

## Research Article

# Hybrid Hypercube Optimization Search Algorithm and Multilayer Perceptron Neural Network for Medical Data Classification

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Received 23 December 2021; Revised 28 January 2022; Accepted 15 February 2022; Published 25 March 2022

Academic Editor: Sajad Jafari

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The hypercube optimization search (HOS) approach is a new efficient and robust metaheuristic algorithm that simulates the dove's movement in quest of new food sites in nature, utilizing hypercubes to depict the search zones. In medical informatics, the classification of medical data is one of the most challenging tasks because of the uncertainty and nature of healthcare data. This paper proposes the use of the HOS algorithm for training multilayer perceptrons (MLP), one of the most extensively used neural networks (NNs), to enhance its efficacy as a decision support tool for medical data classification. The proposed HOS-MLP model is tested on four significant medical datasets: orthopedic patients, diabetes, coronary heart disease, and breast cancer, to assess HOS's success in training MLP. For verification, the results are compared with eleven different classifiers and eight well-regarded MLP trainer metaheuristic algorithms: particle swarm optimization (PSO), biogeography-based optimizer (BBO), the firefly algorithm (FFA), artificial bee colony (ABC), genetic algorithm (GA), bat algorithm (BAT), monarch butterfly optimizer (MBO), and the flower pollination algorithm (FPA). The experimental results demonstrate that the MLP trained by HOS outperforms the other comparative models regarding mean square error (MSE), classification accuracy, and convergence rate. The findings also reveal that the HOS help the MLP to produce more accurate results than other classification algorithms for the prediction of diseases.

## 1. Introduction

Medical data classification is a growing field of research that provides pathologists with vital knowledge for diagnosing and treating diseases. Multilayer perceptron (MLP) neural network is one of the most powerful classification algorithms that has been successfully and widely employed for many medical problems [1–4]. The key point in using MLP is to determine the best values for the parameters of the neural network. The most commonly used gradient-based learning method of MLP is the backpropagation (BP) algorithm. However, this learning method has some flaws, including sluggish convergence, high reliance on the initial solutions, and a proclivity for getting stuck in local optima. Optimization algorithms (OAs) are offered as viable alternatives to gradient-based MLP training approaches in this regard. Several works have been published in the literature, including group search optimizer (GSO) [5], symbiotic organisms search (SOS) [6] algorithm, lightning

search algorithm (LSA) [7], ant lion optimizer (ALO) [8], Krill herd algorithm (KHA) [9], grasshopper optimization algorithm (GOA) [10, 11], artificial bee colony (ABC) [12], social spider optimization algorithm (SSO) [13], hybrid of ABC and dragonfly algorithm (DA) [14], artificial ant colony optimization (ACO) [15], particle swarm optimization (PSO) [16], cuckoo search (CS) [17, 18], moth-flame optimization (MFO) [19, 20], whale optimization algorithm (WOA) [21], gray wolf optimizer (GWO) [22, 23], black hole algorithm (BHA) [24], invasive weed optimization [25], multiverse optimizer algorithm (MOA) [26, 27], bat algorithm [28], and salp swarm algorithm (SSA) [29].

Although various OAs have already been investigated for training MLP neural networks, because of the duality of AOs' exploration and exploitation capabilities, there is still room for new designs and upgrades to current ones [30]. Also, in training MLP, the issue of slow convergence rate and trapping in local optima remains partially unsolved.

The purpose of this study is to introduce a new optimization technique, called the hypercube optimization search (HOS) algorithm, for training MLP to present an improved classification approach for medical data by optimizing the MLP's weights and biases parameters. The HOS is recommended for training MLP to overcome the aforementioned challenges due to its outstanding performance in escaping local optima and fast convergence speed [31, 32]. Also, HOS have fewer parameters and is easy to use, simple in principle, and adaptable when compared to other swarm-based OAs.

This paper's contributions can be summed up as follows:

- (i) To propose a new stochastic learning approach for training MLPs, in order to boost the MLP's performance in the classification of health data.
- (ii) To evaluate HOS-MLP's performance on four important medical datasets: diabetes, breast cancer, coronary heart disease, and orthopedic patients, and compare its performance against eleven different classifiers and eight well-known OA-based MLP trainer techniques.
- (iii) To achieve better outcomes than previous studies, using suggested HOS-MLP in terms of mean square error (MSE), classification accuracy, and convergence rate.

This paper is structured as follows: Section 2 presents the MLP. The HOS algorithm is explained in Section 3, whereas the proposed HOS-MLP approach is introduced in Section 4. Section 5 shows the experimental results and discussion. Finally, section 6 gives a conclusion as well as recommendations for further work.

## 2. Multilayer Perceptron Neural Network

The feedforward neural network (FNN) is one of the most prevalent forms of artificial neural network (ANN) and MLP is a well-known type of FNN that is widely used in solving realistic classification problems [10]. An MLP is made up of three groups of layers: input ( $i$ ), hidden layer ( $j$ ), and output ( $k$ ). Each layer consists of a specific number of neurons, and each neuron has full-weighted connections with the adjacent layer neurons. A single hidden layer MLP network was used in this paper, which was demonstrated in Figure 1.

Each neuron can carry out two functions in the MLP: weighted summation and activation. The weighted sum is calculated using equation (1) for each hidden neuron  $j$  as follow:

$$s_j = \sum_{i=1}^n w_{ij}x_i + \beta_j, \quad (1)$$

where  $w_{ij}$  describes the connection weight,  $\beta_j$  is the biased term,  $x_i$  denotes the input  $i$ , and  $n$  shows the total number of inputs. In the second step, using the outcome of equation (1), an activation function is utilized to calculate the neurons' output. The function is illustrated as follows:

$$f(s_j) = \frac{1}{1 + e^{-s_j}}, \quad (2)$$

The most commonly used sigmoid activation function was selected in the MLP [22, 26]. Utilizing the results of the hidden neurons, the final productions of the output neurons are computed as follows:

$$y_k = f(o_k) = \frac{1}{1 + e^{-s_k}}, \quad (3)$$

$$s_k = \sum_{j=1}^h w_{jk}f(s_j) + \beta_k.$$

MLP's performance depends highly on weights and biases, and training MLP aims to find optimal weights and biases. MLP training is a challenging task that leads to a high-performance MLP [21]. The HOS algorithm is used as a training method for MLPs in the following sections.

## 3. Hypercube Optimization Search Algorithm

The HOS algorithm, inspired by a dove's behavior in exploring new food zones, was proposed by Abiyev and Tunay for solving high-dimensional numerical problems [31]. The HOS algorithm is based on a randomly distributed set of points inside an  $m$ -dimensional hypercube (HC). HOS exhibit fast population convergence by shrinking the area of the HC at each iteration. The HOS algorithm consists of three stages: (A) the initialization process, (B) the displacement-shrink process, and (C) the searching areas process. These stages can be described in detail as follows.

**3.1. Stage A: Initialization Process.** The HOS algorithm begins with the initialization process, in which randomly generated points within a given HC form the candidate solutions matrix. Several starting conditions in the initialization phase should be computed, including (1) lower-upper boundaries ( $lb, ub$ ), (2) size ( $r_{dim}$ ), (3) central value ( $x_c$ ), and (4) dimension of the HC ( $m$ ).

$$m = \text{length}(x_c),$$

$$x_c = \frac{(ub + lb)}{2},$$

$$d = lb - ub, r_{dim} = \frac{d}{2}, \quad (4)$$

$$lb = \min(X \text{ bounds}),$$

$$ub = \max(X \text{ bounds}).$$

At the starting stage, the first HC is created by assigning random values to  $r_{dim}$  and  $x_c$ . The uniformly distributed  $N$  points  $x_i = (x_{i1}, x_{i2}, \dots, x_{im})$  are then randomly produced inside the HC. These points could also be represented in matrix form  $X$  with the size of  $(N \times m)$ . The upper and lower boundaries of the first HC are then calculated using the  $X$  matrix. The  $r_{dim}$  and  $x_c$  of the next HC are determined using

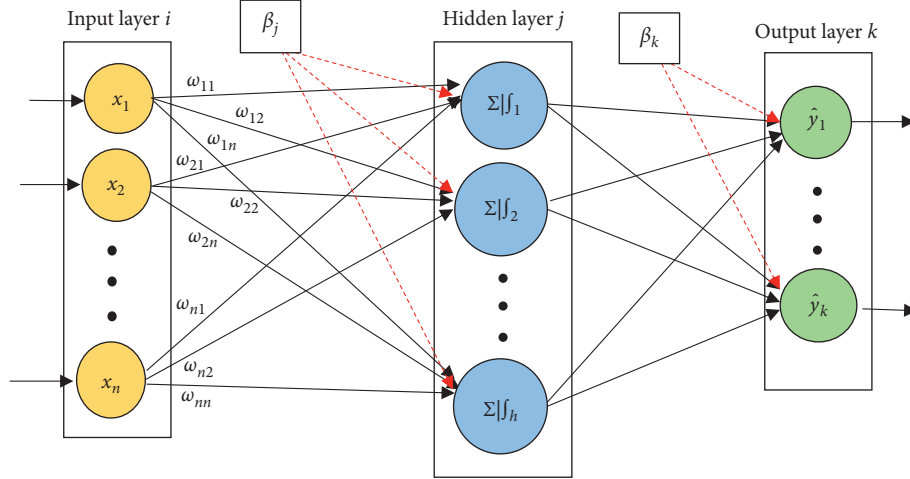


FIGURE 1: Structure of single hidden layer MLP.

those boundaries. The  $X$  matrix is also utilized for evaluation, in which the best value of the fitness function  $F_{best}$  and corresponding  $x_{best}$  point is determined within the population at  $i$  th iteration. Using local search, the  $x_{best}$  point is improved as follows:

$$x_{best}^{new} = x_{best} + \rho \Delta F, \quad (5)$$

where  $F$  is the fitness function, and  $0 \leq \rho \leq 1$ .

**3.2. Stage B: Displacement-Shrink Process.** The displacement-shrink phase aims to determine the center of the next hypercube (new hypercube)  $x_{c_{new}}$  and evaluate the fitness function. The center of the next hypercube is obtained using the average of the sum of the previous hypercube's center and the present best point ( $x_{best}$ ) as follows:

$$x_{c_{new}} = \frac{x_{best}^{new} + x_c}{2}. \quad (6)$$

In this process, each iteration generates fresh data points, and the fitness function is evaluated. The hypercube size has been modified based on the evaluation results. This process is used as a conservative measure to reduce excessive variability in the search space. As a consequence, the size of HC is decreased and the search space is reduced, which is called "shrinking." The density of the search points (population) increases as the hypercube size decreases. The movement of the best value is governed by contraction. For smaller movements, the contraction is stronger. This ensures rapid convergence while also preventing the algorithm from becoming trapped at an undesirable (local) minimum.

The algorithm will cycle through a sequence of points starting from the current position to estimate the maximum distance. The value of the  $F_{best}$  is first compared with the  $F_{mean} = F((x_{best} + x_{last-center})/2)$ . If  $F_{mean}$  value is less than  $F_{best}$  in the given iteration,  $x$  displacements (or  $x$  movements) is computed and normalized twice at each iteration using the following formulas:

$$\text{Normalized } x \text{ (the previous } x \text{ for minimum)} x_n = \frac{x - x_c}{d}, \quad (7)$$

$$\text{Normalized } x_{min} \text{ (current } x \text{ for minimum)} x_n = \frac{x_{min} - x_c}{d}, \quad (8)$$

$$\text{Normalize distance } d_n = \frac{\text{sum}((x_n - x_{min_n})^2)^{0.5}}{d}, \quad (9)$$

$$\text{Re-normalize distance } d_m = \frac{d_n}{\sqrt{m}} \quad (10)$$

To convert the displacement into unity-sided points, each element of  $x$  is first divided by the associated beginning interval (equations (7) and (8)), and then this number is again normalized by dividing it to the diagonal of the points, i.e.,  $\sqrt{m}$

(equations (9) and (10)). If  $F_{mean}$  value in the specified iteration is greater than  $F_{best}$ ,  $x$  displacements will not occur and  $d_m$  will be assigned to 1. The searching areas process is carried out in the next step if the conditions are not met.

**3.3. Stage C: Searching Areas Process.** The phase of the search area generates a new HC by initializing new values to  $r_{dim}$  and  $x_c$  according to the value of  $d_{mm}$ . If the  $0 \leq d_{mm} \leq 1$  condition is satisfied, the factor of convergence  $S$  is calculated and values of the  $r_{dim}$  and  $x_c$  are updated accordingly using the following formulas:

$$\begin{aligned} x_c &= x_{\text{best}}, \\ r_{\text{dim}} &= r_{\text{dim}} * S, \\ S &= 1 - 0.2e^{-3d_{mm}}. \end{aligned} \quad (11)$$

The size of the HC is reduced by multiplying  $r_{dim}$  with  $S$  factor. If  $0 \leq d_{mm} \leq 1$  condition is met, the size of HC remains unchanged. HOS ensure the quick arrival of candidate solutions to a global minimum by reducing the area of the hypercube after each iteration. The entire procedure is repeated till particular termination criteria are met. The HOS algorithm is depicted in Figure 2. More details are provided in [31, 32].

#### 4. HOS for MLP Training

The suggested HOS-MLP method, in which the HOS algorithm is utilized for training the MLP, is explained in detail in this section. When the method is designed, two important aspects are considered: (1) the representation of candidate solutions in HOS for training MLP, and (2) the definition of a fitness function for solution assessment.

The matrix encoding approach is utilized in HOS-MLP to represent candidate solutions. For MLP's weight and bias parameters, each solution provides a set of values. A solution can be represented as follows:

$$\begin{aligned} W_1 &= \begin{bmatrix} w_{1,1} & \cdots & w_{n,1} \\ \vdots & \ddots & \vdots \\ w_{1,h} & \cdots & w_{n,h} \end{bmatrix}, \\ \beta_1 &= \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_h \end{bmatrix}, \\ W_2' &= \begin{bmatrix} w_{1,1} & \cdots & w_{h,1} \\ \vdots & \ddots & \vdots \\ w_{1,k} & \cdots & w_{h,k} \end{bmatrix}, \\ \beta_2 &= \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_k \end{bmatrix}, \\ \text{solution}_i &= [W_1, \beta_1, W_2', \beta_2]. \end{aligned} \quad (12)$$

where  $W_1$  indicates the weight matrix of linkages between hidden neurons and input and  $W_2'$  demonstrates the transpose of the weights matrix of the linkages between the hidden neurons and output. For hidden and output neurons, the  $\beta_1$ , and  $\beta_2$  represent bias values, respectively.

It is worth mentioning that the number of neurons in the input and output layers is specified by the dataset's total

number of features and labels, while the Kolmogorov theorem is utilized to determine the number of neurons within the hidden layer (H) using the following equation:

$$H = 2 * \text{Input} + 1. \quad (13)$$

The MSE is utilized as the objective function for measuring the fitness value of candidate solutions in the proposed HOS-MLP approach as follows:

$$\text{MSE} = \frac{1}{n} \sum_{i=1}^n (y - \hat{y})^2, \quad (14)$$

where  $y$  and  $\hat{y}$  symbolize the actual and predicted class label, and  $n$  is the number of samples in training data. The HOS based MLP training approach is carried out in the following stages:

- (1) Initialization: within an HC, the initial solutions (points) are generated randomly. Each solution represents the possible values for the parameters of MLP.
- (2) Fitness evaluation: the solutions are assigned to MLPs, and the goodness of each MLP is then evaluated using MSE. The objective is to find the best MLP with the least MSE based on the dataset's training samples.
- (3) Creating new HC and update solutions.
- (4) Steps 2 and 3 are repeated until the full number of iterations is completed. Eventually, the solution with the least MSE is reported as the optimal solution. It is then allocated to MLP and the performance of the trained MLP is assessed on the test dataset.

Figure 3 illustrates the suggested HOS-MLP framework.

#### 5. Results and Discussions

In this section, the proposed HOS-MLP model is examined on four medical datasets: orthopedic patients (vertebral column) [33], diabetes [34], coronary heart disease (Saheart) [35], and Wisconsin breast cancer [36]. The characteristics of the medical datasets are summarized in Table 1.

All medical datasets are split into two parts: 66.66% of the data is used for the training set, and the remaining (33.33%) is used for the test set. In this partitioning, stratified sampling is used to retain the initial data distribution in the training and testing. The algorithms have been run 20 different times to produce statistically valid results. The Min-max scaling method was utilized to standardize all feature values within the range [0, 1] using the following equation:

$$x' = \frac{x_i - \min}{\max - \min}. \quad (15)$$

The suggested HOS-MLP is compared with eight well-known and recent Oas, including ABC [12], PSO [16], BAT [28], GA [37], BBO [38], firefly algorithm (FF/FA) [39], monarch butterfly optimization (MBO) [40], and flower pollination algorithm (FPA) [41]. For all OAs, the population size was set to 70, and the maximum number of

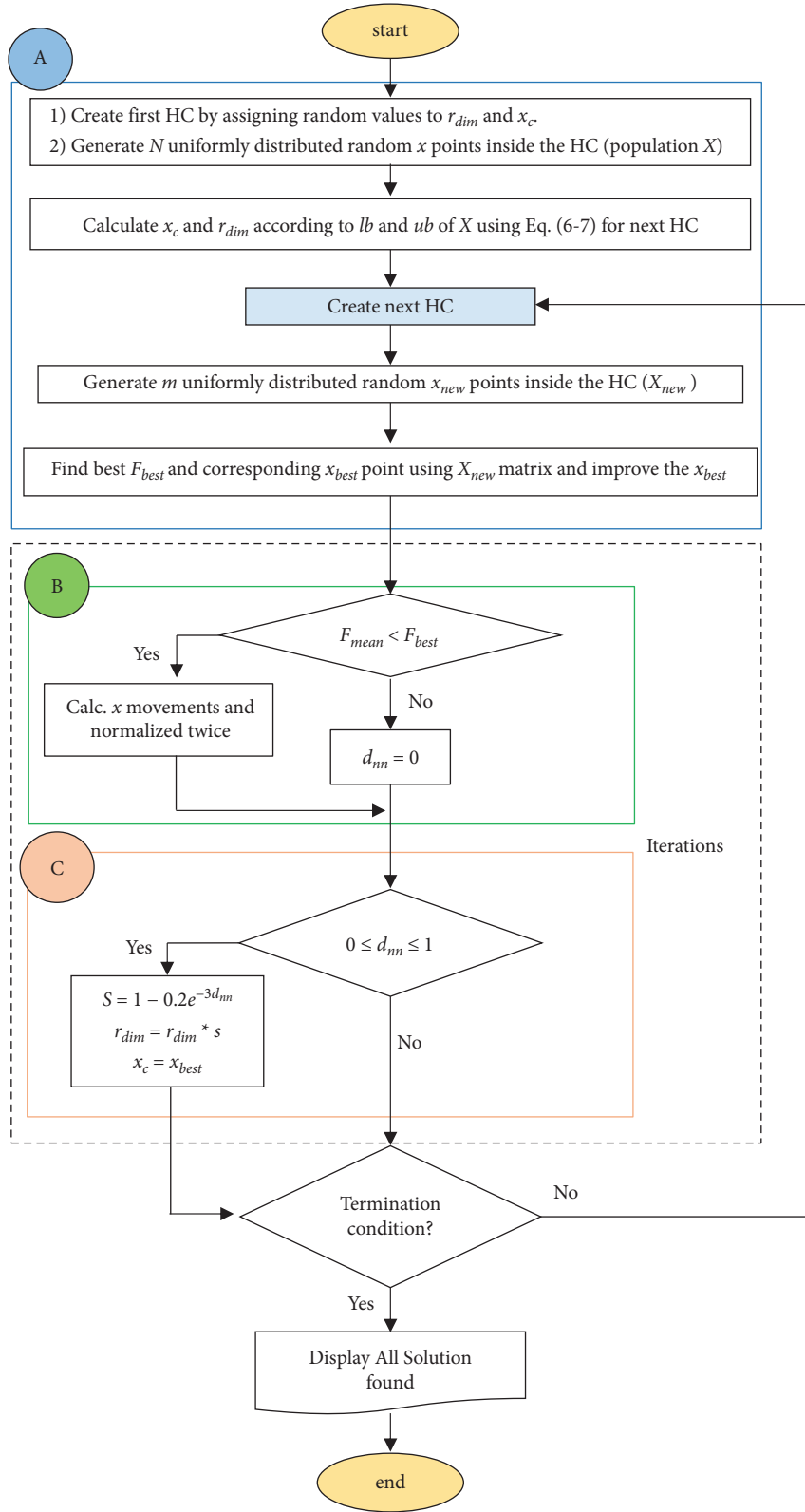


FIGURE 2: The flowchart of the HOS algorithm.

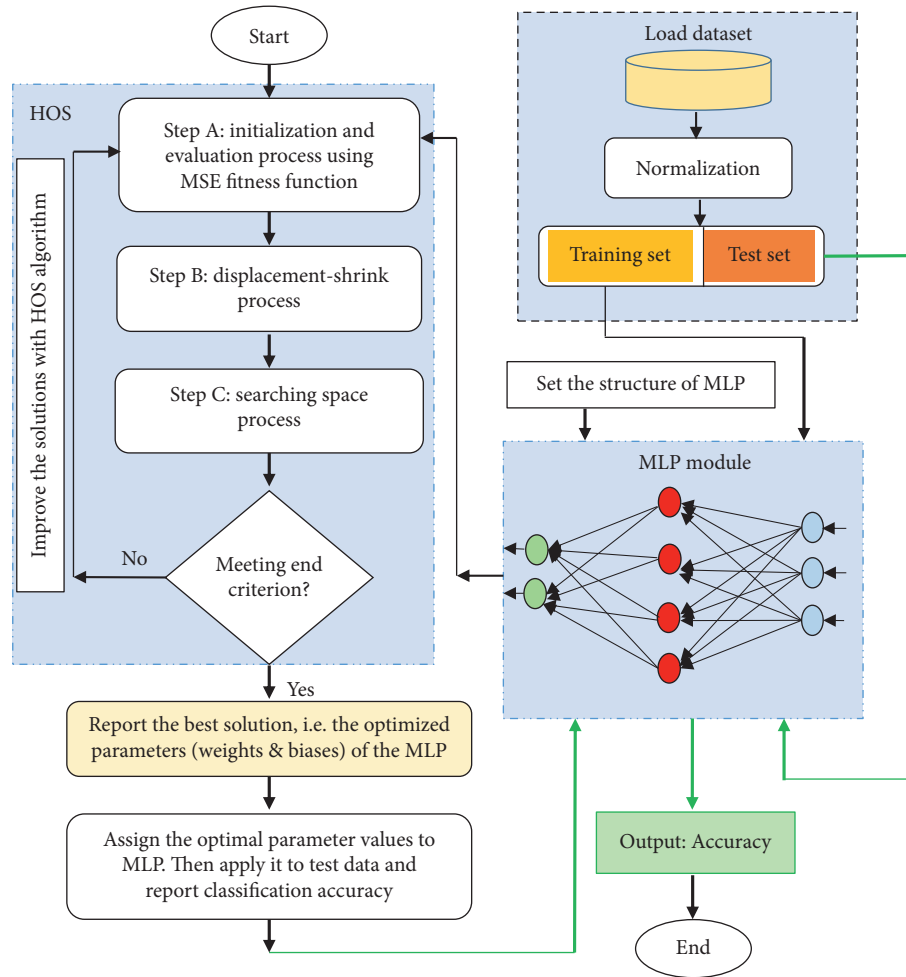


FIGURE 3: The flowchart of suggested HOS-MLP for medical data classification.

TABLE 1: Datasets description.

Dataset	#Features	#Class	#Training sample	#Testing sample	MLP structure (input-hidden-output)
Breast cancer	9	2	469	230	9-19-2
Diabetes	8	2	515	253	8-17-2
Saheart	9	2	310	152	9-19-2
Vertebral column	6	2	161	79	6-13-3

iterations was set to 250 in all experiments. Two optional parameters in the HOS algorithm,  $tolF$ , and  $tolX$ , were set to  $1e-09$  and  $1e-01$ , respectively. The parameters  $tolF$  and  $tolX$  represent relative tolerance for fitness function and vector  $x$  to stop the algorithm. The evaluation measures employed in this work are accuracy, MSE, box plot, and coverage rate. The rest of the parameters were set as suggested in [42].

**5.1. Breast Cancer Dataset.** Many binary classification problems use accuracy and MSE metrics to show the model's ability to split the two-class labels. Table 2 summarizes the testing set results for the suggested HOS-MLP model compared to other OAs models from the literature. From Table 2, Figures 4(a) and 4(b), it can be noticed that the

suggested method performs very better than other methods in terms of convergence rate. Although all algorithms achieved high ratios in terms of average accuracy, the suggested HOS-MLP shows reasonable and competitive results with the lowest MSE average (Figures 4(c) and 4(d)).

**5.2. Diabetes Dataset.** The diabetes dataset evaluation results are illustrated in Table 3 and Figure 5. When the convergence curves in Figure 5(a) and 5(b) are compared to the other algorithms, the suggested strategy has a very high convergence rate, while most methods, such as GOA and ABC, have stagnated after 98 iterations. The proposed approach displays the maximum ratios in terms of average and best accuracy (Table 3 and Figure 5(c)). The boxplot

TABLE 2: The performance results of comparative methods on the breast cancer dataset in the terms of mean square error (MSE) and classification accuracy.

Comparative algorithms	MSE			Accuracy (%)		
	Best	Worst	Mean	Best	Worst	Mean
ABC-MLP	0.03400	0.03843	0.03639	98.319	94.958	96.891
BAT-MLP	0.01624	0.06023	0.03432	98.319	92.437	96.218
BBO-MLP	0.02938	0.03442	0.03195	98.319	96.639	97.255
FF-MLP	0.03043	0.03279	0.03209	97.899	96.639	97.311
FPA-MLP	0.03079	0.03320	0.03216	98.319	95.378	97.241
GA-MLP	0.02786	0.03206	0.03020	97.479	95.378	96.751
MBO-MLP	0.02351	0.03887	0.02974	97.899	94.958	96.695
PSO-MLP	0.03062	0.03999	0.03496	97.899	95.378	97.045
HOS-MLP	0.01833	0.02819	0.023464	97.521	93.4733	96.833

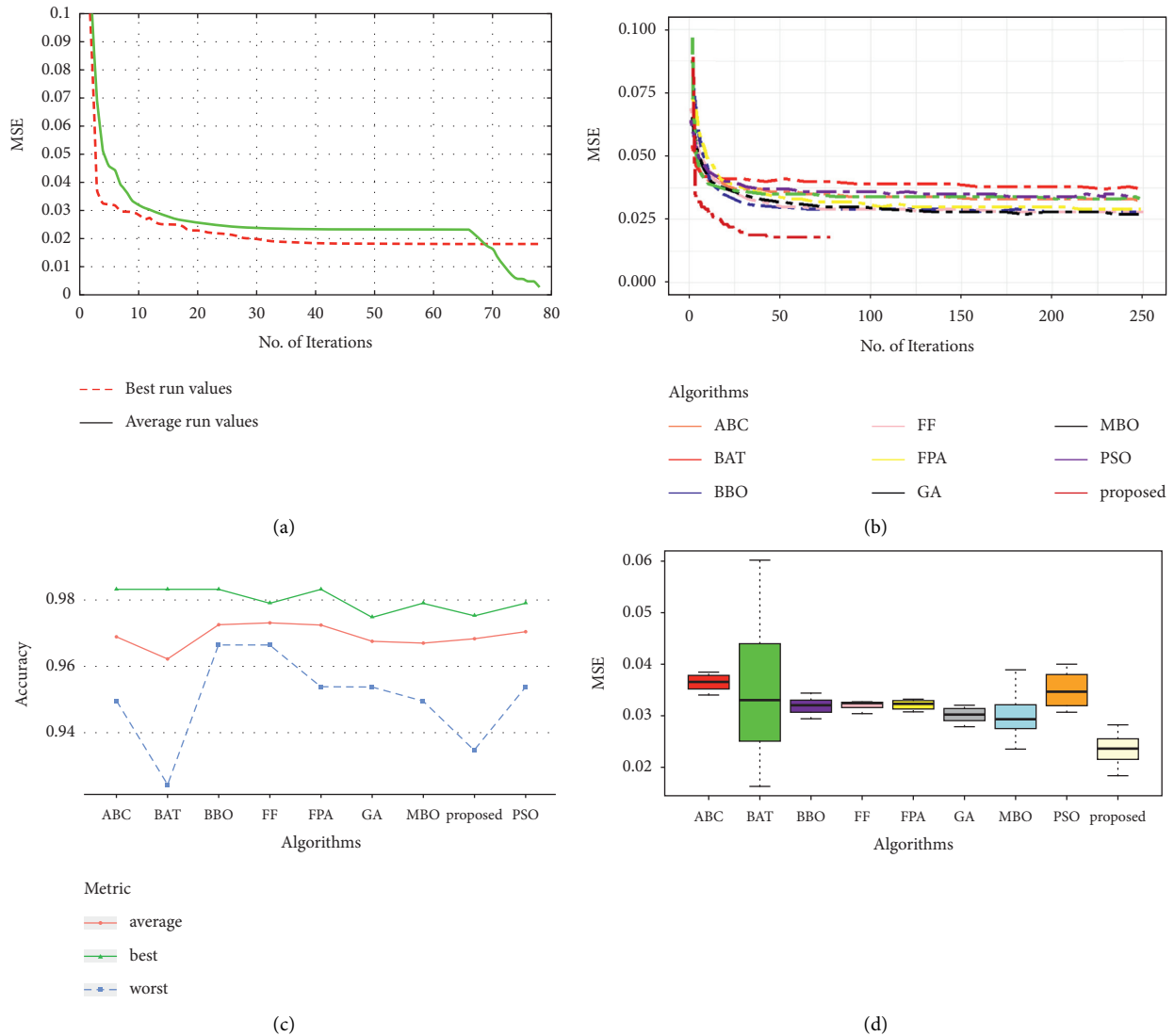


FIGURE 4: Performance analysis of the breast cancer dataset: (a) convergence curve of the proposed approach, (b) convergence curve for the compared methods, (c) accuracy for the compared methods, and (d) box plot for the compared methods.

(Figure 5(d)) indicates that, while GOA has a more compact box, the proposed approach has the lowest error and acceptable stability.

**5.3. Saheart Dataset.** Comparing the HOS-ML model with other OAs models from Table 4, we obtained better accuracy and MSE. This observation proves that HOS-ML can accurately model classification tasks. Figure 6 demonstrates the proposed HOS-ML model's accuracy, MSE, convergence speed, and stability. In terms of convergence speed, Figures 6(a) and 6(b) illustrate that, relative to the other algorithms, the proposed MLP-based trainer has a very fast convergence rate and the smallest MSE average (see Figure 6(d)). The suggested strategy produces an improved performance in contrast to other methods in terms of average accuracy (Figure 6(c)).

**5.4. Vertebral Dataset.** The results of the evaluations for the vertebral dataset is shown in Table 5 and Figure 7. For this dataset, the evaluation results of all MLP-trainers were very close and competitive, but our proposed approach showed very faster convergence as can be seen in Figures 7(a) and 7(b). The boxplot (Figure 7(d)) also confirms that the proposed approach has the smallest MSE. Moreover, our suggested algorithm has obtained outstanding performance in terms of worst, average, and best accuracy (Table 5 and Figure 7(c)).

The average classification accuracy of eleven different classifiers on 4 medical datasets is shown in Table 6 and Figure 8. These classifiers are Naïve Bayes (NB), Bayes network learning (BayesNet), support vector machine (SVM) [43, 44], MLP using backpropagation (MLP), K nearest neighbor (KNN), AdaboostM1 [45], bagging, fuzzy lattice reasoning (FLR) classifier, random forest (RF) [46],



TABLE 3: The performance results of comparative methods on the diabetes dataset in the terms of mean square error (MSE) and classification accuracy.

Comparative algorithms	MSE			Accuracy (%)		
	Best	Worst	Mean	Best	Worst	Mean
ABC-MLP	0.15635	0.16900	0.16276	80.534	70.992	74.822
BAT-MLP	0.14357	0.17267	0.15299	79.389	73.282	76.374
BBO-MLP	0.14947	0.15574	0.15230	77.099	73.282	75.611
FF-MLP	0.15074	0.15300	0.15199	77.481	75.191	76.349
FPA-MLP	0.15161	0.16008	0.15582	78.244	72.137	75.242
GA-MLP	0.14571	0.15739	0.15156	78.244	72.137	75.165
MBO-MLP	0.15326	0.17385	0.16355	78.626	70.611	74.733
PSO-MLP	0.15438	0.16916	0.16372	78.244	67.176	73.104
HOS-MLP	0.14051	0.15314	0.14548	80.237	74.701	77.840

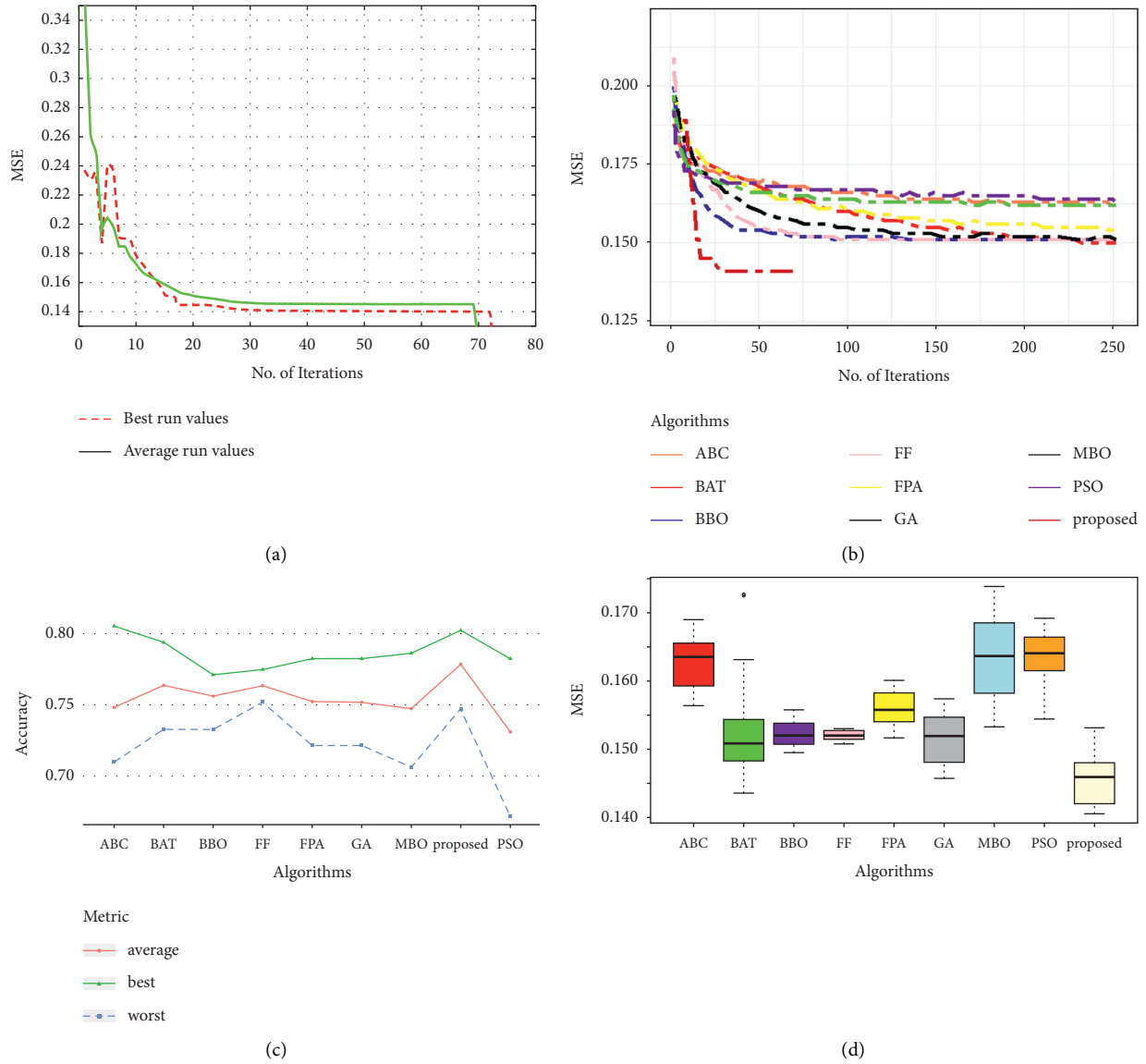


FIGURE 5: Performance analysis of the diabetes dataset: (a) convergence curve of the proposed approach, (b) convergence curve for the compared methods, (c) accuracy for the compared methods, and (d) box plot for the compared methods.

TABLE 4: The performance results of comparative methods on the Saheart dataset in the terms of mean square error (MSE) and classification accuracy.

Comparative algorithms	MSE			Accuracy (%)		
	Best	Worst	Mean	Best	Worst	Mean
ABC-MLP	0.17556	0.18474	0.18007	76.582	67.722	71.160
BAT-MLP	0.15843	0.17620	0.16510	75.949	68.987	72.405
BBO-MLP	0.16308	0.17000	0.16646	75.316	69.620	72.911
FF-MLP	0.167397	0.17072	0.16916	74.051	69.620	71.730
FPA-MLP	0.16852	0.17657	0.17273	76.582	68.354	72.869
GA-MLP	0.16391	0.17165	0.16776	75.949	68.354	71.814
MBO-MLP	0.17005	0.19585	0.18274	76.582	68.354	72.932
PSO-MLP	0.17505	0.18158	0.17867	77.848	64.557	72.658
HOS-MLP	0.15063	0.17096	0.16015	76.973	67.101	74.842

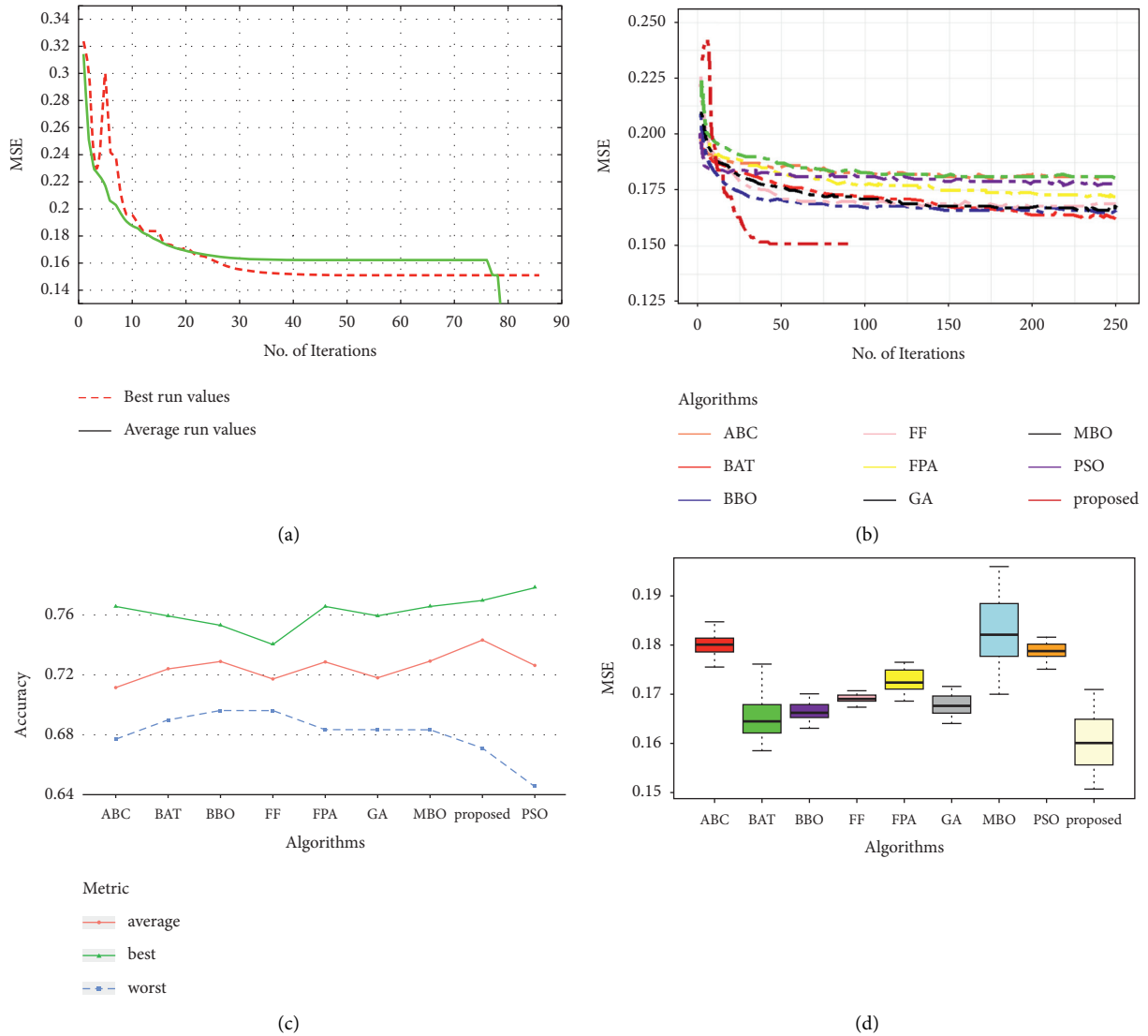


FIGURE 6: Performance analysis of the Saheart dataset: (a) convergence curve of the proposed approach, (b) convergence curve for the compared methods, (c) accuracy for the compared methods, and (d) box plot for the compared methods.

TABLE 5: The performance results of comparative methods on the vertebral dataset in the terms of mean square error (MSE) and classification accuracy.

Comparative algorithms	MSE			Accuracy (%)		
	Best	Worst	Mean	Best	Worst	Mean
ABC-MLP	0.081348	0.099784	0.091211	90.566	77.358	84.371
BAT-MLP	0.069138	0.155741	0.099395	89.623	68.868	83.553
BBO-MLP	0.080143	0.096075	0.088869	88.679	84.906	86.730
FF-MLP	0.084314	0.099139	0.092277	87.736	84.906	86.384
FPA-MLP	0.092432	0.100673	0.096533	88.679	83.962	86.730
GA-MLP	0.080455	0.086119	0.083506	88.679	83.962	85.786
MBO-MLP	0.088745	0.119880	0.102397	90.566	76.415	85.660
PSO-MLP	0.099944	0.116638	0.108178	90.566	77.358	85.031
HOS-MLP	0.046793	0.078007	0.062629	93.670	91.139	92.405

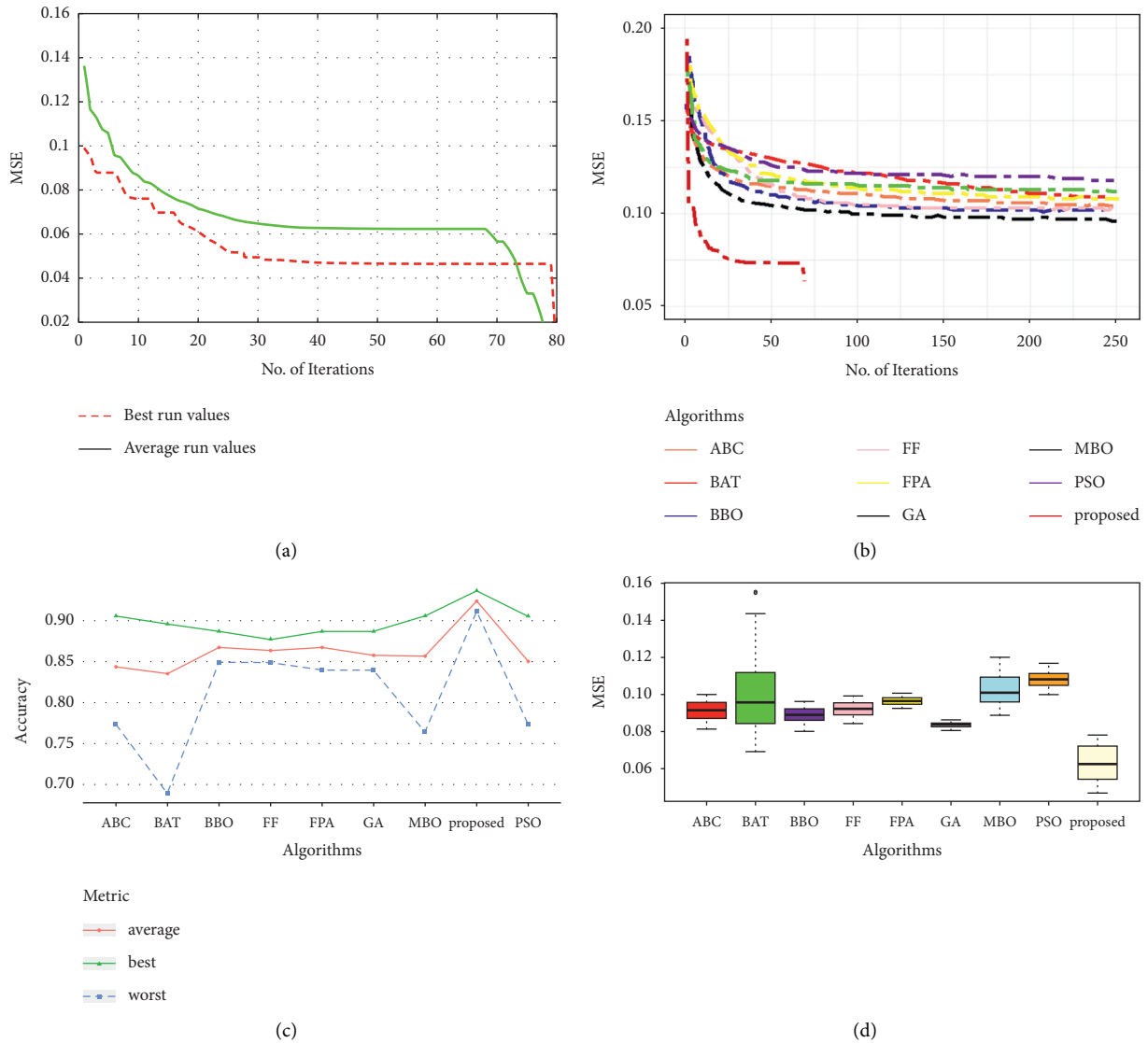


FIGURE 7: Performance analysis of the vertebral dataset: (a) convergence curve of the proposed approach, (b) convergence curve for the compared methods, (c) accuracy for the compared methods, and (d) box plot for the compared methods.

TABLE 6: Comparison of accuracy (%) for the twelve classification algorithms. Bold values represent the best results.

Dataset	NB	BayesNet	SVM	MLP	KNN	AdaboostM1	Bagging	FLR	RF	FURIA	LMT	HOS-MLP
Breast cancer	94.95	96.21	95.79	95.37	95.79	94.53	94.95	89.49	95.79	94.95	96.21	96.833
Diabetes	77.01	78.16	80.84	74.32	72.79	77.01	77.77	67.04	76.24	77.39	79.31	77.840
Saheart	70.12	70.12	72.72	66.88	60.38	71.42	70.12	64.28	64.93	74.67	74.02	74.842
Vertebral	72.5	78.75	88.75	90.00	81.25	85.00	88.75	87.5	90.00	83.75	90.00	92.405

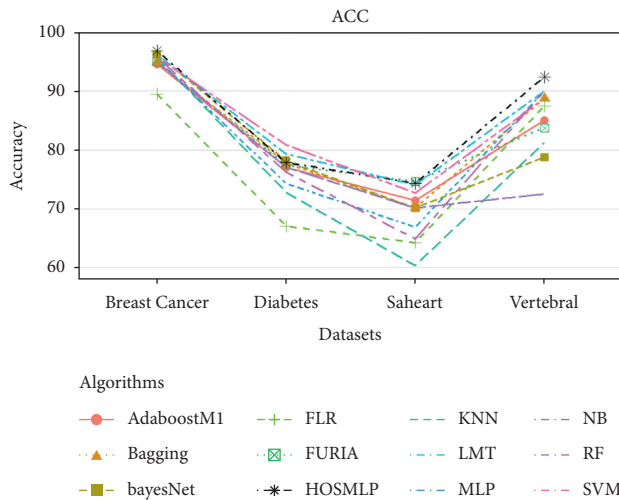


FIGURE 8: The classification performance of twelve classifiers on 4 medical datasets.

fuzzy unordered rule induction algorithm (FURIA), and logistic model tree (LMT).

As shown in Table 6 and Figure 8, the proposed algorithm has the best performance among the eleven algorithms on 3 medical datasets. For the diabetes dataset, the proposed HOS-ML ranked 4<sup>th</sup>, after SVM, BayesNet, and LMT.

Overall, the experimental findings demonstrate that the MSE results of the proposed HOS-MLP are greatly better relative to other MLP-based optimization techniques for all medical datasets. The outstanding advantage of HOS is that it can achieve accurate results with a significantly higher convergence rate than other existing methods. However, some parameters in HOS should be adjusted, and some elements of HOS can be tweaked to increase the algorithm's classification accuracy in certain datasets.

## 6. Conclusion

This study introduced an improved classification approach, HOS-MLP, to increase the precision of medical diagnosis. The HOS algorithm was employed to adjust the MLP weights and bias values. The high-performance, simplicity, and fast convergence speed of the HOS algorithm were the inspiration behind the choice of HOS for training MLP. To evaluate the efficacy of the suggested HOS-MLP, its classification performance was assessed on four challenging real biomedical datasets: coronary heart disease, orthopedic patients, diabetes, and breast cancer. The performance of the model was compared with eleven different classifiers and eight well-known OA-based MLP-trainers such as ABC, GA, BAT, BBO, PSO, FF, FPA, and MBO. The experimental results of HOS on those biomedical classification problems are promising in terms of convergence rate compared to existing OAs. It managed to demonstrate better classification accuracy in most cases. We conclude that the HOS can train MLP well for classifying biomedical datasets since the HOS-trained MLP presents a higher convergence speed and better

classification accuracy than current MLP training techniques and existing state-of-the-art classifiers.

In future work, HOS can be utilized to find the optimal structure of the MLP neural network, including the number of hidden layers and nodes. HOS can also be employed to train other forms of ANNs, such as the radial basis function (RBF). It may also be a valuable contribution to solving engineering classification problems using the proposed HOS-MLP.

## Data Availability

No data were used to support this study.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## References

- [1] S.-J. Lee, C.-H. Tseng, G. T. R. Lin et al., "A dimension-reduction based multilayer perception method for supporting the medical decision making," *Pattern Recognition Letters*, vol. 131, pp. 15–22, 2020.
- [2] M. Hosseinzadeh, O. H. Ahmed, M. Y. Ghafour et al., "A multiple multilayer perceptron neural network with an adaptive learning algorithm for thyroid disease diagnosis in the internet of medical things," *The Journal of Supercomputing*, vol. 77, no. 4, pp. 3616–3637, 2020.
- [3] M. Desai and M. Shah, "An anatomization on breast cancer detection and diagnosis employing multi-layer perceptron neural network (MLP) and Convolutional neural network (CNN)," *Clinical eHealth*, vol. 4, pp. 1–11, 2021.
- [4] T. Bikku, "Multi-layered deep learning perceptron approach for health risk prediction," *Journal of Big Data*, vol. 7, no. 1, pp. 1–14, 2020.
- [5] L. Abualigah, "Group search optimizer: a nature-inspired meta-heuristic optimization algorithm with its results, variants, and applications," *Neural Computing & Applications*, vol. 33, no. 7, pp. 2949–2972, 2021.
- [6] H. Wu, Y. Zhou, Q. Luo, and M. A. Basset, "Training feed-forward neural networks using symbiotic organisms search algorithm," *Computational Intelligence and Neuroscience*, vol. 2016, Article ID 9063065, 14 pages, 2016.
- [7] H. Faris, I. Aljarah, N. Al-Madi, and S. Mirjalili, "Optimizing the learning process of feedforward neural networks using lightning search algorithm," *The International Journal on Artificial Intelligence Tools*, vol. 25, no. 06, Article ID 1650033, 2016.
- [8] L. Abualigah, M. Shehab, M. Alshinwan, S. Mirjalili, and M. A. Elaziz, "Ant lion optimizer: a comprehensive survey of its variants and applications," *Archives of Computational Methods in Engineering*, vol. 28, no. 3, pp. 1397–1416, 2020.
- [9] P. A. Kowalski and S. Łukasik, "Training neural networks with Krill herd algorithm," *Neural Processing Letters*, vol. 44, no. 1, pp. 5–17, 2016.
- [10] A. A. Heidari, H. Faris, I. Aljarah, and S. Mirjalili, "An efficient hybrid multilayer perceptron neural network with grasshopper optimization," *Soft Computing*, vol. 23, no. 17, pp. 7941–7958, 2019.
- [11] L. Abualigah and A. Diabat, "A comprehensive survey of the Grasshopper optimization algorithm: results, variants, and

- applications,” *Neural Computing & Applications*, vol. 32, no. 19, Article ID 15533, 2020.
- [12] J. A. Bullinaria and K. Alyahya, “Artificial bee colony training of neural networks,” *Nature Inspired Cooperative Strategies for Optimization (NICSO 2013)*, vol. 512, pp. 191–201, 2014.
- [13] S. Z. Mirjalili, S. Saremi, and S. M. Mirjalili, “Designing evolutionary feedforward neural networks using social spider optimization algorithm,” *Neural Computing & Applications*, vol. 26, no. 8, pp. 1919–1928, 2015.
- [14] W. A. H. M. Ghanem and A. Jantan, “A cognitively inspired hybridization of artificial bee colony and dragonfly algorithms for training multi-layer perceptrons,” *Cognitive Computation*, vol. 10, no. 6, pp. 1096–1134, 2018.
- [15] K. Salama and A. M. Abdelbar, “A novel Ant colony algorithm for building neural network topologies,” *Lecture Notes in Computer Science*, vol. 8667, pp. 1–12, 2014.
- [16] S. Mirjalili, S. Z. Mohd Hashim, and H. Moradian Sardroudi, “Training feedforward neural networks using hybrid particle swarm optimization and gravitational search algorithm,” *Applied Mathematics and Computation*, vol. 218, no. 22, Article ID 11125, 2012.
- [17] J.-h. Yi, W.-h. Xu, and Y.-t. Chen, “Novel back propagation optimization by cuckoo search algorithm,” *The Scientific World Journal*, vol. 2014, Article ID 878262, 8 pages, 2014.
- [18] E. Valian, S. Mohanna, and S. Tavakoli, “Improved cuckoo search algorithm for feed forward neural network training,” *International Journal of Artificial Intelligence & Applications*, vol. 2, no. 3, pp. 36–43, 2011.
- [19] M. Shehab, L. Abualigah, H. Al Hamad, H. Alabool, M. Alshinwan, and A. M. Khasawneh, “Moth-flame optimization algorithm: variants and applications,” *Neural Computing & Applications*, vol. 32, no. 14, pp. 9859–9884, 2020.
- [20] W. Yamany, M. Fawzy, A. Tharwat, and A. E. Hassanien, “Moth-flame optimization for training multi-layer perceptrons,” in *Proceedings of the 2015 11th International Computer Engineering Conference (ICENCO)*, pp. 267–272, Institute of Electrical and Electronics Engineers Inc., Cairo, Egypt, December, 2016.
- [21] I. Aljarah, H. Faris, and S. Mirjalili, “Optimizing connection weights in neural networks using the whale optimization algorithm,” *Soft Computing*, vol. 22, no. 1, pp. 1–15, 2018.
- [22] S. Mirjalili, “How effective is the Grey Wolf optimizer in training multi-layer perceptrons,” *Applied Intelligence*, vol. 43, no. 1, pp. 150–161, 2015.
- [23] S. Amirsadri, S. J. Mousavirad, and H. Ebrahimpour-Komleh, “A Levy flight-based grey wolf optimizer combined with back-propagation algorithm for neural network training,” *Neural Computing & Applications*, vol. 30, no. 12, pp. 3707–3720, 2018.
- [24] E. Pashaei and E. Pashaei, “Training feedforward neural network using enhanced Black hole algorithm: a case study on COVID-19 related ACE2 gene expression classification,” *Arabian Journal for Science and Engineering*, vol. 46, no. 4, pp. 3807–3828, 2021.
- [25] L. Huang, P. G. Asteris, M. Koopialipoor, D. J. Armaghani, and M. M. Tahir, “Invasive weed optimization technique-based ANN to the prediction of rock tensile strength,” *Applied Sciences*, vol. 9, no. 24, p. 5372, 2019.
- [26] H. Faris, I. Aljarah, and S. Mirjalili, “Training feedforward neural networks using multi-verse optimizer for binary classification problems,” *Applied Intelligence*, vol. 45, no. 2, pp. 322–332, 2016.
- [27] L. Abualigah, “Multi-verse optimizer algorithm: a comprehensive survey of its results, variants, and applications,” *Neural Computing & Applications*, vol. 32, no. 16, Article ID 12381, 2020.
- [28] N. M. Nawi, M. Z. Rehman, and A. Khan, “A new bat based back-propagation (BAT-BP) algorithm,” in *Advances in Intelligent Systems and Computing*, pp. 395–404, Springer-Verlag, New York, USA, 2014.
- [29] L. Abualigah, M. Shehab, M. Alshinwan, and H. Alabool, “Salp swarm algorithm: a comprehensive survey,” *Neural Computing & Applications*, vol. 32, no. 15, Article ID 11195, 2020.
- [30] V. K. Ojha, A. Abraham, and V. Snášel, “Metaheuristic design of feedforward neural networks: a review of two decades of research,” *Engineering Applications of Artificial Intelligence*, vol. 60, pp. 97–116, 2017.
- [31] R. H. Abiyev and M. Tunay, “Optimization of high-dimensional functions through hypercube evaluation,” *Computational Intelligence and Neuroscience*, vol. 2015, Article ID 967320, 11 pages, 2015.
- [32] O. Maciel, A. Valdivia, D. Oliva, E. Cuevas, D. Zaldívar, and M. Pérez-Cisneros, “A novel hybrid metaheuristic optimization method: hypercube natural aggregation algorithm,” *Soft Computing*, vol. 24, no. 12, pp. 8823–8856, 2020.
- [33] N. Jahan, R. Mustafa, R. Karim, and M. S. Hossain, “Classification of orthopedic patients using supervised machine learning techniques,” in *Advances in Intelligent Systems and Computing*, pp. 659–669, Springer, Cham, Switzerland, 2021.
- [34] M. S. Shanker, “Using neural networks to predict the onset of diabetes mellitus,” *Journal of Chemical Information and Computer Sciences*, vol. 36, no. 1, pp. 35–41, 1996.
- [35] A. H. Gonsalves, F. Thabtah, R. M. A. Mohammad, and G. Singh, “Prediction of coronary heart disease using machine learning,” in *Proceedings of the 2019 3rd International Conference on Deep Learning Technologies-ICDLT 2019*, pp. 51–56, Association for Computing Machinery, New York, USA, July, 2019.
- [36] W. H. Wolberg and O. L. Mangasarian, “Multisurface method of pattern separation for medical diagnosis applied to breast cytology,” *Proceedings of the National Academy of Sciences*, vol. 87, no. 23, pp. 9193–9196, 1990.
- [37] D. Rivero, J. Dorado, E. Fernández-Blanco, and A. Pazos, “A genetic algorithm for ANN design, training and simplification,” in *Proceedings of the 10th International Work-Conference on Artificial Neural Networks, IWANN 2009*, pp. 391–398, Salamanca, Spain, June, 2009.
- [38] I. Aljarah, H. Faris, S. Mirjalili, and N. Al-Madi, “Training radial basis function networks using biogeography-based optimizer,” *Neural Computing & Applications*, vol. 29, no. 7, pp. 529–553, 2018.
- [39] S. Nandy, A. Mitra, and T. Mukherjee, “Study of PSO and firefly algorithm based feed-forward neural network training algorithms,” in *Proceedings of the 2020 7th International Conference on Signal Processing and Integrated Networks (SPIN)*, pp. 908–913, Noida, India, February, 2020.
- [40] P. Soltani and E. Hadavandi, “A monarch butterfly optimization-based neural network simulator for prediction of siro-spun yarn tenacity,” *Soft Computing*, vol. 23, no. 20, Article ID 10521, 2019.
- [41] G. S. Shehu and N. Çetinkaya, “Flower pollination-feedforward neural network for load flow forecasting in smart distribution grid,” *Neural Computing & Applications*, vol. 31, no. 10, pp. 6001–6012, 2019.

- [42] S. Saremi, S. Mirjalili, A. Lewis, and S. M. A. L. S Saremi, "Grasshopper optimisation algorithm: theory and application," *Advances in Engineering Software*, vol. 105, pp. 30–47, 2017.
- [43] E. Pashaei and N. Aydin, "Markovian encoding models in human splice site recognition using SVM," *Computational Biology and Chemistry*, vol. 73, pp. 159–170, 2018.
- [44] E. Pashaei, A. Yilmaz, and N. Aydin, "A combined SVM and Markov model approach for splice site identification," in *Proceedings of the 2016 6th International Conference on Computer and Knowledge Engineering (ICCKE)*, pp. 200–204, Mashhad, Iran, October, 2016.
- [45] E. Pashaei, A. Yilmaz, M. Ozen, and N. Aydin, "Prediction of splice site using AdaBoost with a new sequence encoding approach," in *Proceedings of the 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, pp. 3853–3858, Budapest, Hungary, October, 2016.
- [46] E. Pashaei, M. Ozen, and N. Aydin, "Random forest in splice site prediction of human genome," in *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016*, E. Kyriacou, S. Christofides, and C. Pattichis, Eds., vol. 57, pp. 518–523, Springer, Cham, Switzerland, 2016.