DOA Estimation Method based on Neural Network*

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***Abstract*—Traditional signal direction of arrival (DOA) estimation algorithm has exist some problems, such as a large amount of calculation and slow convergence speed .In this paper, neural network method is used to improve the performance of DOA estimation. Due to the fact that BP neural network is inclined to be trapped in local minimum point, particle swarm optimization (PSO) algorithm is applied to optimization the weights and threshold. The model of DOA estimation based on PSO-BP neural network is constructed and trained. Simulation results show that, compared with classical RBFNN method and traditional MUSIC algorithm, the optimized BP neural network method has higher estimation accuracy and real-time performance.**

Key words—DOA estimation ; neural network ; Particle swarm optimization

I Introduction

Direction of arrival estimate is the core of passive direction finding technology. It's an important research topic in array signal processing, which is widely used in radar, communication, electronic detectors, biomedicine and other aspects of science and technology. DOA estimation mainly using antenna (sensor) array to receive data, determine the spatial location of multiple interesting signal in a certain space at the same time.(That is the direction angle of array reference signals arrive, referred to as DOA.) With the development of digital signal processing technology, traditional high-resolution DOA estimation methods can be implemented with digital hardware, such as MUSIC algorithm[1], ESPRIT algorithm[2], Maximum Likelihood method[3]. But due to a large amount of calculation and poor adaptability to the environment, the algorithm is not easy to achieve real-time and accuracy requirements.

Neural Network consists of some number of interconnected processing units, which has an ability of approach to nonlinear mapping and generalization. In this paper, neural network method is applied to DOA estimation. The advantage is that the modeling process is the use of neural network training sample construction, rather than precise mathematical equations. This method avoids the eigen-decomposition, and can implement fast parallel calculation.

II Antenna array model

Consider the far-field narrow band signals assumption, assuming that the space has M antenna array to form a Uniform linear array, and array element space is less than or equal to half-wave. Taking array 1 as the reference element, D uncorrelated zero-mean narrowband signal are incident on the uniform linear array, and signals direction are θ_i (i=1,2, ⋯ ,D). Assuming that the background noise is zero mean Gaussian white noise, its variance is σ^2 and uncorrelated with signals. The observation data of the K element at time t is:

$$x_k(t)=\sum_{i=1}^{D}a_k\theta_i s_i(t)+n_k t \tag{1}$$

Thus the mathematical model of far field narrow band signals can be get:

$$X(t)=AS(t)+N(t) \tag{2}$$

$X(t)$ is M-dimensional snapshot data, $X(t)=[x_1(t),x_2(t),\cdots,x_M(t)]^T$. A is $M\times D$

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array matrix and can be expressed as:
$A(\theta)=[a(\theta_1),a(\theta_2),\cdots,a(\theta_D)]$;S(t) is space signal vector , $S(t)=[S_1(t),S_2(t),\cdots,S_D(t)]^T$; N(t) is M-dimensional noise vector,

$N(t)=[n_1(t),n_2(t),\cdots,n_M(t)]^T$ .This shows that the direction information of the spatial signal is contained in the receiving signal vector or array covariance matrix:

$$\begin{aligned} R &= E[X(t)X^H(t)] \\ &= AE[S(t)S^H(t)]A^H + E[N(t)N^H(t)] \\ &= AR_S A^H + R_N \end{aligned} \tag{3}$$

$[\bullet]^H$ represent conjugate transpose of matrix. R_N is covariance matrix of receiving noise signal. R_S is covariance matrix of incident signal and contains all the information about incident signal.

III DOA ESTIMATION MODEL BASED ON NEURAL NETWORK

By formula (1) can be seen, the direction of arrival estimation problem that we trying to solve is a mapping problem. It's trying to map the antenna output signal X(t) and the direction of signal {θ=[θ1,θ2,⋯,θk]}[4].Traditional methods based on high resolution require a large number of matrix inversion and computation time, and cannot meet the requirement of fast direction finding. In this paper, neural network is used to construct the inverse transform of receiving vector and direction of arrival, to achieve fast direction finding. A typical neural network model of DOA is shown in figure 1.

The feasibility of the application of RBFNN in uniform array is verified by references [5]~[7]. When using neural network to DOA estimation, there are phase differences, feature vector and covariance matrix and other features can be extracted. The covariance matrix is rich in orientation information, so it is used widely. In this paper, the covariance matrix of the array received signal is used as the input of BP neural network. If antenna array have M elements, then the covariance matrix R_s have M2 elements. Since the covariance matrix is Hermite matrix and diagonal elements do not contain orientation information, it is usually used the processed upper (lower) triangular matrix as the input signal of neural network. The elements of the upper triangular element can be expanded to the vector:

$$r=[R_{12},R_{13},\cdots,R_{1M},R_{23},\cdots R_{M-1M}]^T \tag{4}$$

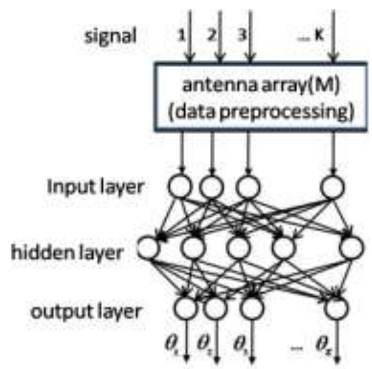

Fig.1 DOA estimation model based on NN

Because the elements in the vector are complex numbers, we can separate the real and imaginary part from each other, so the dimension of the new vector is 2 times that of the original. Using its normalized vector as the input of the network, then the output of the neural network is a combination of different incident angles {θ=[θ1,θ2, ⋯,θk]}.

The DOA estimation procedure based on neural network is as follows:

(1) The covariance matrix R_s of the incident signal is calculated according to the mathematical model;
(2) Transfer the upper triangular array of covariance matrix into a column vector;
(3) Normalized column vector as the input of neural network;
(4) Set correlation parameter of BP the neural network;
(5) A training sample is trained to train the

neural network

(6) The test sample and the trained neural network are used to DOA estimation.

IV SIMULATION EXPERIMENT

According to the above model and steps, we carried out the simulation experiment.

A. *Experiment1*

Single signal, the array elements number of uniform linear array is 5, the number of snapshots is 500, array element space is half-wave. Training samples and testing samples use the signal with 15db SNR. Number of neurons in the input layer is 20 and in the output layer is 1.Assume that training samples is[-45° ~45°],testing samples is [-44.5° ~4.5°],we can verify the effect of BP and RBF NN in DOA estimation.

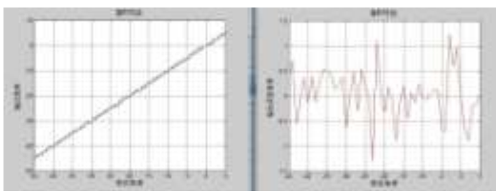

Fig.2 DOA estimation output and error curve based on BP neural network

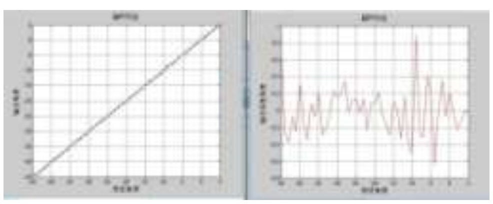

Fig.3 DOA estimation output and error curve based on RBF neural network

From the experimental results, it can be seen that the estimation of BP and RBF NN both close to the actual results, but RBF's results are more accurate.

B. *Experiment2*

Two irrelevant signals, other conditions are the same as before. Number of neurons in the input layer is 20 and in the output layer is 2.Training samples: the interval between the two signals is 20 and 25 degrees, with a step size of 1 degree, we can obtain 137 sets of data. Testing samples: the interval between the two signals is 23 degrees, with a step size of 1 degree, we can obtain 68 sets of data.

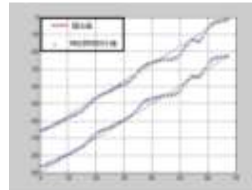

Fig.4 DOA estimation output based on BP neural network

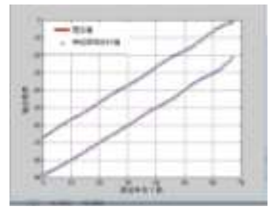

Fig.5 DOA estimation output based on RBF neural network

Figure 4 and 5 show that BP and RBF neural network can effectively estimate the arrival direction of two signals. Since the BP network is based on gradient descent method, it is easy to fall into local minimum, so simulation result is not as good as RBF's result. Therefore the particle swarm optimization (PSO) algorithm is used to optimize the weights and thresholds of BP neural network in this article, and through the BP algorithm to train the BP NN to achieve the specified accuracy, finally establish the corresponding DOA estimation model to improve the effect of accuracy. We can draw a conclusion that the result of PSO -BP is good at BP NN. Reference [8] describes a method which can decrease input neurons, and the estimation is more close to the actual results.

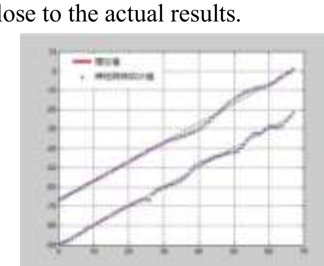

Fig.6 DOA estimation output based on PSO-BP neural network

V CONCLUSION

In this paper, the DOA estimation model of ULA is constructed by neural network. The experimental results verify the validity and feasibility of the model.

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