based on empirical risk minimization principle, which may easily lead to the over fitting risk during learning process. By introducing the structural risk minimization principle to the ELM and weighted ELM algorithms, a proposed Modified Weighted Extreme Learning Machine algorithm (M-WELM) are employed to solve the over fitting problem by considering , both the empirical risk and the structural risk and adjusts the proportion of the two risks [6]. The flow chart of Proposed M-WELM are shown in Figure 2.

The traditional extreme learning machines are based on the empirical risk minimization principle and the training error minimization principle, whose drawback is that it is likely to suffer from over fitting, which reduces the generalization capability consequently. According to the statistical theory, the actual risks include the empirical and structural risks, and a model with good generalization performance should be able to balance empirical and structural risks to obtain the best compromise. The structural risk minimization principle into the ELM algorithm and proposed Modified Weighted ELM and WELM model are employed.

Assume that an input and output sample data set for regression analysis is $T = \{(x_1, y_1), \ldots, (x_1, y_1)\}$, where $xi\in Rn$and $y\in R$, $i = 1, \ldots, l$. The condition of the structural risk and adjust the proportion of the empirical and structural risks by ζ instead of the C in formula (7), and the optimization model of the optimal regression function can be established as follows

$$\min \frac{1}{2}\|\beta\|^2 + \frac{1}{2}\,\xi\,\sum_{i=1}^{N}\|\delta_i\|^2 \text{For ELM} \qquad \text{--------- (6)}$$

Or

$$\min \frac{1}{2}\|\beta\|^2 + \frac{1}{2}\,\xi W\,\sum_{i=1}^{N}\|\delta_i\|^2 \text{For M-WELM} \qquad \text{--------- (7)}$$

$$\text{Subject to} \begin{cases} y_{i} - \beta_i h\,(x_i) = \delta_i \\ \delta_i \geq 0, \quad i = 1, \ldots N \end{cases}$$

Where $\delta 2i$ denotes the sum of the square errors, represents the empirical risk and $\|\beta\|2$ represents the structural risk, according to the maximal margin principle in statistical theory [2]. According to formula (6), the formula above is the conditional extreme problem and can be transformed into the Lagrange equation as follows

$$L_{ELM} = \frac{1}{2}\|\beta\|^2 + \frac{1}{2}\,\xi W\,\sum_{i=1}^{N}\|\delta_i\|^2 - \sum_{i=1}^{N}\alpha_i[y_i - \beta h\,(x_i) - \delta_i] \qquad \text{--------- (8)}$$

where the Lagrange multiplier $\alpha i$is the constant factor of sample xiin the linear combination to form the final decision function. Further, by making the partial derivatives with respect to variables **(**β, δi, αi) all equal to zero.

$$\beta = \left(\frac{1}{\xi} + H^T W H\right)^{-1} H^T W T \qquad \text{--------- (9)}$$

Solve the linear equations and then get the following nonlinear mapping equation are shown below

$$f(x) = \sum_{i=1}^{N}\alpha_i\, k_{EL:M}\,(x_i, x) \qquad \text{--------- (10)}$$

The steps of the M-WELM algorithm can be summarized as follows.

Given a training set T, activation function G, and hidden node number N, consider the following.

Step1 - Transform formula (6) of conditional extreme problem
Step2 - Calculateαiusing formulas
Step3 - Calculate the output weight β.

The M-WELM is able to be generalized to cost sensitive learning and can also deal with data with imbalanced class distribution as the WELM. On the other hand, it’s over fitting risk can be reduced by considering both the empirical and structural risks simultaneously. The obtained results are used to predict the presence of heart diseases. The performance of proposed method are evaluated in terms of certain parameters to improve the classification accuracy.

Experimental Results

The performance of the proposed method are evaluated to predict the presence of heart disease. The heart disease data sets, which were used in this research, were obtained from the Heart Disease Databases available in the UCI Machine Learning Repository [13]. These databases contain data information on heart disease clinical instances, contributed by the Cleveland Clinic Foundation (CCF), [12] consists of 303 records. In the experiments, the samples are randomly divided into two sample groups rare 70% for training and the remaining 30% for test. The process is repeated randomly train-test procedure and to calculate the classification accuracy and prediction error of every algorithm. In which the heart disease dataset are split into two non-overlapping sets as training set and a testing set. In which training set consists of 80%, 50%, or 30% of the heart disease datasets while the testing set consists of the remaining 20%, 50%, or 70% of the heart disease dataset. The regression models are trained on the training set and the results are then tested on the testing set.

The performance of proposed method are measured under confusion matrix. The confusion matrix is obtained to calculate the accuracy of classification. A confusion matrix shows how many instances have been assigned to each class. In this experiment the two classes are considered as Yes (heart disease) and No (no heart diseases) as2x2 confusion matrix. Table 1 shows the confusion matrix.

Table 1 Confusion Matrix

	Presence of Heart Disease	Absence of Heart Disease
Predicted Heart Disease	TP	FN
Predicted No Heart Disease	FP	TN

- TP (True Positive) - It denotes the number of records classified as true while they were actually true.
- FN (False Negative) - It denotes the number of records classified as false while they were actually true.
- FP (False Positive) - It denotes the number of records classified as true while they were actually false.
- TN (True Negative) - It denotes the number of records classified as false while they were actually false.

$$\text{Accuracy}(A) = \frac{(TP + TN)}{(TP + TN + FP + FN)}$$

$$\text{Precision} = \frac{TP}{(TP + FP)}$$

$$\text{Recall} = \frac{TP}{(TP + FN)}$$

The proposed Modified Weighted Extreme Learning Machine are compared with Weighted Extreme Learning Machine (W-ELM) [7], Modified Extreme Learning Machine (M-ELM) [6],Extreme Learning Machine (ELM) [3], Support Vector Machine (SVM) [5], Bayesian Network [8] and K-NN [16].

Table 2 Performance Comparison of ELM (80% sample for training and 20% for testing)

Classifiers	Accuracy (%)	Precision (%)	Recall (%)	Execution Time (Seconds)	Error Rate
M-WELM	98	95.6	71	0.32	0.02
W-ELM	96.3	93.2	73.6	0.39	0.04
M-ELM	94.2	91.5	75.5	0.40	0.06
ELM	92.3	89.5	78.5	0.45	0.08
SVM	91.6	86.3	80.3	0.48	0.08
Bayesian Network	86.5	84.2	82.3	0.52	0.13
KNN	82.1	81.6	86.3	0.51	0.18

heart disease datasets for 80% samples are used for training in terms of accuracy, precision, recall and execution time. These performance metrics are used to evaluate the algorithms.

Table 2 shows the performance comparison of proposed M-WELM for 80%sample for training and 20% sample for testing. It is clear that the proposed modified Weighted ELM achieves high classification accuracy of 98% and better results to predict the presence of heart disease.

Table 3 Performance Comparison of M-WELM (50%sample for training and 50% for testing)

Classifiers	Accuracy (%)	Precision (%)	Recall (%)	Execution Time (Seconds)	Error Rate
M-WELM	95.2	92.5	75	0.38	0.05
W-ELM	92.3	90.2	78.6	0.42	0.08
M-ELM	86.2	87.6	79.5	0.45	0.14
ELM	84.3	85.3	81.5	0.49	0.16
SVM	81.6	82.6	83.5	0.51	0.19
Bayesian Network	75.6	79.6	85.6	0.56	0.24
KNN	72.6	75.8	89.5	0.58	0.27

Table 3 shows the performance comparison of proposed M-WELM for 50%sample for training and 50% sample for testing. It is clear that the proposed Modified Weighted ELM achieves high classification accuracy and better results to predict the presence of heart disease.

Table 4 Performance Comparison of M-WELM (30%sample for training and 70% for testing)

Classifiers	Accuracy (%)	Precision (%)	Recall (%)	Execution Time (Seconds)	Error Rate
M-WELM	92.3	90.8	79.8	0.42	0.08
W-ELM	90.6	86.5	82.5	0.45	0.09
M-ELM	88.6	81.6	84.6	0.48	0.11
ELM	85.2	79.5	86.5	0.51	0.15
SVM	80.3	75.8	88.5	0.55	0.2
Bayesian Network	78.6	72.5	89.3	0.59	0.21
KNN	71.3	70.8	91.6	0.62	0.29

Table 4 shows the performance comparison of proposed M-WELM for 30%sample for training and 70% sample for testing. It is clear that the proposed Modified Weighted ELM achieves high classification accuracy and better results to predict the presence of heart disease.

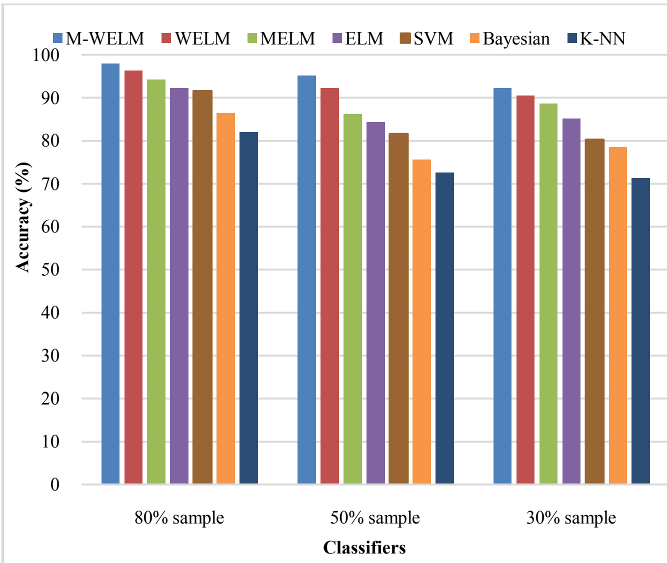

Figure 3 Accuracy Comparison of Various Classifiers

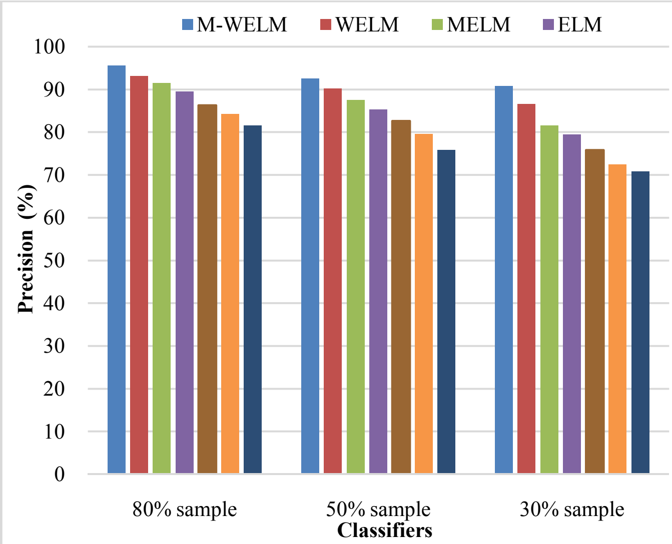

Figure 4 Precision Comparison of Various Classifiers

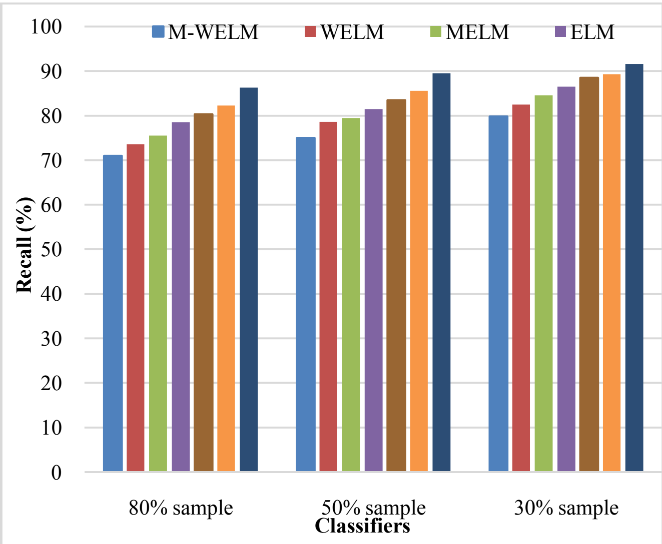

Figure 5 Recall Comparison of Various Classifiers

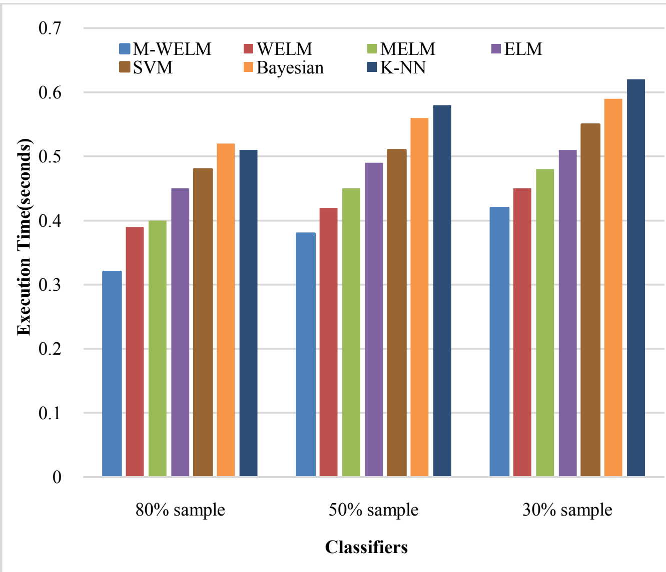

Figure 6 Execution Time Comparison of Various Classifiers

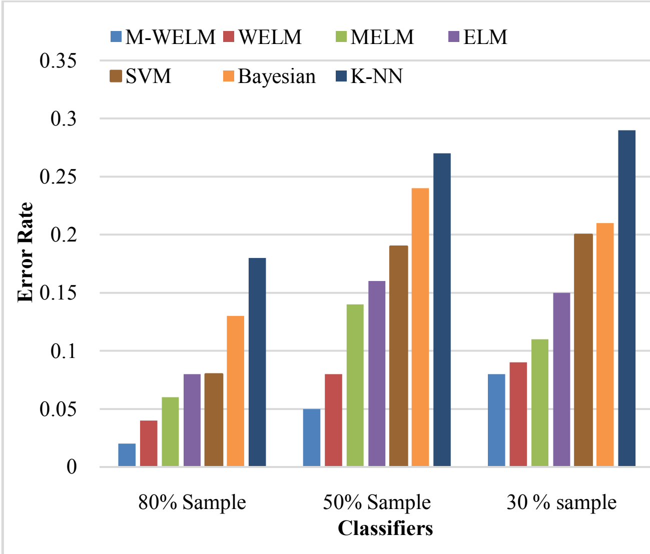

Figure 7 Error Rate Comparison of Various Classifiers

Figure 3-7 shows the performance comparison of Proposed M-WELM with the existing classifiers such as W-ELM,M-ELM, ELM, SVM, Bayesian Network and K-NN classifier in terms of accuracy, precision, recall, Execution time and Error Rate. From the graph it is clear that the proposed M-WELM shows better classification accuracy and robust for 80% sample for training and 20% testing when compared to other existing techniques. The highest training dataset 80% achieves good classification accuracy and it easily predict the presence of heart disease.

CONCLUSION

Heart Disease Prediction System is developed by employing a Modified Weighted Extreme Learning Machine technique. This proposed method extracts hidden knowledge from a heart disease database. This is the most effective model to predict patients with heart disease of reasonable accuracy. The proposed method reduces the over fitting issues during learning process. From results it has been seen that Modified Weighted Extreme Learning Machine provides accurate results and excellent predictive performance as compare to other techniques. From the obtained results it is easy to diagnosis the cardiovascular disease.

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