An improved BP neural network algorithm and its application

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Abstract
In order to overcome the disadvantages such as such as low convergence speed, falling into local minimum easily, bad generalization ability of BP neural network algorithm, the paper presents a new wavelet neural network and applies it to evaluate university PE teaching. First, the improved algorithm uses wavelet algorithm to redesign and simplify the algorithm structure of BP algorithm; Second, genetic algorithm and BFGS algorithm are used to speed up the convergence of BP algorithm and calculation flows are redesigned; Finally, based on constructing evaluation indicator system of PE teaching, the improved algorithm is applied to evaluate PE teaching and experimental results indicate that the improved algorithm can improve evaluation accuracy and algorithm efficiency, decrease calculation time and can be used for evaluating other complicated systems practically.
Key words: WAVELET NEURAL NETWORK ALGORITHM, BP ALGORITHM, GENETIC ALGORITHM, PE TEACHING EVALUATION

Introduction

As an important subfield and the quintessence of Artificial Neural Network, BP Neural Network accelerated the development in this field. In 1985, Rumelhart and some other scholars advanced the Error Back Propagation theory that was improved as BP Neural Network theory today. BP Neural Network has integrated system, explicit algorithmic process, data identification and simulation function. BP algorithm also owns the excellent ability to solve nonlinear problem, therefore, the value of practical application is outstanding. Along with researching deeply, the defects of BP Neural Network have been found, such as low convergence speed, long training time, falling into local minimum easily, bad generalization ability, few principles to build network structure. This disadvantage can depress the accuracy of BP Neural Network and damage the practical effect. So, improving BP Neural Network step by step is significant not only for theory, but also for practical application[1.2].
Nowadays, the improvements of BP neural network algorithm mainly include the following categories.

(1)Overcome the defects of falling into local extreme easily of BP algorithm[1,2]. These improvements conclude the reasons of

falling into local extreme easily of BP algorithm as follows: the nonlinear relation between output and input of BP algorithm result in the error of network; and the energy function of the model is a nonlinear space with many poles. For above two reasons, the BP model is easily falling into local extreme and can not break away, this will lead the model fail to go global extreme.

(2)Speed up the learning process of BP model in rate of converge through adjusting the inertia factor α and learning rate η of BP model dynamically[3.4]. In order to speed up the convergence of BP model, the η should be less than certain value, otherwise it is impossible for BP model to realize the fast convergence rate.

(3)Improve generalization ability of BP model[5,6]. These improvements conclude that the factors, such as exert certain impact, are both qualitative and quantitative of BP model, and presents corresponding measures.

(4)Confirm the structure of BP model[7,8]. Confirming the best structure is the most important because the first job is determining the layers of the neural network and the number of nodes of every layer in the application of the BP model.

For the first three improvement categories, because the learning time and influence of BP model are complex, and priori knowledge of objective function will cause great difficulties to ensure the practical effects of BP model, so these improvements are not satisfied up to now. For the forth improvements categories, because the theoretical achievements at present are not enough to determine the number of nodes of every layer and the number of layers of BP model and the two number are always determine by the users' experience now, so the results of this improvements are not satisfied too.

In order to conquer the flaws in the training of BP neural network algorithm, this paper improves ordinary BP algorithm with genetic algorithm then advances a new BP neural network algorithm called wavelet neural network algorithm to improve BP training process. The mathematic approaches of this algorithm had been given in this paper clearly, and the paper realizes the whole algorithm taking PE teaching for Example. For confirming the practicability, contrasting the new algorithm with the other algorithms is necessary. The comparison shows that the improved algorithm had superiorities to improve original BP algorithm. The superiorities include simple algorithm process, fast convergence speed, getting out local minimum easily, and small oscillation and so on. In brief, this new algorithms can make the whole BP training process fast and stable.

Designing Wavelet BP Neural Network Algorithm

The algorithm structure and expression of wavelet neural network and BP neural network are always the same, which consist of input layer, hidden layer and out layer. The key difference of the two algorithm is that wavelet neural network takes wavelet transformation function as its excitation function and that of BP neural network is Sigmoid function[6]. The working principle of wavelet neural network model is that it changes waveform and the scale of wavelet bases continuously to adjust the weights and threshold of the network taking advantage of the principle of minimum error function[9].

$f'(i)$ means the ith input and o_k means the kth output of wavelet neural and network model respectively, and $y(j)$ means the jth output of wavelet layer, in the above equation $i = (1,2,...,input)$, $j = (1,2,...,hidden)$, $k = (1,2,...,output)$, w_{ij} is the connection weights between the ith input and the jth wavelet element, v_{jk} is the connection weights between the jth wavelet element and kth wavelet layer, M_j is the jth corresponding sliding scale of wavelet neural and network model, L_j is the jth corresponding contraction coefficient, F means wavelet function, Φ means the function of output layer.

Following are the relation between input and output of different layers.

The relation between input and output in the wavelet layer can be seen as equation 1 and 2.

$$net_j = \sum_{i=1}^{input} v_{ij} f'(i), \qquad j = 1,2,...,Input \qquad (1)$$

$$y(j) = F(f'(net_j)), \qquad j = 1,2,...,Input \qquad (2)$$

The relation between input and output in the output layer can be seen as equation 3 and 4.

$$net_k = \sum_{i=1}^{Hiddenoutput} w_{jk} y_j \qquad j = 1,2,...,Hidden \quad (3)$$

$$y(j) = \Phi(f'(net_j)), \qquad j = 1,2,...,Hidden \quad (4)$$

From equation 3 and 4, it can get the relation model between input and output of wavelet neural network easily, like equation 5.

$$O = \Phi(\sum_{j=1}^{Hidden} v_j F((\sum_{i=1}^{Input} w_{ij} f(i) - M_j)/L_j \quad (5)$$

Improving Wavelet Neural Network Algorithm with Genetic algorithm

(1)Chromosomes expression and initial population generation. The training process of neural network is the process of determining the weights, thresholds and telescopic translation operators, so it should takes weights IW, LW and threshold b_1, b_2 and telescopic translation operators a, b as decision variables in training neural network with genetic algorithm and then makes decision variables as a letter string and takes it as a solution to the problem. The algorithm uses real number encoding, the string is as follows IW_{11}, $IW_{12},...,IW_{ji},...,IW_{JI}$, LW_{11}, $LW_{12},...,...,$ LW_{KJ}, $a_1, a_2,...,$ $b_1, b_2,...,b_J$, $b1_J$, $b2_1, b2_2,...,b2_k$. In which IW_{ji} means the connection weights between the ith neuron in input layer and the jth neuron in hidden layer, LW_{kj} means the connection weights between the jth neuron in hidden layer and the kth neuron in output layer, a_J means the expansion and contraction parameters of the jth neuron, b_J means the translation parameters of the jth neuron, $b1_J$ means the threshold of the jth neuron and $b2_k$ means the threshold of the kth neuron in output layer[8].

Initial population process includes determining population size, cross probability and specifying a random value interval of IW and LW of each genes and then generates a new gene.

(2)Target function and fitness function. Genetic algorithm only can be evolved along with the increase direction of fitness function increase value , so the fitness function can be designs as reciprocal form of object function, see as equation 6 and equation 7.

$$fit(i) = 1/E(i) \quad (6)$$

$$E(i) = \frac{1}{2p}\sum_{p=1}^{p}\sum_{k=1}^{K}(d_k^p - a2_k^p) \quad (7)$$

In which, d_k^p means target output, and $a2_k^p$ means the actual output of network.

(3)Evolution computation.

Evolution computation is conducted through selecting operator and is a process of population generational renewal. Using fitness of each chromosome, the algorithm selects the chromosome of next generation from population based on sampling mechanism of fixed selection probability. The evaluation tendency of the population is decided by the characteristics of selection operator which is always be described through three aspects of sampling space, sampling mechanism and selection probability.

(4) Genetic computation. Genetic computation includes cross operation and mutation operation. And cross operation conducted here occurred in the same loci of different two chromosomes, not means the concrete chromosomes. Cross operation rate means the ration of genes involve in crossover operation to total numbers of genes. Weights value breaks the value space of initial weights though mutation operation and searches toward a more extensive space

Improving adaptive method of Pheromone Evaporation Intensity ρ

Pheromone evaporation intensity ρ can affect the global search performance of genetic algorithm directly. If ρ value is too small, the cumulative pheromone intensity in the selected road will be too large and easy to early-maturing, and If ρ value is too large, the cumulative pheromone intensity in the unselected road will be evaporated and will be become small and that makes global search performance of genetic algorithm decreased. If the ρ has no improvement after many circulation calculation times, equation 8 can be taken as adaptive method of Pheromone evaporation intensity ρ.

$$\rho(t+1) = \begin{cases} \exp(-\alpha)\rho(t), & if\ \exp(-\alpha)\rho(t) \succ \rho_{\min} \\ \rho_{\min} & else \end{cases} \quad (8)$$

According to experiment test, it will has preferable calculation effects when the value of α lies in the space of [0.0001, 0.001]. The value of $\rho_{\min}$ cannot be too small also and take it equal to 0.2 in the paper.

In order to highlight the mechanism that how the optimal solution of last generation attract the next generation, the next generation of attractive highlight on the generation of optimal solution, equation 9 can be used to update pheromone.

$$\tau(G_{wi}) = (1-\rho)\tau_j(G_{wi}) + \sum_{1}^{num} \Delta\tau_j(G_{wi}) \quad (9)$$

In which only num ants find their optimal solution and the global pheromone can be updated by these num ants; $\sum_{1}^{num} \Delta\tau_j(G_{wi})$ means the pheromone summary of the ants that got their optimal solution in this circulation calculation.

Improving the Convergence Speed of the Algorithm

BFGS (Broyden, Fletcher, Goldfarb and Shanno) algorithm is a very effective optimization algorithm, especially its superiorities in solving high dimensional optimization problems compared with gradient descent methods. So the paper uses BFGS algorithm to improve the speed up convergence speed of original wavelet neural network algorithm and remedies the disadvantages of too long search time of original genetic algorithm. The paper takes relative average output error equation of wavelet neural network as objective function, suppose $W(w_1, w_2, ...)^T$ as weight vector of wavelet neural network, its updating equations can be seen as equation 10, equation 11 and equation 12.

$$H^{k+1} = H^k + \frac{\mu^k \Delta W^k (\Delta W^k)^T - H^k \Delta G^k (\Delta W^k)^T - \Delta W^k (\Delta W^k)^T H^k}{\Delta G^k (\Delta W^k)^T} \quad (10)$$

$$W^{k+1} = W^k - \beta H^k \nabla E_{RR}(W^k) \quad (11)$$

$$\mu^k = 1 + (\Delta G^k)^T H^k \Delta G^k / ((\Delta H^k)^T \Delta G^k) \quad (12)$$

In which, $\Delta W^k = W^{k+1} - W^k$, $\Delta G^k = \nabla E_{RR}(W^{k+1}) - \nabla E_{RR}(W^k)$, k means the number of training, suppose $P^k = H^k \nabla E_{RR}(W^k)$, β can be gotten by adaptive method and should satisfy the equation 13.

$$E_{RR}(W^k + \beta P^k) = \min_{\beta \geq 0} E_{RR}(W^k + \beta P^k) \quad (13)$$

The Application of the Improved Algorithm

(1)Establishment of evaluation Indicators of PE teaching.

Taking successful experience in evaluation system of classroom teaching at home and abroad as reference, also in consideration of the special nature of PE teaching, it overcomes the shortcoming that traditional course evaluation starts from four dimensions as teaching contents, teaching attitude, teaching method and teaching effect, thus lacking of features of PE teaching evaluation. The paper, while designing specific evaluation indicators system, carries out evaluation on learners' learning outcome based on learners' behavior changes before and after PE learning. Evaluation dimension stretches from such five aspects as students' sports skill, verbal skill, teaching attitude, discernment and cognitive skill; evaluation contents mainly include completion quality of sports actions, ability to state action specification, ability to understand PE principles and concepts, ability to use PE knowledge and skill and ability to analyze problems in PE; behavioral expression is mainly to investigate the changes of students' behavior after PE teaching; action verbs correspond to behavioral expressions, mainly helping evaluators list verbs of ability mastering. PE teaching evaluation system established in this paper is shown as table 1 [10,11,12].

(2)Experimental results and analysis.

Experimental data come from database of Shanghai University of Sports(SUS), and Shanghai Jiaotong University(SJU) and South China University of Technology(SCUT). Relevant data of 300 learners of each university are selected as the basis for data training and experimental verification in the paper, totally 900 learners' data for study data that come from practical investigation and visit of two specific PE students. In order to make the selected learners' data representatives, 150 learners(50 learners from each university) with more than 3 years learning experience, 600 learners with 2 years learning experience, 150 learners with less than 2 years learning experience.

Limited to paper space, the evaluation of intermediate results is omitted here, only

providing parts of evaluation results and final comprehensive evaluation results, see table 2.

In order to prove the value of the algorithm presented in the paper, different algorithms which are popular used for different universities and researchers are realized with the same calculation platform in the paper. The indicators of the calculation platform can be listed as follows Intel i3 2120, 2GB DDR3, AMD Radeon HD 7450 and 3.3GHz CPU, and windows XP. The table 3 can shows that the evaluation accuracy and time consuming of the different algorithms. Form the table we can see clearly that the algorithm in the paper has greater value than that's of BP neural network [9] and fuzzy evaluation algorithms [12] in evaluation accuracy or time consuming. In realization practice, the paper takes some obvious indicators as sample to calculate evaluation accuracy in order to make our comparison more believable.

Table 1. Indicator system for PE teaching evaluation

Evaluative dimension	Content	Behavior	Action Verb	Case
Behavior Skill	Behavior type	Can finish the action or not	Can complete	Demonstration teaching of behavior (standing broad jump)
	Behavior Quality			
	Personal Difference	Quality of Behavior completion (accuracy , strength speed, etc.)	Can implement	
Speech Skill	Behavior Name	Can state contents correctly to be evaluated or not	Can state in speech or written form or not	State the exercise essentials of like standing broad jump
	Behavior Essentials			
	Behavior Requirement			
	Protection and Help			
Teaching Attitude	Selection of specific teachers and specific exercises	Teacher's attitude positive or not, students like and accept the teacher	Select (yes or not)	Active and conscientious or not, late for class or not
Ability to Distinguish	Can respond to different words an action or not	Different reactions to different Behaviors	Distinguish different behaviors	Distinguish triple jump from standing broad jump
Cognitive Strategy	Guide teachers' cognitive action using concepts	Can use different internal methods to solve actual problems or not	Use	Previous experience in teaching application
Specific Ability	Distinguish specific behavior (gestures, actions concepts)	Can distinguish the attributes of different behaviors or not	Distinguish	Distinguish standing broad jump action from different actions
Concepts Defining	Classify and understand relationship among different concepts	Can analyze specific concept using its definition	Classify specific behavior	Classify behaviors about broad jump based on its concept
Rule	Can understand the concept of different behavior and	Can illustrate or not	Understand and Demonstrate the behavior	Understand standing broad jump accurately and demonstrate demonstration the action

	demonstrate the behavior			

Table 2. Parts of secondary evaluation results

	Teaching Attitude	Cognitive Strategy	Specific Ability	Specific Ability	Concepts Defining	Rule	Final evaluation
SUS	4.321	3.822	4.501	4.345	4.631	4.561	4.475
SJU	4.099	3.528	4.330	4.091	4.421	4.381	4.217
SCUT	3.993	3.408	4.185	3.872	4.199	4.175	3.988

Table 3. Realization results of different algorithms

	Algorithm in the paper	Ordinary BP model	Fuzzy Evaluation
Evaluation Accuracy	94.67%	82.92%	71.44%
Time Consuming (S)	12	783	11

Conclusion

Learning algorithm of neural network is always an important research contents in the research field of neural network theory and application research. Among which, learning algorithm about the feed-forward neural network has not been a very satisfactory solution in particular. In this paper, a new wavelet neural network algorithm is advanced and improved and is applied to evaluate PE teaching. The experimental results show that the improved algorithm advanced in the paper is valuable in evaluating PE teaching and also applicable to evaluate others complicated system. the coming study should pay attention to the combination of generality with individuality of evaluation indicator system as well as the robustness of evaluation methods.

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References

1. Li Y. J., Cheng H. M., Jiang, L. H. (2010) Construction of BPMN-based Business Process Model Base. *International Journal of Intelligent Information Processing* , 1(2), p.p.32-38.
2. Dokoon S. F. (2014) An Improved BP Neural Network Algorithm Based on Factor Analysis. *Journal of Convergence Information Technology*, 5(4), p.p.103-108.
3. Liu Y., Zhen D. Q. (2013) Research on Evaluation of Project Management Maturity Model Based on BP Neural Network. *Advances in Information Sciences and Service Sciences*, 5(2), p.p.693-701.
4. Zhang D. M., Lu X. L. (2013) Minimizing Network Coding Resources with Improved BP Algorithm. *Journal of Digital Content Technology and its Applications*, 7(3), p.p.461-471.
5. Patricia M., Victor H. S. (2012) Genetic Optimization of Neural Networks for Person Recognition Based on the Iris. *TELKOMNIKA Indonesian Journal of Electrical Engineering*, 10(2), p.p.309-320.
6. Cai J. M., Yang M. S. (2009) .Optimal Model of Multi_agent Supply Chain Demand Forecasting Based on Genetic Algorithm. *Industrial Engineering Journal*, 19(5), p.p.81-85.
7. Yam X. D., Swum Q. S. (2012) An Improved BP Algorithm and Its Application. *TELKOMNIKA Indonesian Journal of Electrical Engineering*, 10(5), p.p.1081-1086.
8. Lee X. H. Swum Q. S. (2012) Aquaculture Monitoring System Design Based on BP Algorithm. *International Journal of*

Advancements in Computing Technology, 5(3), p.p.779-788.
9. Ding S. F. Jia W. K. (2012) An Improved BP Algorithm for System Evaluation. *Journal of Computing Technology*, 25(6), p.p.103-108.
10. Zhao H. G. (2012) The Study on the Education Method of the PE Courses in Teachers Training Colleges. *Journal of Nanjing University*, 14(2), p.p.80-84.
11. Zhang H. W. (2011) The Report on Experiment of Teaching the Course of Chorus and Conducting Its Curriculum in Normal Institution. *Journal of Qujing Normal University*, 14(4), p.p.115-119.
12. Yu J. H. (2011) Study on Evaluation System for University's Off-campus Practice Teaching Bases (PTBs). *Journal of Education Research*, 21(7), p.p.34-39.