Research on Plot Authenticity Identification Method Based on PSO-MLP

PENG Wei\textsuperscript{1}, LIN Qiang\textsuperscript{2}
\textsuperscript{1}Air Force Early Warning Academy, Wuhan, Hubei Province, 430019, China
\textsuperscript{2}Air Force Early Warning Academy, Wuhan, Hubei Province, 430019, China
1769533864@qq.com

Abstract. Aiming at the influence of the clutter plots produced by the complex and strong clutters such as mountains, sea and cities on radar tracking performance, a method based on PSO-MLP is proposed to identify the authenticity radar plots. The method further distinguishes the target plots from the clutter plots, filters the residual clutter plots, and effectively improves the radar processing capacity and tracking performance. Based on the study of some differences between clutter and target plots, this method extracts multi-dimensional characteristic parameters, including doppler velocity, original amplitude and so on. Firstly, the parameters of MLP algorithm are optimized by PSO algorithm, and then the authenticity identification of clutter plots is carried out by MLP algorithm after parameter optimization, and then the remaining clutter plots are filtered out. Finally, the overall accuracy rate of plot identification reaches 85.75\%. The experimental results show that the proposed algorithm has a high and stable accuracy of plot identification.

1. Introduction
Radar will inevitably be affected by the external environment in the process of working. In the actual radar echo, there are always clutters such as ground objects, clouds, rain, oceans and so on. Commonly used clutter suppression technology is to take corresponding measures in signal processing, such as moving target display, moving target detection, constant false alarm rate, etc. However, due to the characteristics of clutter itself, the movement of radar platform and the complexity of the actual environment, no matter which method is adopted, a large number of residual clutters will inevitably be generated \cite{1}\cite{2}. After the residual clutter is processed by CFAR detection and plot coagulation, the false plots will be acquired by the radar target extractor together with the real target plots. On the one hand, these false plots will affect the aircraft association, and even produce false tracks, seriously affecting the normal tracking of real targets by radar; on the other hand, too many false plots will lead to saturation of the whole data processing system, seriously affecting the normal detection efficiency of radar. Therefore, it is necessary to distinguish the target trace from the residual clutter trace after target detection in order to further filter the residual clutter trace.

At present, in order to solve this problem, some experts and scholars at home and abroad have done some corresponding research using radar echo characteristic parameters. Literature \cite{3} proposes a method to distinguish clutter plots based on clutter characteristics and echo signal amplitude. The residual clutter plots are filtered by analyzing clutter characteristics and accumulating echo information. However, due to the complexity of clutter characteristics, the effect in practical application is limited. In reference \cite{4}, a clutter suppression method based on clutter graph is proposed...
for dense clutter interference. By analyzing the density of plots in time domain and space domain, different levels of clutter regions are identified and identified in real time, and then different clutter suppression methods are used for aircraft initiation. To some extent, these two algorithms filter out the remaining clutter plots, but they do not fully analyze the difference between clutter plots and target plots. Literature [1] by extracting appropriate characteristic parameters from clutter residual signal and target signal after signal processing, K-nearest neighbor algorithm is used to identify the authenticity clutter residual plots. The rejection rate of clutter residual plots is close to 70% after the identification of authenticity target plots. The feature extraction process of this method is complex and tedious, and the suppression rate of clutter trace is low, and some targets are filtered while clutter is suppressed.

Aiming at the influence of excessive clutter residual plots on radar detection and tracking performance after target detection, a new method of radar plot identification based on PSO-MLP algorithm is proposed by using the characteristic parameters of radar plot data. On the basis of studying the difference between clutter plots and target plots, this method extracts the characteristic parameters generated during the formation of radar plots. Firstly, the parameters of MLP algorithm are optimized by PSO algorithm. Then, the optimized MLP neural network algorithm is used to identify the plots, and then the remaining clutter plots are filtered out. Finally, the effect comparison of clutter plot trace filtering is given.

2. MLP Neural Network

MLP (Multi-Layer Perceptron), or multi-layer perceptron, is an artificial neural network with trend structure, which maps a set of input vectors to a set of output vectors. MLP has many layers. The first layer is the input layer and the last one is the output layer. The middle layer is called the hidden layer. Each layer includes a certain number of neurons. The neurons of MLP are connected by intra-layer and inter-layer connections. Fig. 1 is a schematic MLP structure with two hidden layers. There are N1 nodes in the input layer, N2 and N3 neurons in the hidden layer 1 and 2, respectively, and N4 neurons in the output layer. In addition to the output layer, each layer has a bias node [5].

![Figure 1. Double hidden layer MLP structure diagram.](image)

The feedforward calculation process of MLP is calculated from the input layer to the output layer in turn. The calculation method of each node in the feedforward process is as follows:

\[ x_i = f (W_{ij}x_j + b_{ij}) \] (1)

The commonly used activation functions are sigmoid function (logistic function), tanh function and ReLU function. The activation function used in this paper is sigmoid function:

\[ f(x) = \text{sigmoid}(x) = \frac{1}{1 + e^{-x}} \] (2)
MLP algorithm is a typical supervised learning algorithm. Its loss function is defined as:

$$J(W,b;x,y) = \frac{1}{2} \| h_{W,b}(x) - y \|^2$$

(3)

Among them, \( h \) is the output value of MLP algorithm; \( y \) is the actual value; \( \| \cdot \| \) is any distance norm, usually take 2 norms.

Generally, the loss function is minimized by weight optimization algorithm, and the stochastic gradient descent method (sgd) is adopted in this paper. The calculation method is as follows:

$$\nabla W = - \frac{\partial J(W,b,x,y)}{\partial W}$$

(4)

In addition, regularization method is used to avoid over-fitting and improve the generalization ability of the model. The size of the weights is directly added to the errors by using regularization and other methods, and the limitation of the weights becomes larger during training. The training process needs to reduce the overall error. At this time, on the one hand, it can reduce the error between the actual output and the sample, but also reduce the weight size [7]. The regularization methods include L0 regularization, L1 regularization and L2 regularization, but L2 regularization is commonly used in neural networks. Its principle formulas are as follows:

$$J = J_0 + \frac{\lambda}{2m} \sum w^2$$

(5)

Among them, \( J_0 \) is a general loss function; \( \lambda \) is a hyperparameter with a range of [0,1]; \( w \) is the weight of each layer in the neural network. The operation here is the 2-norm operation of the matrix for each weight matrix (that is, the sum of the squares of each element). Because the regularization parameters \( \lambda \) are too sensitive and have a great impact on the identification accuracy, this paper optimizes the selection of regularization parameters by grid search method.

3. Particle swarm optimization

Particle swarm optimization (PSO), also known as particle swarm optimization (PSO) or bird swarm foraging (BFO), belongs to evolutionary algorithm. Birds and other organisms in the process of finding food, on the one hand, rely on their own exploration, on the other hand, rely on the experience exchange between partners, so that they can quickly and accurately find the best food source in the search area. PSO is an evolutionary optimization algorithm based on the above biological phenomena. Every optimization problem solution is a bird in the search space, i.e., "particle". Each particle contains two kinds of information: position and velocity. Through the position information, the fitness value of the particle can be calculated to determine the quality of the particle, and the velocity information determines the direction and distance of their flight [8][9].

4. A model of vertex authentication algorithms based on MLP neural network

This paper presents a radar plot identification algorithm based on MLP neural network, which consists of three steps: the analysis of plot data, the construction of MLP neural network algorithm model and plot identification.

4.1 Analysis of plot data

In the process of plot formation, many characteristic parameters can be generated to distinguish target from clutter. In this paper, by studying and comparing some differences between clutter plots and target plots, Doppler velocity, number of plots, distance span, azimuth span, original amplitude, background amplitude, plot grade and plot quality are selected and extracted. Quantity and azimuthal condensation plot number and other characteristic parameters.

4.2 MLP neural network algorithmic model

In this paper, PSO-MLP algorithm is used to authenticate radar plots. The definition of particles is determined by the parameter vectors \( \lambda \), and the fitness of each particle in the population is evaluated.
by the fitness function value, which is determined by the fitness function and the parameter vector. In this paper, the accuracy of radar plot identification is selected as the fitness function.

The steps of radar plot identification based on PSO-MLP algorithm are as follows:

1. Initialize PSO algorithm parameters. Particle size \( n \), particle dimension (number of parameters to be optimized) \( m \), local learning factor \( c_1 \), global learning factor \( c_2 \), inertia weight \( \omega \), maximum number of iterations \( T_{\text{max}} \), convergence accuracy \( \xi \) and the range of regularization parameters \([\lambda_{\text{min}}, \lambda_{\text{max}}]\).

2. Input training set, calculate the average value of fitness function by 5-fold cross-validation, record and compare the optimal individual fitness function value and global optimal fitness function value traversed by each particle and the corresponding parameters \([\lambda_1, \lambda_2]\).

3. After calculating each particle in the particle swarm, we judge whether the iteration termination condition is satisfied or not, and if the condition is satisfied, we output the optimal parameter combination; if the condition is not satisfied, we update the velocity and position of the particle by formula (6) and formula (7), and then return to step (3).

4. The MLP model with the optimal output parameters is used to identify the plots in the test set and calculate the accuracy of plot identification.

4.3 Plot identification

The collected radar plot data are first analyzed, and then the target plot and clutter residual plot are judged by PSO-MLP algorithm model to obtain the identification accuracy. In this paper, the PSO-MLP-based radar detection plot trace authenticity identification algorithm flow is shown in Figure 2.

5. Experimental results and analysis

The data used in this experiment are all plot data collected from the X-type ATC radar. 9000 training data were randomly selected from the plot data, including 5000 target plots and 4000 clutter plots, and 4500 test data were selected, including 2500 target plots and 2000 clutter plots.

The experiment is divided into two parts: experiment 1, using PSO algorithm to optimize the selection of regularization parameters and obtain the optimal combination of parameters; experiment 2, using MLP algorithm under the optimal parameters, authenticity and falsity of the obtained radar plot data are identified, accuracy of plot identification is tested, and the effect before and after plot identification is compared.

5.1 PSO algorithms to optimize MLP algorithmic parameters

In this experiment, PSO algorithm is used to optimize the selection of regularization parameters. Five folds cross validation is used to calculate the average value of the accuracy of radar plot identification, record and compare the accuracy of each particle’s traversal plot identification and the corresponding combination of parameters, from which the optimal combination of parameters is selected.

Figure 2. Flow chart of radar plot identification algorithm based on PSO-MLP.
In this experiment, the parameters of MLP algorithm are set as follows: regularized parameters $\lambda \in [0.000001, 1]$; the parameters of PSO optimization algorithm are set as follows: the number of particle population $N = 20$, particle dimension $D = 1$, inertia weight $\omega = 0.8$, local learning factor $c_1 = 2$, global learning factor $c_2 = 2$, the maximum number of iterations $T_{\text{max}} = 50$, convergence accuracy of the algorithm $\xi = 0.001$.

The experimental results are shown in Figure 3.

Fig. 3 shows that the accuracy of radar plot identification is finally stable at about 0.8575. The corresponding optimal regularization parameters $\lambda = 0.000001$. Iteration times/Accuracy of plot identification

5.2 Trace discrimination analysis of MLP algorithms under optimal parameters

In this experiment, the MLP algorithm under the optimal regularization parameters is used to identify the authenticity radar plots, and the effect before and after the plot identification is compared. The specific contrast effect is shown in the figure below. Among them, the red "%" represents the clutter plot, and the green "+" represents the target plot.

Fig. 4. Primitive plot map.
Figure 5. Post-identification plot map.

From figs. 4 and 5, it can be seen that the algorithm can identify target plots accurately, but the accuracy of clutter plots identification is slightly lower, and the number of clutter plots identified as target plots is slightly more. Although there are a small number of target and clutter plots identification errors, the number of plots in each frame of radar in practical work is limited, so it will not affect the normal tracking efficiency of radar in practice.

Figure 6. After filtering target plot map.

Figure 7. Real target plot map.
From figs. 4, 6 and 7, it can be seen that after filtering the clutter plots identified from the original plots, the whole plot trace interface is much cleaner, only a small part of the clutter plots remain, and the target plots loss is less. It can be seen that PSO-MLP algorithm has certain advantages in radar plot identification.

6. Concluding remarks
Aiming at the influence of the clutter plots produced by the complex and strong clutters in mountain area, sea surface and city on radar tracking performance, this paper presents a method of identifying the authenticity radar plots based on PSO-MLP algorithm. This method extracts characteristic parameters on the basis of fully studying some differences between clutter plots and target plots, and uses PSO-MLP algorithm. The authenticity of radar plots is identified. The experimental results show that the accuracy of the algorithm is 85.75%, and the residual clutter filtering effect is obvious.

References
[1] Wei Tao. Clutter suppression and true-false target discrimination[D]. Xidian University, 2017.
[2] Hall, T.M., Shrader, W.W.. Statistics of clutter residue in MTI radars with IF limiting[P]. Radar Conference, 2007 IEEE, 2007.
[3] Wu Z H , Shi Z S , Shi Z M , et al. An emulation method of sensor clutter plots elimination using statistical characteristics analysis[J]. Applied mechanics and materials, 2012, 170-173:3345-3348.
[4] Luo Xingwang, Zhang Boyan, Liu Jia, Lin Hongjiang, Yu Juan. Researches on the method of clutter suppression in radar data processing[J]. Journal of systems engineering and electronics., 2016, 38(01):37-44.
[5] Zhang Pengcheng, Jia Yanyan. A dynamic regional combined short-term precipitation forecasting approach based on multilayer perceptron[J]. Computer applications and software, 2018, 35(11): 153-158+183.
[6] Yin Zhendong, Wu Zhilu, Ren Guanghui, Zhang Zhongzhao. MLP neural based adaptive UWB modulation scheme recognition algorithm[J]. Journal of chongqing university of posts and telecommunications, 2008(02): 156-159.
[7] Han Ling. The classification model of RS images based on artificial neural network-MLP[J]. Bulletin of Surveying and Mapping, 2004(09): 29-30+42.
[8] Zhang Canbin, Duan Shizhong, Zhao Shumin. A PSO algorithm for improving fitness function in array synthesis[J]. Radar science and technology, 2004(09): 29-30+42.
[9] Man Chuntao, Liu Bo and Cao Yongcheng. The application based on support vector machine optimized by particle swarm optimization and genetic algorithm[J]. Journal of Harbin university of science and technology, 2019(03): 87-92.
[10] Wang Caiyun, Huang Panpanpan, Li Xiaofei, Wang Jianing, Zhao Huanyou. Radar HRRP target recognition based on AEPSO-SVM algorithm[J/OL]. Systems engineering and electronics, 2019-07-17, http://kns.cnki.net/kcms/detail/11.2422.tn.20190628.1423.002.html.