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Diagnosing the Heart Diseases through Recurrent Neural Network in Associates with Artificial Fish Swarm Optimization

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Abstract: The main objective of this study is to use Artificial Intelligence (AI) technique to diagnose normal and abnormal cardiac disease situations. This research considers couple of benchmark database Cleveland and Hungarain from UCI data repository. This research considers RNN (Recurrent Neural Network) – A LSTM (Long Short-Term Memory) technique diagnoses heart diseases effectively. It is apparent from the investigation that tuning weights play a vital role is enhancing the output performance. Identifying the optimal weights through manual consumes more time and complex is process. The research involves optimization techniques to resolve the above issue. The optimization technique involve during process are PSO (Particle Swarm Optimization) and AFSO (Artificial Fish Swarm Optimization). The results shows that optimization involves in this process enhance the process effectively over traditional approach. AFSO associate RNN-LSTM achieves 98.34% accuracy that is better over comparative techniques.

Keyword: *Heart diseases, Artificial Intelligence, Artificial Fish Swarm Optimization (AFSO), Recurrent Neural Networks.*

Introduction

Because of contemporary life way of inhabitants, mortality and morbidity risk are caused by diseases such as diabetes, heart disease and chronic respiratory diseases. Of these, heart disease has high mortality rate in the world. [1] According to World Health Organization (WHO), worldwide fatality highly occurred due to heart diseases of approximately 30%. [2,3]. Heart failure (HF), clinical syndrome, is affected on structural and /or functional cardiac abnormality that results on reduced cardiac output and/or high intra-cardiac pressure during rest or stress. HF diagnosed based under child age signs and symptoms, although HF could start antenatal. Different investigations have confirmed HF diagnosis along with echography and biomarkers [4]. It highly targets male patients and commonness raises high analogously with lifetime. It has evaluated because of overaging, overall patients increase in time of 2050. Electrocardiogram is the most widely used diagnostic tool. An Electrocardiogram (ECG), digital signal, is noted on keeping electrodes on human body surface to detect voltage changes due to heart's electrical activity. [5,6]

In past ten years, it was tremendous interest growth for automated classification numerous heart arrhythmias field under signals of ECG proposing techniques of ML (machine learning) along with adaptive back-propagation neural network, support vector machines (SVM),) and principal component analysis (PCA). On learning process, the methods have limitations and computational limitations that limit the ability to adapt to personalized health systems. [7] One of the shortcomings of the study, which was developed from a classical Machine Learning algorithm, was that the critical functionality was in the correct optimal problem. Recently, to mention the barriers, second category Deep Learning approaches made huge effect in ECG classification area. Like, Recurrent Neural Network (RNN) [8,9] and Long Short Term Memory (LSTM) Network [10,11] are hugely suggested.[12] RNNs can mention this short coming of sequential prediction replicate direct time elapse. Therefore,

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RNNs and LSTM architectures prefer exact automatic classification of short-term ECG signals. Long short-term memory (LSTM), rare intermittent neural system with option has associated with previous data to current task. [16] Classification problem, difficult task, is owing to large number of parameters involved. New evolutionary algorithms, such as artificial fish swarm optimization algorithm (AFSO) and particle swarm optimization (PSO) algorithm, have been employed for weight optimization process.[17] Artificial fish swarm algorithm depicts fish, hunting and fish behaviour succeed optimum. The algorithm is a fast integration speed, a powerful global search function and a major weakness[18].

Literature Review

Jalil Nourmohammadi- Khiarak et al. [19] 2020 had suggested that cardiac disease data has challenges such as feature selection, sample size, lack of magnitude for certain characteristics, sample imbalance and so on. In examination, imperialist competitive algorithm with meta-heuristic approach has selected salient characteristics of heart disease. It also gives maximum optimal reaction of feature selection about genetic while comparing the further optimization algorithms. K-nearest neighbour algorithm has worn classification. Evaluation result express proposed algorithm, feature selection technique developed with exactness.

Annisa Darmawahyuni et al. [20] 2020, had proposed that CHF (Congestive Heart Failure) characterized using helplessness of heart to pump blood sufficient through entire body with no increase in intra-cardiac pressure. The model containing the first fifteen minutes of ECG signals (model 1) had the greatest accuracy, sensitivity, specificity, precision, and F1-score among 24 LSTM models (99.86%, 99.85%, 99.85%, 99.87%, and 99.86%, respectively). At closure, suggested LSTM model presents the clinician with preliminary CHF diagnosis to develop medical attention.

Zahra Ebrahimi et al. [21] 2020, had proposed vivid examination at length of current DL methods on ECG signal with the aim of classification purposes. The paper observes numerous DL methods namely Deep Belief Network (DBN), Gated Recurrent Unit (GRU), Convolutional Neural Network (CNN), Recurrent Neural Network (RNN) and Long Short-Term Memory (LSTM). CNN has highly detected apt technique as means to feature extraction with 52% of 75 studies published between 2017 and 2018. DL methods express exact classification of A trial Fibrillation (AF) (100%), Supraventricular Ectopic Beats (SVEB) (99.8%), and Ventricular Ectopic Beats (VEB) (99.7%) with help GRU/LSTM, CNN, and LSTM independently.

A.M.Baraniand.R.Latha [22] 2020, had proposed, developing countries like India, Heart diseases are high in number than past ten years. This proposed work contains three parts, first part deploys the simulation tool on identifying heart diseases level with proposed Artificial Fish Swarm Optimization. The suggested study identified under observed and predicted datasets from hospitals. Second part predicts activities such as searching, swarming. Final part evaluates proposed AFSO algorithm performance and proves proposed algorithm value.

RenjiP. Cherian et al. [23] 2020, had proposed Predicting heart disease is considered to be vital issues on clinical data analysis. At last, prediction process occur using Neural Network (NN) model which intakes propositionally shorten features. This paper brings out newly hybrid algorithm, PSO combined LA update (PM-LU) algorithm decodes aforesaid optimization crisis with mixture of LA (Lion Algorithm) and concept of PSO algorithm.

Haotian Shi et al., [24] 2019, predicted that ECG heartbeat classification performance will improve, that paper presents an automatic classification system. Deep structure with multiple input layers was predicted using CNN and LSTM network. For the MIT-BIH arrhythmia database, the suggested system was approximated. Class-oriented system obtained general accurate 99.26% and field oriented schema acquired accurate 94.20%. While comparing earlier works, demonstrates outstanding network performance.

Proposed Methodology

Cleveland, Hungarian, and Switzerland three-databases (included in *Heart Disease Data Set*, *UCI Machine Learning Repository*) each provide 720 data points to diagnose disease status of heart disease. The hungarain consists of 294 databases and Cleveland includes 303 databases; among that 80% of database used for training and 20% used for testing. The RNN performance above other AI approaches that are not considered to be the finest to diagnose normal and abnormal heart disease conditions has recently been shown in the recent literature. In terms of enhancement of performance, configuring RNN with proper weights is an alternative option. The procedure of manually determining suitable weights for RNN configuration is time-consuming. The suggested method comprises RNN configuration optimization approaches that decrease computational complexity.

Long Short-Term Memory

RNN under Hopfield NN is highly used on a variety of tasks, including natural language processing, time series forecasting, and computer modelling. Main RNN feature ends the hidden layers which linked to other. In way, temporal relationship on input signal studied and influence of historical sequence information in the recent output has completely examined. In theory, RNs can model time sequence data with any length; during practice, long-term temporal dependence is difficult to capture because RNN can easily withstand gradient fading with gradient bursting, especially during adjusting process node/unit parameters via back propagation via the time (PPDT) algorithm, while increasing in sample depth.

An LSTM network is expanded form of RNN. Merging to regular RNNs, LSTM adds various gates on controlling network information flow. Figures 1 expresses LSTM unit configuration along with forget gate, input gate, output gate, and different input-output connections access under above mentioned gates. The three gate units are LSTM network integral part to make sure the storing and updating information in LSTM unit. Gateway responsible for failed to delete state information in LSTM unit; At input gate user selects and sends input information to memory unit and at output gate the memory unit to access the measured information is forwarded for output.

Calculation time for forward pass on the LSTM unit is described in detail, $f_t = \sigma(W_f \cdot [y_{t-1}, x_t] + b_f)$ (1)

$$c_t^{'} = \tanh(W_c \cdot [y_{t-1,} x_t] + b_c \qquad (2)$$

$$i_t = \sigma(W_i \cdot [y_{t-1}, x_t] + b_i) \qquad (3)$$

$$c_t = f_t \otimes c_{t-1} + i_t \otimes c_t^{'} \qquad (4)$$

$$o_t = \sigma(W_o \cdot [y_{t-1}, x_t] + b_o) \qquad (5)$$

$$y_t = o_t \otimes \tanh(c_t) \qquad (6)$$

Here W and b show weight matrix and bias parameters should be studied during training process; f_t, i_t, c_t and o_t express forget gate, input gate, memory cell and output gate, respectively; x_t and y_t denote input and LSTM unit output at time t; c_t' is intermediate variable; $\sigma(\cdot)$ and $\tanh(\cdot)$ are sigmoid and hyperbolic tangent activation functions, as:

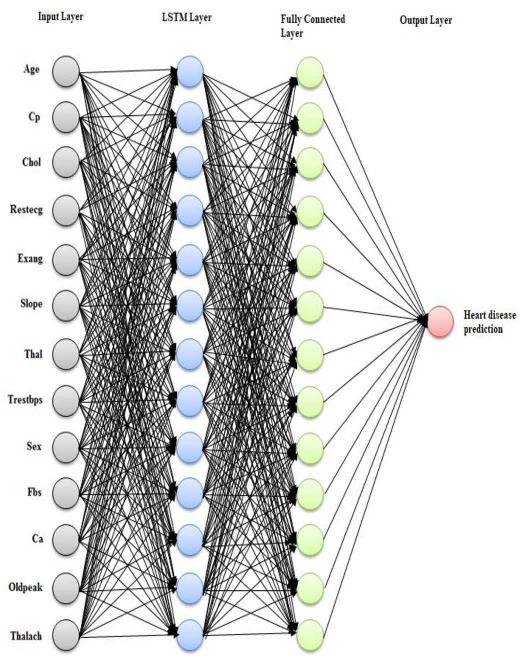
$$\sigma(x) = \frac{1}{1+e^{-x}} \qquad (7)$$

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \qquad (8)$$

Sigmoid activation function output value narrowed between 0 and 1 whereas hyperbolic tangent activation function output value situated in the middle of -1 and 1. Consequently, inputs are normalized [-1, 1], which can improve the training capability and LSTM network robustness, shown in Figure 1:

$$x_{normalized} = \frac{2(x - x_{\min ima})}{x_{\max ima} - x_{\min ima}} - 1 \qquad (9)$$

Here, x_{maxima} and x_{minima} indicates maximum and minimum values on input vector x



Artificial Fish Swarm Optimization

Dr. Li Xiao-Lei, 2002, suggested AFSO as kind of bionic algorithm, and it is a kind of mass intelligence algorithm. It first creates the simple underlying behaviours of artificial fish (AF), and then finally reveals the global optimization through the local search behaviours of AF individuals.

The principle of the algorithm

In a body of water, the fish is said to be nutritious area on personal search or hanging after other fish. Therefore, water area having the highest number of fish is generally the most nutritious, and Figure 2 shows visual perception of artificial fish.

Artificial Fish (AF) senses the exterior on the view in Figure 1. S denotes AF current state, visual denotes visual distance and S_v AF visual position at certain moment. While visual position surpasses recent state and moves one pace further on the direction and comes to S_{next} state; or else, a study visit of view continues. The high rate study tours that AF does, greater knowledge about the entire vision levels that AF receives. Of course, there is no need to move across complex or infinite states that will find global optimization on accepting some local optimization with some uncertainty.

Let $S=(s_1,s_2,\ldots,s_n)$ and $S_v= (s^v_1, s^v_2,\ldots, s^v_n)$ and process is shown:

$$s_i^v = s_i + Vis.rd(), \quad i \in (0,n] \qquad (10)$$

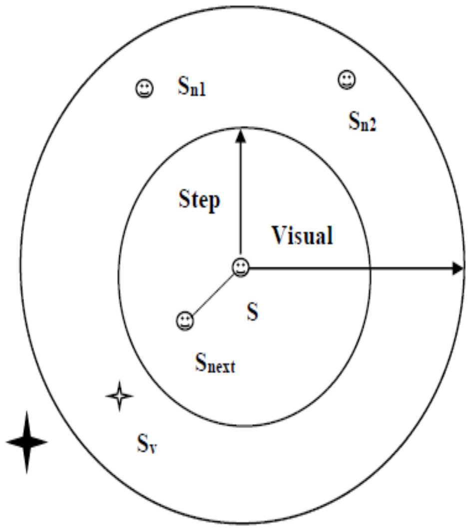


Fig 2: Vision concept of artificial fish

$$S_{next} = S + \frac{S_v - S}{\|S_v - S\|}.\, Step.rd() \qquad (11)$$

Where n denotes number of variables, s_i denotes optimizing variable, *Step* is step length, and rd () produces random numbers in the middle of zero and 1, Vis. is indicated as Visual. Model of AF contains two parts (variables and functions). Variables contain: AF current position denoted by S, *Step* is moving step length, *Visual* acts for visual distance, try number denoted by *try_number* and crowd factor ($0<\delta<1$) is denoted by δ. Functions have AF behaviours: AF_Prey, AF_Swarm, AF_Follow, AF_Move, AF_Leap and AF_Evaluate.

The basic functions of AFSO

Fish normally keep on one place for infinite food, so we simulate fish behaviour under characteristic on getting global optimal as fundamental design of AFSO. The fundamental AF behaviours said as follow on maximum:

Initial solution

The method of obtaining acceptable weights by producing random solutions in the range of -10 to 10 in terms of the number of input attributes. Iteration contains 10-solutions for the computing process as well as the two mathematical expressions listed below.

$$I_i = I_1, I_2, \ldots I_n \qquad (12)$$

Fitness Computation

The method identifies best solution suitable for the research environment and to evaluate the feasibility of the solutions developed above. The following process details the updating process.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \qquad (13)$$

AF_Prey: It known as fundamental biological behaviour that tends to food; In general, fish recognizes food concentration on the water and then chooses course to determine motion on sight or sensation. *Behaviour description*: Let S_i AF as recent state to find state S_j approximately at visual distance, where Y as food concentration (objective activity value), higher visual, easier it finds and combines global extreme value of AF.

$$S_j = S_i + Vis.rd() \qquad (14)$$

If $Y_i < Y_j$ is maximum complexity, it moves one step further; $S_i^{(t+1)} = S_i^{(t)} + \frac{S_j - S_i^{(t)}}{\|S_j - S_i^{(t)}\|}.\, Step.rd()$

(15)

Or else, randomly pick state S_j where determine if meets forward position. When this is unable to be completed later the try_number hours and will move approximately one step. While try_number n AF_Prey as small, AF swims approximately, causing to escape from local extreme value field.

$$S_i^{(t+1)} = S_i^{(t)} + Vis.rd() \qquad (16)$$

AF_Swarm: Fish naturally congregate on groups during moving process and life habit that guarantees the colony existence and avoids risks. *Behaviour description*: Let S_i as current AF state, S_c as centre position and n_f as number of companions within current neighbourhood (d_{ij}< Vis.), n denotes the entire fish number. If $Y_C > Y_i$ and $\frac{n_f}{n} < \delta$, i.e. there is more food in the sub-centre (higher exercise activity value) and not too crowded, which goes one step above the sub-centre;

$$S_i^{(t+1)} = S_i^{(t)} + \frac{S_c - S_i^{(t)}}{\left\| S_c - S_i^{(t)} \right\|} . Step.rd() \qquad 17)$$

Or else, enables predatory behaviour. Crowd factor controls the size of the clusters, and the best AF is only clustered in the best area assures AF moves optimally over entire field.

AF_Follow: During fish swarm moving process, fish or multiple foods get food, neighbourhood side partners move to get food swiftly. *Behaviour description*: Let S_i as AF present state inspects companion S_j on neighbourhood (d_{ij}<Visual) that contains highest Y_j. If $Y_j > Y_i$ and $\frac{n_f}{n} < \delta$, Sub-S_j state contains a higher food concentration (higher exercise activity value) where surrounding area stays too vacant, which is one step above Comrade S_j,

$$S_i^{(t+1)} = S_i^{(t)} + \frac{S_j - S_i^{(t)}}{\left\| S_j - S_i^{(t)} \right\|} . Step.rd() \qquad (18)$$

Perhaps, implements prey behaviour.

AF_Move: The fish swims roughly the water and seek food or companions over large frontiers.

Behaviour description: Selects a state randomly in view and then moves on to this state, in fact, default AF_Prey behaviour.

$$S_i^{(t+1)} = S_i^{(t)} + Vis.rd() \qquad (19)$$

AF_Leap: The fish stop within the water, the result of the behaviour of each AF is same, target values difference (food concentration, CF) is less than in some iterations and could fall to the local end change parameters randomly to stationary states to skip current state.

Behaviour description: If objective function is almost same or difference and less proportion in given iterations (m - n), choose some random fish in entire swarm of fish and set the parameters randomly for AF selected. β function cause a parameter or other abnormal action (values) for some fish, *eps* small constant.

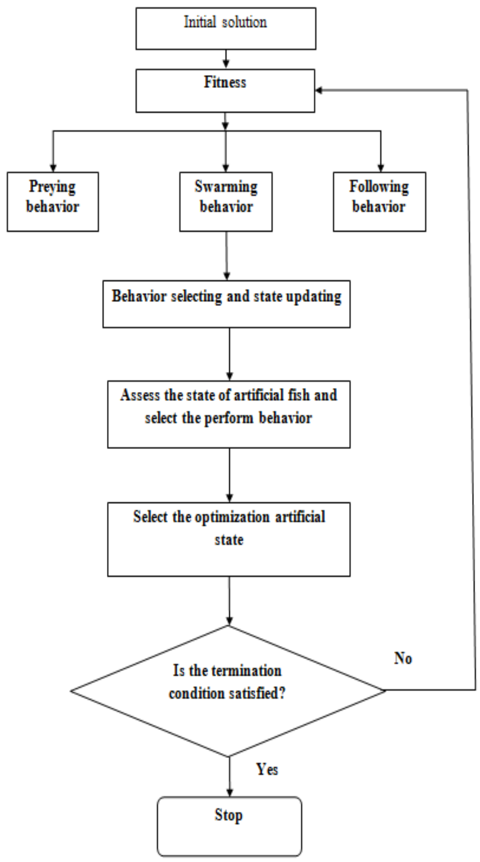


Fig: 3 Flowchart of Artificial Fish Swam Optimization

$$if\,(Best\ FC(m) - Best\ FC(n)) < eps$$

$$S_{some}^{(t+1)} = S_{some}^{(t)} + \beta.Vis.rd() \qquad (20)$$

AF_Swarm causes some fish trapped on local extreme values to travel on some fish direction on global extreme value, resulting AF escaping local extreme values. AF_Follow Accelerates moving AF condition while accelerating AF's move from local radical values to the global radical value field.

Measures	Database	
	Cleveland	**Hungarian**
Sensitivity	0.9393	0.9473
Specificity	0.9285	0.9090
Accuracy	0.9344	0.9333
PPV	0.9393	0.9473
NPV	0.9285	0.9090
FPR	0.0714	0.0909
FNR	0.0606	0.0526
FDR	0.0606	0.0526

Results and Discussion

Proposed techniques and comparative techniques performance evaluate through following measures accuracy, sensitivity, specificity, False Discovery Rate (FDR), False Negative Rate (FNR), False Positive Rate (FPR), Negative Predictive Value (NPV), and Positive Predictive Value (PPV). The results show that the proposed approach has an accuracy of 98.36% in Cleveland database and 98.33% in Hungarian database, respectively. Proposed approach shows that tuning optimal weights enhance the performance of predicting accuracy over traditional method. The mathematical formulation for the utilised measures is shown in Table 1, which is used to assess the included procedures performance.

1) FalsePositive(FP) - Heartdisease incorrectly identified.
2) TruePositive(TP) - Heartdisease correctly identified.
3) FalseNegative(FN) - Heartdisease incorrectly rejected.
4) TrueNegative(TN) - Heartdisese correctly rejected.

Measures	Mathematical Expression
Sensitivity	$\frac{TP}{TP + FN}$
Specificity	$\frac{TN}{TN + FP}$
Accuracy	$\frac{TP + TN}{TP + TN + FP + FN}$
PPV	$\frac{TP}{TP + FP}$
NPV	$\frac{TN}{TN + FN}$
FNR	$\frac{FN}{FN + TP}$
FPR	$\frac{FP}{FP + TN}$
FDR	$\frac{FP}{FP + TP}$

Table-1. Performance Measures Mathematical Expression.

Measures	Database	
	Cleveland	**Hungarian**
Sensitivity	0.9696	0.9736
Specificity	1.0000	1.0000
Accuracy	0.9836	0.9833
PPV	1.0000	1.0000
NPV	0.9655	0.9565
FPR	0	0
FNR	0.0303	0.0263
FDR	0	0

Table-2. Performance measures for proposed technique (RNN-AFSO)

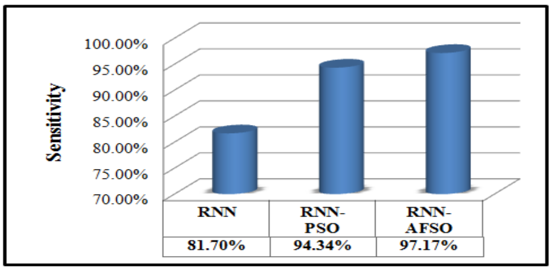
Table-3. Performance measures for proposed technique (RNN-PSO)

Measures	Database	
	Cleveland	**Hungarian**
Sensitivity	0.8181	0.8157
Specificity	0.8928	0.9090
Accuracy	0.8524	0.8500
PPV	0.9000	0.9393
NPV	0.8064	0.7407
FPR	0.1071	0.0909
FNR	0.1818	0.1842
FDR	0.1000	0.0606

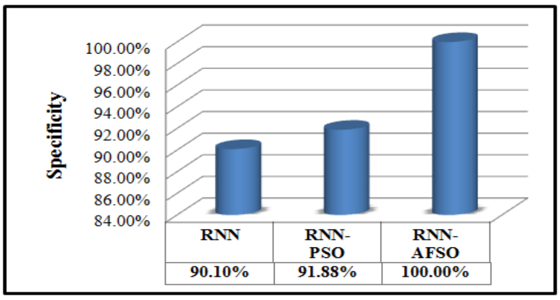
Table-4. Performance measures for proposed technique (RNN).

Table 2 indicates RNN performance associates AFSO to configure optimal weights for couple of database along with comparative techniques showed in subsequent table 3 and 4. It is apparent from investigative results that proposed approach with better performance over comparative techniques. In both cases accuracy is greater over other techniques, the proposed methods attain 98.36% and 98.33% respectively for Cleveland and Hungarian database. The proposed results are 4.92% and 5% respectively for Cleveland and Hungarian database better than RNN-PSO. Especially, proposed results are 13.12% and 13.33% respectively for Cleveland and Hungarian database that is far better than traditional RNN. The average performance of the employed techniques w.r.t standard measures shown in figure 4 apparent that proposed approach having greater performance measures over other comparative approach.

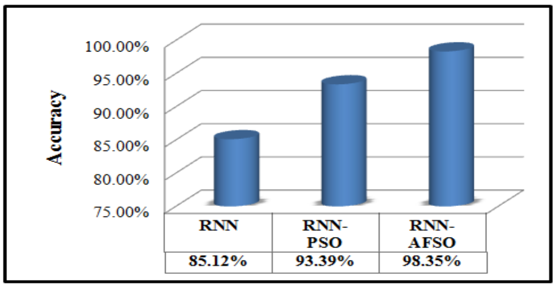
Average performance of employed techniques w.r.t measures



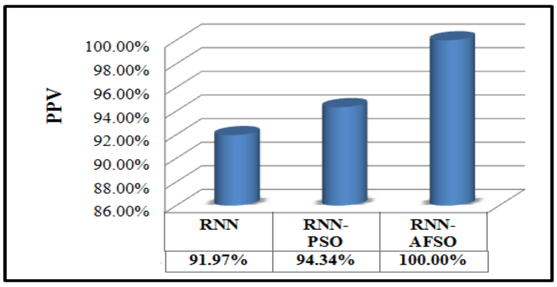
(a)



(b)



(c)



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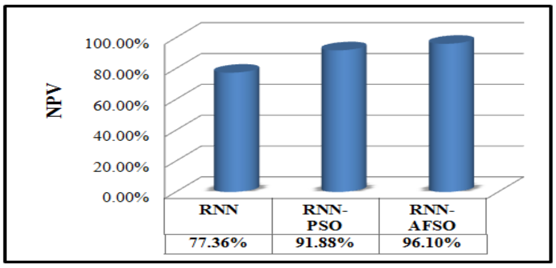

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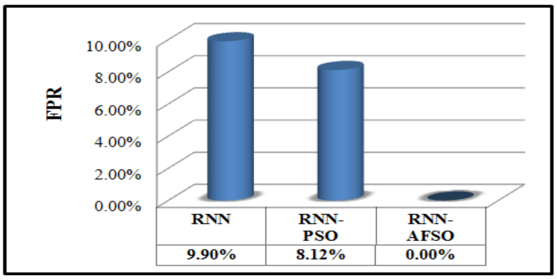

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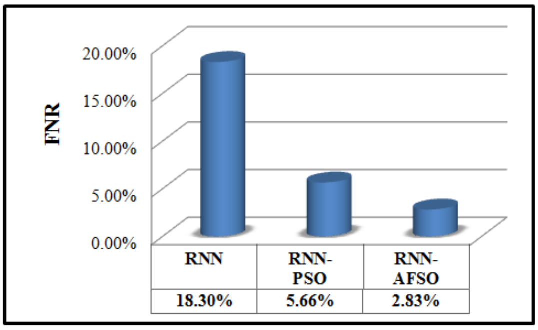

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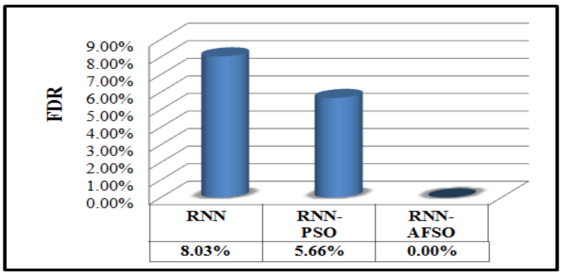

(h)

Conclusion

The purpose of incorporating RNN in associate with optimization techniques to identify heart diseases successfully accomplished with the average accuracy of 98.34%. The results evident that proposed technique having 4.96% greater accuracy over RNN associates PSO and the accuracy of 13.22% far better than conventional RNN. This could be apparent other performance measures that the proposed approach having significant performance over other employed techniques. Identifying the optimal weights for RNN-LSTM shows that greater performance over traditional approach. The researchers want to develop a method for configuring RNN weights in the future, which they may use to diagnose additional research in biomedical.

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