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Intelligent Diagnosis Model of Alzheimer's Disease Based on PSO Algorithm Optimized BP Neural Network

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Abstract: In this paper, an intelligent diagnosis model of Alzheimer's disease is established based on the PSO algorithm optimized BP neural network. After descriptive analysis and normalization of patient-specific information characteristic data, the model was established by parameter selection of BP neural network, optimization of BP neural network by PSO algorithm and sensitivity analysis of neural network connection weights, and the intelligent diagnostic model of Alzheimer's disease was tested. The results showed that the model has strong applicability in terms of the degree of Alzheimer's disease in patients, and provides a certain reference basis for accurate diagnosis of the developmental stage of Alzheimer's disease.

1. Introduction

Alzheimer's disease, known as dementia in everyday life, is a disease that not only takes a toll on the physical and mental health of the patient, but can only be suppressed through treatment. The disease is clinically classified into five stages: normal cognition, subjective memory complaints, early mild cognitive impairment, late mild cognitive impairment, and Alzheimer's disease. Nowadays, patients and relatives have limited knowledge about the disease, which leads to patients missing the best time for treatment [0]. Therefore, it is important to perform early and accurate diagnosis of Alzheimer's disease development stages by various data indicators.

Therefore, this paper designs an intelligent judgment model of Alzheimer's disease based on the specific information characteristics of the collected patients, i.e., a classification model of Alzheimer's disease based on people's structural brain characteristics and cognitive behavioral data. In this paper, we decided to build an intelligent diagnosis model of Alzheimer's disease based on the PSO algorithm optimized BP neural network after reviewing relevant information.

2. Model Preparation

2.1 Descriptive Analysis

In this paper, firstly, the statistical analysis of the indicators that have great relevance to Alzheimer's disease is carried out, and the maximum, minimum, mean, standard deviation, etc., and the RAVLT is displayed in the form of scatter chart_ learning, RAVLT_ Forgeting and other characteristic frequency analysis can be used to estimate or predict the overall trend; Finally, the results of discrete trend analysis of characteristic frequency analysis are displayed in the form of box graph. The discrete trend uses statistical indicators such as maximum, minimum, 25% quantile, median, and 75% quantile to measure the difference of data distribution. The results of the analysis are shown in Table 1.

Table 1 Descriptive Analysis Results

Name	max	min	average	standard deviation	Kurtosis	Skewness
RAVLT_learning	14	-5	3.71	2.80	-0.311	0.373
RAVLT_forgetting	15	-12	4.14	2.48	1.57	-0.017
FAQ	30	0	5.96	7.96	0.551	1.286
ADASQ4	10	0	5.03	2.85	-1.037	0.178
MMSE	30	20	27.44	2.35	0.572	-1.014
RAVLT_immediate	69	7	35.77	11.70	-0.242	0.339
RAVLT_learning	11	-4	4.27	2.78	-0.625	0.193
Hippocampus	10769	3091	6679.52	1159.05	-0.243	-0.034
MidTemp	28103	9375	19089.02	3006.02	0.081	0.035
ICV	2110290	1116280	1558187.19	165627.84	-0.276	0.244
DIGITSCOR	80	0	40.24	12.65	0.318	-0.261
LDELTOTAL	22	0	7.13	5.59	-0.798	0.476
FAQ	29	0	3.36	5.45	3.595	1.98
WholeBrain	1364690	669364	1004257.64	107135.87	-0.076	0.12

According to the above table, the coefficient of variation is small, and there is only a small probability that outliers may occur. The statistics in the above table can find the state of the data processing center, and the data performance is good.

2.2 Zero Mean Processing

In order to speed up the convergence, this problem is built before the model. First, the data RAVLT _learning, RAVLT_forgetting, FAQ and other features are zero-mean processed. The so-called zero-mean is the variable minus its mean value.

3. Establishment of Intelligent Diagnosis Model for Alzheimer's Disease Based on PSO Algorithm and BP Neural Network Optimization

According to the literature, neural network can reflect the function and structure of human brain neural network in physiology to a certain extent, abstract the basic characteristics of the real brain according to a certain theory, and simplify it into an information processing system[0]. The particle swarm algorithm is a stochastic global search algorithm, and the combination of the two can make the algorithm more perfect and more accurate[0].

3.1 Parameter Selection of BP Neural Network

In the BP neural network model, the data of brain structure characteristics and cognitive behavior characteristics can be used as the input of the network model, and the category of Alzheimer's disease (“CN”, “MCI”, “AD”) can be used as the output of the network model. The number of hidden layer nodes m is the core part of the neural network structure, which can be calculated by formula (1):

$$m = \sqrt{l + n} + \alpha \tag{1}$$

In equation (1), l is the input layer of the neural network; m and n are the number of nodes, α is the adjustment constant, $\alpha = 1,2,3,\cdots 10$; according to the input data take $l = 14$, according to the output data take $n = 3$; the data selected in this problem, when $m = 7$ the error is the smallest, that is, take $\alpha = 6$. In order to let the neural network back propagation to update the weights and bias, reduce the error to improve the prediction accuracy of the index, we choose mean square error function as the loss function of the network, as in equation (2).

$$E = \frac{1}{2n}\sum_{i=1}^{n}(y_i - t_i)^2 \tag{2}$$

In equation (2), E is the total error, n is the number of samples of Alzheimer's patients, i is the dimensionality of the data, y_i is the type output value of the unknown category of Alzheimer's patients, and t_i is the label value.

3.2 PSO Algorithm Optimization BP Neural Network

Determine the A-dimensional space containing the group formed by N particles.

$$A = l \times m + m \times n + m + n \tag{3}$$

The position X_i and velocity V_i of the ith particle in the A-dimensional space.

$$X_i = (x_{i1}, x_{i2}, x_{i3}, \cdots x_{iA}), i \in [1,2,\cdots,N] \tag{4}$$

$$V_i = (v_{i1}, v_{i2}, v_{i3}, \cdots v_{iA}), i \in [1,2,\cdots,N] \tag{5}$$

Due to the limitation of maximum position X_{max} and maximum speed V_{max}, blind search in space is avoided, and the value range of both is $X_i \in [-X_{max}, X_{max}]$ and $V_i \in [-V_{max}, V_{max}]$.

The individual value of the searched optimal position is P_{best}.

$$P_{best} = (p_{i1}, p_{i2}, p_{i3}, \cdots p_{iA}), i \in [1,2,\cdots,N] \tag{6}$$

A single particle shares information with other particles of the whole particle swarm. In the particle swarm, the global optimal position reached by the particle is recorded as G_{best}:

$$G_{best} = (g_{i1}, g_{i2}, g_{i3}, \cdots g_{iA}), i \in [1,2,\cdots,N] \tag{7}$$

The particle swarm's individual extreme value and global extreme value adjust its own speed and position, and the update formula is:

$$v_{i+1} = \omega v_i + c_1 r_1 (P_{best} - x_i) + c_2 r_2 (G_{best} - x_{i+1}) \tag{8}$$

$$x_{i+1} = x_i + v_{i+1} \tag{9}$$

In equation (8), ω is the inertia weight. ω is

$$\omega(t) = \omega_{max} - \frac{(\omega_{max} - \omega_{min})t}{t_{max}} \tag{10}$$

In equation (10), the meaning of t is the number of iteration steps; then t_{max} is the maximum number of iteration steps; c_1 , c_2 are the learning factors of the algorithm, the former represents the empirical coefficients of individual particles and the latter represents the empirical coefficients of the particle swarm, and r_1 , r_2 are random numbers of [0,1].

In this paper, the number of populations is taken as 30, the particle dimension is 2, the velocity range is taken as [-0.5, 0.6], the position range is taken as [-2,2], $c_1 = c_2 = 3$, $\omega_{min} = 0.2$, $\omega_{max} = 0.9$, and the maximum number of iteration steps is 250.

3.3 Sensitivity Analysis of Neural Network Connection Weight

For models:

$$y = f(x_1, x_2, \cdots x_n) \tag{11}$$

where x_i is the ith influencing factor for optimizing the BP neural network based on the particle swarm algorithm.

The sensitivity method used is a sensitivity analysis method based on the numerical calculation of the connection weights of the neural network proposed by Garson. The purpose of this sensitivity analysis is to calculate the sensitivity of the structural brain features and cognitive behavioural features of a neural network to an unknown category of Alzheimer's disease based on the product of the weights of the input and output layers of the neural network performing the connection thereby.

$$Q_{ik} = \frac{\sum_{j=1}^{L}\left(\frac{|w_{ij}v_{ik}|}{\sum_{r=1}^{N}|w_{rj}|}\right)}{\sum_{i=1}^{N}\sum_{j=1}^{L}\left(\frac{|w_{ij}v_{jk}|}{\sum_{r=1}^{N}|w_{rj}|}\right)} \tag{12}$$

Where: w_{ij} and v_{ik} are the link weights of the nodes in the i-th neural network input layer and the nodes in the jth neural network hidden layer, and the weights of the links between the jth hidden node and the nodes in the k-th neural network output layer, respectively. The chemical components that have a great impact on the unknown type of Alzheimer's disease can be screened according to Q_{ik} to reduce the dimension of the network input.

4. The Solution of the Intelligent Diagnosis Model of Alzheimer's Disease Based on the Optimization of BP Neural Network Based on PSO Algorithm

4.1 Principle and Steps of Neural Network Solution

In order to facilitate the classification of patients with Alzheimer's disease of unknown categories, we have established a 14-input and three-output neural network topology diagram, as shown in Figure 1, where RAVLT_ learning, RAVLT_ forgetting,FAQ,ADASQ4,MMSE,RAVLT_ immediate, RAVLT_ Learning, Hippocampus, MidTemp, ICV, DIGITSCOR, LDELTOTAL, FAQ, WholeBrain as the input layer, and Alzheimer's disease “CN”, “MCI”, and “AD” categories as the output layer[0].

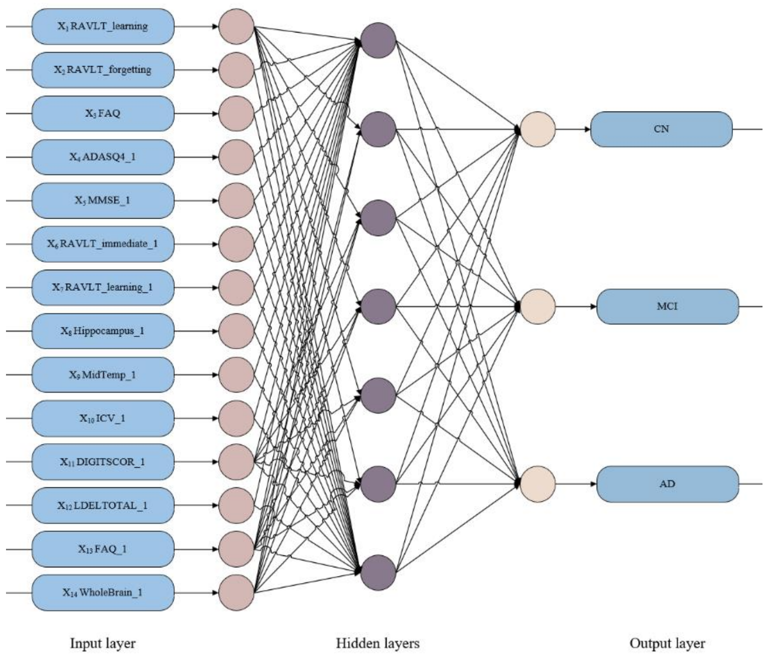

Figure 1 Topological Structure of Neural Network

(1) Construct a particle swarm algorithm based optimization BP neural network, determine the number of nodes, set the activation function, etc. [0];

(2) Build BP neural network to initialize PSO algorithm parameters, build a single particle network and particle swarm network, select the appropriate spatial dimension A and population

number N, and set the number of iterations to 1000;

(3) Brain structure characteristics and cognitive behavior characteristics “RAVLT_learning, RAVLT_forgeting, FAQ, ADASQ4, MMSE, RAVLT_immediate, RAVLT_learning, Hippocampus, MidTemp, ICV, DIGITSCOR, LDELTOTAL, FAQ, WholeBrain” are used as training sets, and the “CN”, “MCI”, and “AD” categories of Alzheimer's disease are used as output sets to build a network model;

(4) Iterative optimization, calculate the fitness value of each particle;

(5) The iterative process compares the fitness and continuously updates the particle swarm network;

(6) Update the position and speed of all particles in the particle swarm;

(7) Use the data in the attachment to test the trained neural network and output the test results. The algorithm flow is shown in Figure 2.

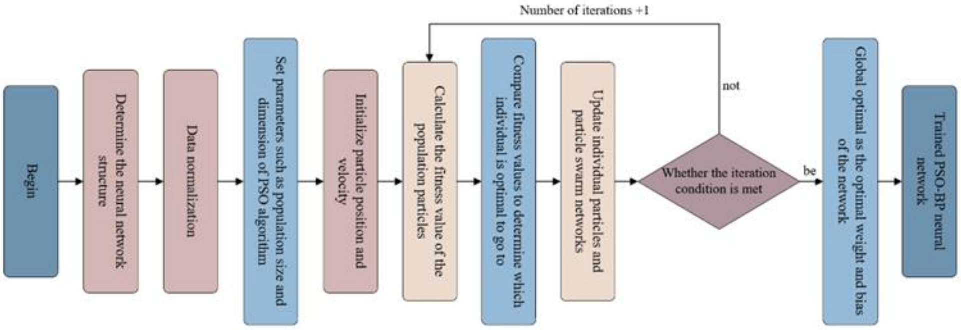

Figure 2 Flow Chart of POS-BP Neural Network Algorithm

4.2 Neural Network Solution Results

The model divides the data into three parts, namely training, validation and test, as shown in Table 2.

Table 2 Comparison of Simulation Results between Classical BP Neural Network and This Model

Parameter	**Algorithm model**	
	Classical BP neural network	PSO-BP Neural Systems Network
Training time (s)	75.5348	7.4632
Training times	10	8
Performance value	0.4678	0.9356
Test accuracy (%)	95.724	99.365
Overall accuracy (%)	98.545	99.659

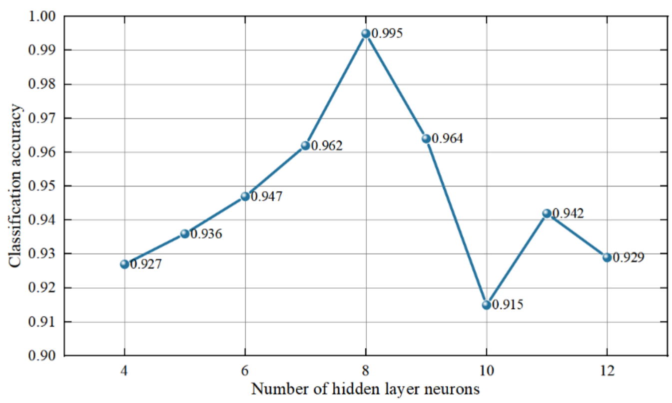

Figure 3 Classification Accuracy with Different Number of Neurons in Hidden Layers

The mean and standard deviation of the experimental results were taken, and the results are shown in Figure 3. According to Fig. 3, the number of neurons in the hidden layer was finally chosen to be 8 in this paper, taking all factors into consideration. [0]

Figure 4 shows the regression analysis of PSO-BP Neural Systems Network data. Because neural network is supervised machine learning, it can perform regression analysis and calculate R value according to the brain structure characteristics and cognitive behavior characteristics classified by neural network model and the intelligent diagnosis of Alzheimer's disease[0].

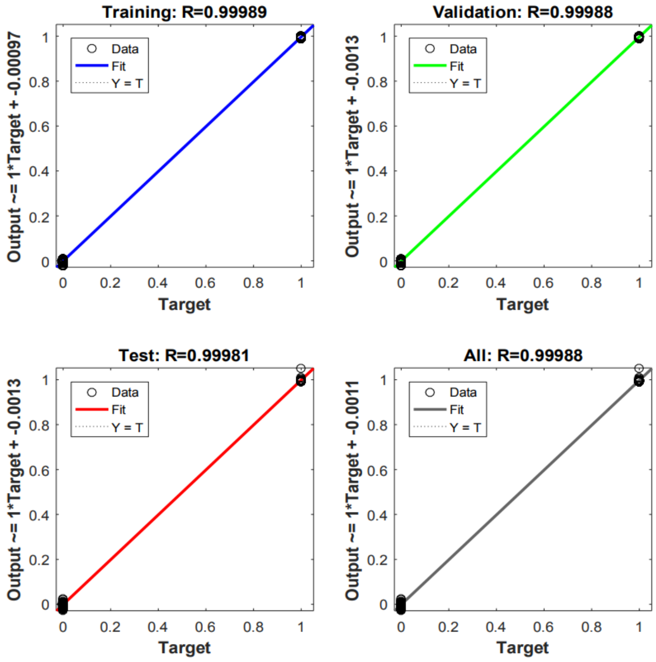

Figure 4 Regression Analysis of PSO-BP Neural Systems Network Data

As shown above, the overall R-value of the model in this paper is closer to 1 for both the test and training sets, and the function has a better fit.

5. Conclusion

This paper proposes an intelligent diagnosis and classification method for Alzheimer's disease based on PSO-BP Neural Systems Network algorithm. As the results show: the PSO-BP Neural Systems Network is suitable for intelligent diagnostic classification of Alzheimer's disease, and the classification accuracy of both the classical BP neural network model and the model in this paper is higher than 96% ; For the problem that the dimension of the input layer is too high, the PCA dimension reduction algorithm ensures that the dimension is reduced and the key feature information is retained with the minimum information loss, which improves the running speed and fitting degree of the model; The overall accuracy of the model established in this question remains at about 99%. Compared with the classical BP Neural Systems Network, the classification accuracy of the proposed model in this paper has the advantages of more stable and stronger generalization ability, which is more in line with the requirements of intelligent diagnosis and classification of Alzheimer's disease. Repeat the previous 100 experiments and compare them with the actual Alzheimer's disease. The average accuracy is 99.43%, and the standard deviation is 3.01%. The BP neural network optimised by the PSO algorithm is therefore highly applicable to the intelligent diagnosis of the degree of prevalence of Alzheimer's disease.

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