Underwater Detection Signal Based on LM-BP Neural Network Algorithm

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Abstract. The algorithm of underwater signal detection based on LM-BP neural network has a very broad application prospect. It is an important means of underwater background weak signal detection and a good method of phase space reconstruction. In this paper, the band-pass LM algorithm combined with BP neural network is used to process the underwater signal, which can effectively filter the magnetic noise in the underwater environment and extract the characteristics of the underwater detection signal. This paper first analyzes the time-frequency characteristics of the underwater detection signal, then studies the BP neural network of LM algorithm, and studies the design of band-pass filter, finally analyzes the application example based on LM-BP algorithm.

Keywords: Underwater Detection Signal, LM-BP Neural Network Algorithm

1. Introduction
Underwater signal includes ship magnetic field signal and other weak signals in chaotic background. Because underwater signal is difficult to detect ship target signal directly from time-domain waveform, it is necessary to study the detection algorithm that can effectively improve the signal-to-noise ratio. According to the received signal, the phase space of the background signal is reconstructed, and the prediction model of the underwater signal is obtained[1-2]. By subtracting the predicted chaotic signal from the received signal, the transient weak signal submerged in the background signal can be detected[3-4]. The underwater signal detection algorithm based on LM-BP neural network algorithm has a wide application prospect in the field of real-time processing such as communication and automation. It is an important foundation for weak signal detection in chaotic background and a better method of phase space reconstruction. Therefore, it is of great practical significance to study the underwater signal detection algorithm based on LM-BP neural network.

2. Time frequency characteristic analysis of underwater detection signal
The characteristic curve of the underwater detection signal has obvious characteristics, which can be used for the effective recognition of the target. The characteristic curve is the time-domain feature of underwater signal, but in practical application, the target signal is often submerged by the environmental magnetic interference, so it is necessary to analyze the frequency-domain feature of underwater signal, combined with the frequency-domain feature to process the target signal[5-6]. The frequency domain analysis results of various typical underwater signals show that generally speaking, underwater signals have several characteristics as shown in Figure 1.
Very low frequency signal

Spectrum and distance correlation
Frequency spectrum is related to speed

**Figure 1.** Characteristics of underwater signals

The underwater target signal generated by the simulation based on the magnetic dipole model is shown in Figure 2 below. The underwater target signal belongs to the extremely low frequency signal. Therefore, it is necessary to filter the signals of sleeping targets contaminated by non-Gaussian noise. According to the frequency-domain characteristics of the target, the corresponding band-pass filter can filter out the high-frequency noise and retain as much target information as possible.

![Figure 2. Underwater signal spectrum](image)

**Figure 2.** Underwater signal spectrum

### 3. BP neural network of LM algorithm

As a kind of multi-layer forward network with one-way propagation, BP algorithm is often used in BP neural network, but there are two important problems in BP algorithm: slow convergence speed and local minimum of cost function. The main methods to speed up BP convergence are BP algorithm using heuristic information technology and BP algorithm adding numerical optimization technology. For the approximation of continuous functions, the convergence performance of basic BP algorithm is poor, and the convergence time and iteration steps increase or even do not converge with the improvement of accuracy. The fast BP algorithm using heuristic information technology is simple and intuitive, and can improve the convergence speed of the network to a certain extent, but the accuracy is limited. BP algorithm can greatly speed up the learning speed at the beginning of learning, but after the error drops to a certain extent, the learning starts to slow down, because the error changes very little at this time, but the learning speed still has a large change, which is easy to produce oscillations, so it can be said that it is related to the selection of parameters and the nature of the algorithm.

LM algorithm is gradually applied with the advantages of fast operation speed and less iteration steps, but it also has the disadvantages of large storage and needs to store approximate Hessian matrix. Conjugate gradient algorithm is usually faster than the algorithm with variable learning speed and momentum term. It needs more storage space than simple algorithm and is suitable for networks with a large number of weights. Newton method needs more computation and more storage space than conjugate gradient algorithm in the iteration, but the number of iterations is usually less. The iterative formula of LM algorithm is as follows:

\[
x^{k+1} = x^k - \left( A(x^k)^T A(x^k) + \lambda_k I \right)^{-1} A(x^k)^T f(x^k)
\]

\[
\begin{align*}
\min & \quad \| f(x^k) + A(x^k)(x - x^k) \|_2 \\
\text{s.t.} & \quad \| x - x^k \|_2 \leq \delta
\end{align*}
\]
Where $h_k$ is the trust region radius, LM algorithm is used to train the weight of the network, and the algorithm shown in formula (2) is used to iterate the weight.

4. Band pass filter design
The filter can obtain better frequency characteristics with lower order, but its phase is nonlinear. The system of other filters is always stable, and it is easy to realize linear phase, but it needs higher order. FIR keeps the phase characteristic of the target signal after filtering without distortion.

4.1. BP neural network
BP network is one of the most commonly used feed forward neural networks, which contains one input layer, one output layer, one or more hidden layers. Each layer contains several nodes, each node represents a neuron. There is no coupling relationship between the nodes on the same layer. The information starts from the input layer and spreads in one direction between the layers, passes through the hidden layer nodes in turn, and finally reaches the output layer nodes. The general step of BP algorithm is to initialize the network weight, threshold and related parameters. Secondly, calculate the total error as follows:

$$E = \frac{1}{2p} \sum_k E_k$$

Where $p$ is the number of samples,

$$E_k = \frac{1}{2} \sum_j (y_{kj} - y'_{kj})^2$$

Take a sample of data and input it into the network, and then calculate the nodes of each layer forward according to the following formula,

$$O_j = f(a_j) = \frac{1}{1 + e^{-a_j}}$$

In which, $a_j = \sum_{i=0}^{n} w_{ij} O_i$ is the input weighted sum of node $j$; $i$ is the adjacent layer node of signal source direction of node $j$, is the output of node $i$, and is the input of node $j$. Since the correction of weight is carried out after inputting all samples and calculating the total error, BP algorithm belongs to batch processing method. The whole process is divided into two stages. First, the input layer of BP network is calculated layer by layer, then the output of each layer is calculated according to the input samples, and finally the output of network output layer is calculated, which is a forward propagation process. Secondly, the correction of the weight is calculated and corrected from the output layer of the network layer by layer. This is a back propagation process. These two steps are iterative until convergence.

4.2. Application example of LM-BP algorithm
In the specific sea area, the underwater detection signal based on lm-pm neural network algorithm is tested. Because of the influence of the environment magnetic noise, the underwater signal is easily submerged by the ocean background noise, and the underwater target can not be detected directly from the measured data. The band-pass filter and BP neural network are used to process the measured data. Firstly, the measured signal is filtered to remove the high-frequency magnetic noise and retain as much information of underwater target signal as possible. After the output signal filtered by BP neural network is processed by LM algorithm, the underwater target signal becomes very obvious. The underwater target can be accurately detected by simple amplitude threshold detection, as shown in Figure 3 below.
Figure 3. Output signal processed based on LM-BP algorithm

For the weak signal detection of BP neural network based on LM algorithm, it is better to choose discrete as the background signal to detect the transient signal. The weak signal detection of BP neural network based on LM algorithm can detect the underwater detection signal.

5. Conclusions

BP neural network based on LM algorithm is used to detect the weak underwater signal in the ocean background. According to the theory of reconstructed phase space, the detection error of this method is related to the appropriate network structure of reconstructed phase space, and it can detect the weak signal in the chaotic noise background. In a word, the underwater signal detection algorithm based on LM-BP neural network algorithm has a wide application prospect in the field of communication, automation and other real-time processing. It is an important basis for weak signal detection in chaotic background and a better method of phase space reconstruction. In this paper, the band-pass LM algorithm combined with BP neural network is used to process the underwater signal, which can effectively filter the magnetic noise in the underwater environment and extract the characteristics of the underwater detection signal.

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