Ship Recognition Based on Magnetic Field and Improved Back Propagation Neutral Network

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Abstract. It is important and difficult for underwater weapons to get ship's structure parameters from limited physical field signals. The degree of recognition will directly affect weapons' attacking result. Nowadays, some researchers used acoustic model to recognize underwater object, however, few research about ascertaining these parameters such as object's length, width and tonnage have been found. In this paper, we proposed an improved Back Propagation (BP) neural network model that can escape local optimum thanks to optimizing the initial weight values and threshold values by Particle Swarm Optimization (PSO) algorithm to solve it. The method can study the relationship between the positions and values of magnetic field curve's extremums and structure parameters directly. Its high accuracy and good robustness have been validated by a test.

Introduction

Recently, many researchers pay more attention to the ship recognition problem which is of great consequence to weapons. Object recognition can help weapons to differentiate that object is real or false, friend or foe, then weapons can attack object accurately. Objects in the air can be recognized easily by many instruments such as radar [1]; however, those underwater objects identification is difficult. The traditional acoustic calculation model or instruments such as sonar can find the object but can not recognize it accurately. Ke-wei Yan [2] has introduced a ships identification system based on BP neural network and ship's line spectrum and continuous spectrum of DEMON, which can only recognize the ships' screw type but can not get ship's structure parameters. Hu [3] has got characteristic vector by singular value decomposition (SVD) of image matrix and designed classifier with BP neural network. But the method has been used to identify mine and benthal vitta.
In this paper, we proposed an improved BP neural network model that can escape local optimum thanks to optimizing the initial weight values and threshold values by PSO algorithm to solve it. The method can study the relationship between the positions and values of magnetic field curve's extremums and structure parameters directly. Its high accuracy and good robustness have been validated by a test.

The relationship between ship's magnetic field and structure parameters

In this section, we are interested in the relationship between ship's magnetic field and structure parameters. Magnetic field is one of the most important physical fields for ship. There are many methods to measure or calculate it. It is said that magnetic field attenuate so quickly that we can not differentiate it from background magnetic field around while the distance between measuring point and ship achieves a certain value in triaxial directions. It is obvious that four critical positions of longitudinal and horizontal directions that the magnetic field will approach zero exceeding those positions have close contact with ship's length and width parameters. In the same way, the maximums of magnetic field in the standard measuring depth have close contact with ship's tonnage. Aiming at ship's structure parameters, we should receive the nonlinear relationship between them.

Ship's recognition based on PSO-BP neural network

The classical BP neural network

Artificial neural networks thanks to its strong studying ability have been found wide applications in many areas. There are many practicable models such as RBF neural network, Hopfield neural network and BP neural network [4] which is the most effective network because of its simple structure and strong nonlinear learning ability. It is well-known that feed forward network having three layers can settle any nonlinear problem while the activation function of hidden layer node is *Sigmoid*. The ship's recognition based on magnetic field's character curve can be reduced to a nonlinear problem, so we has built the BP neural network model which has a single hidden layer to settle the problem. Model's structure has been shown as Fig.1. Where we choose the positions and values of magnetic field curve's extremums as the input vectors; the output vector is object's length, width and tonnage; R is the dimension of input; S1 is the number of hidden layer nerve cells; S2 is the dimension of output; the transfer function of hidden layer is *tansig*; the transfer function of output layer is *purelin*. But classical BP algorithm is apt to get a local optimum and sensitive to initial weight value and bias value. In order to improve its robustness, a hybrid optimal model PSO-BP has been introduced.

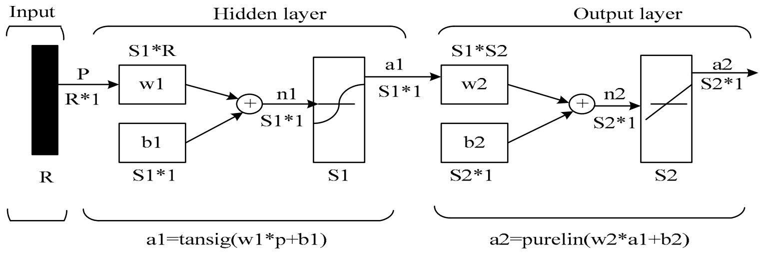

Fig.1 A classical BP neural network

The principle of PSO-BP algorithm

The bad robustness of BP neural network comes of that the network starting from different initial weight values and threshold values, and then different initial values may induce different training results. In order to get optimal initial weight values and threshold values, we choose PSO algorithm as its optimal algorithm [5, 6].

PSO that originated from studing the action of birds finding food was proposed firstly by Dr Eberhart and Kennedy in 1995. The approach is that provide a set of particles and the velocity as initialization values, and then search for the optimal solution of particles by iteration; every particle refresh velocity and direction data by P_{best} (the single extreme found by each particle) and G_{best} (the global extreme found by the whole particle swarm) in every iteration, the regulating rule of the position and the velocity follow formulas (1) and (2):

$$V(t+1) = wV(t) + C_1 \times R_1 \times [P_{best}(t) - X(t)] + C_2 \times R_2 \times [G_{best}(t) - X(t)] \quad (1)$$

$$X(t+1) = X(t) + V(t+1) \quad (2)$$

where V represents the velocity of different iterations, X represents the position of the particle, C_1 and C_2 represent accelerated coefficients that are both positive value, w represents the inertia mass that controls the impact of the previous velocity of the particle, R_1 and R_2 are two random numbers with the range of [0, 1].

The principle of PSO-BP is that we have PSO algorithm application in BP neural network's learning mechanism. BP neural network's the optimal initial weight values and bias values have been mapped as the particles and the velocity of PSO algorithm respectively, and then regulate them according to formulas (1) and (2). The detailed procedures have been introduced infra.

*step*1: Build the BP neural network's topology and ascertain the key parameters such as the dimensions of input and output vectors, the numbers of neural cells, training methods and so on;

*step*2: Initialize the PSO algorithm, generate N groups of particles vector random that is $X_i = [x_{i1}, x_{i2}, ..., x_{iR}, x_{i(R+1)}] (i = 1 \sim N)$ .where the preceding R groups and the last group have been mapped as the weight values and bias values respectively, and then train the net to get root -mean-square error of the net;

*step*3: ascertain the basic parameters of PSO algorithm;

*step*4: follow the rule of PSO to regulate the velocity and direction to find the optimal weight value and threshold value which make the root-mean-square error of net is the least;

*step*5*:* train the network via the optimal weight value and threshold value till the network has been steady, then use the testing samples to valid the network's forecast accuracy and its generalization ability.

The validation test of ship recognition based on PSO-BP

Fundamental parameters of BP neural network

We have received thirty groups of ship's basic structure parameters such as length, width, tonnage and magnetic field data such as four critical positions of longitudinal and horizontal directions that the magnetic field will approach zero exceeding those positions and ship's triaxial magnetic field maximums. Number them from 1 to 30 and choose 25 groups of data as training vector *A* whose dimension is 25×10, and then choose the rest as testing vector *B* whose dimension is 5×10.

Input and output samples of training: we have selected magnetic field data of vector *A* as input samples and ship's basic structure parameters data of vector *A* as output samples;

Input of testing: magnetic field data of vector *B* have been selected as input of testing samples,

Theoretic output: ship's basic structure parameters data of vector *B* have been selected as the theoretic output vectors.

The node of hidden layer: the number is determined by $S1 = \sqrt{R \times S2} + k$ where R=7, S2=25, k is a natural number. The preferable number (S1) is equal to 9 after trying many times. The training algorithm is Levenberg Marquardt (LM).

Fundamental parameters of PSO algorithm

The population size is 50, the dimension of particle is the total number of weight values and threshold values, and we choose net's Root-Mean-Square (RMS) error as adaptation function. The Other parameters areC_1=2, C_2=2, w=0.8.

Train and evaluate the network

After setting parameters, train the network according to PSO-BP algorithm, we input the vectors of testing samples, and then the structure parameters predicted by PSO-BP neural network will be compared with actual value. In order to evaluate the precision of the model, we choose the max relatively root mean square error *ERR* as the criterion, the equation has been shown as formula (3):

$$ERR = \mathrm{RMS}(k)/\max(t(k), k=1,2\ldots5 \qquad (3)$$

Where RMS(k) is the root mean square error of a ship's structure parameters and t(k) is the actual value. It is clear that *ERR* of length, width and tonnage shown as Fig.2 (a)~(c)are less than 5%, which indicated that PSO-BP neural network can study the nonlinear relationship between magnetic field data and structure parameters truly. Its high accuracy and good robustness have been validated primly.

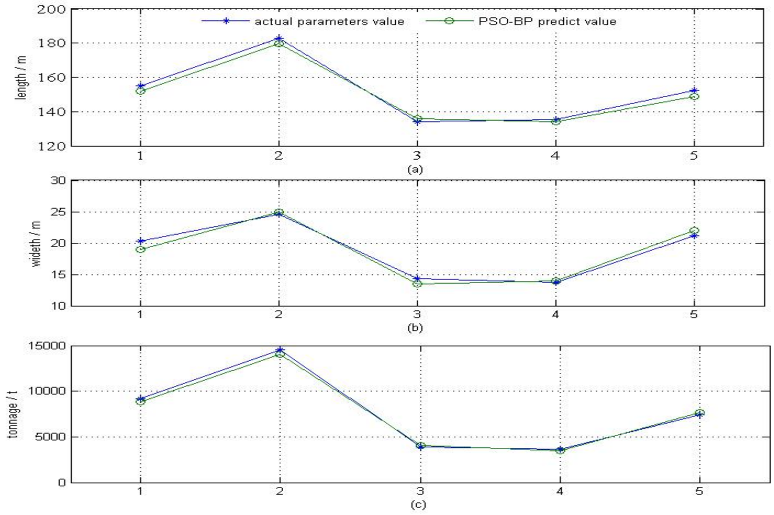

Fig.2 Comparison diagram of PSO-BP predicting and actual values

Summary

We develop the application of BP neural network in ship recognition according to the magnetic field curve and test the model's validity by an experiment. Comparing with other existing methods it presents advantages in ascertaining ship's structure parameters such as length, width and tonnage; second, by learning nonlinear relationship between ship's magnetic field data and structure parameters directly; we improve the accuracy of model and get good robustness thanks to optimizing the initial weight values and threshold values by PSO.

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