International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.7, No.2 (2014), pp.339-344
http://dx.doi.org/10.14257/ijsip.2014.7.2.31

The Improved Recognition Method of Radiation Signal under the Condition of Unstable SNR

Yun Lin*, Xiaochun Xu and Jinfeng Pang

College of Information and Communication Engineering
Harbin Engineering University
Harbin, China
linyun@hrbeu.edu.cn

Abstract

The existing recognition methods of radiation source signal are extremely sensitive to the change of signal-to-noise ratio (SNR). In order to solve this problem, in this paper, it proposes a radar signal recognition method based on fractal box dimension and neural network under the condition of unstable SNR. Firstly, it extracts box counting dimension features of four different radiation source signals, and then uses the characteristic values of stable box counting dimension as the inputs of the neural network. Finally, it can recognize the four different kinds of radiation source signals. Simulation results show that, taking the box counting dimension characteristics as the input of the neural network to train, test and classify, it has good recognition rate in a certain changed range of SNR, and it has more widely application in the application environment.

Keywords: *radiation source signal recognition; fractal box dimension; neural network; unstable SNR*

1. Introduction

Radar signal recognition [1] is an important part of the modern electronic reconnaissance and electronic support system. It is also the key problem need to be solved in radar signal processing. The traditional identification methods [2-4] usually recognize radar signals based on several important parameters characteristics, including the pulse width PW, signal pulse repetition intervals PRI, signal carrier frequency RF, intra-pulse modulation information MOP, signal arrive angle AOA, signal pulse amplitude PA, and signal pulse arrival time TOA, *etc*. First, estimating these parameters, and then using them to match with the characteristic parameters in the database to reach the purpose of recognition. However, with the signal environment getting more and more complicated and the emerging of different radar signals, the recognition rate is always low using the traditional characteristic parameters. And it has high requirements of the stability of noise environment. With the rapid development of science and technology, people began to focus on some of the strong anti-interference signal characteristics. While the fractal box dimension [5] has been widely used in mechanical fault diagnosis [6], exploration [7] and other areas. This article will introduce the fractal box dimension as the characteristic parameters to the radar signal recognition, in preparation for the subsequent identification. Because the fractal box dimension has good noise immunity, so even if the SNR unstable environment, the value of extracted features is still relatively stable.

ISSN: 2005-4254 IJSIP

The article first proposed the fractal box dimension characteristics of four kinds of radar signals for feature extraction, and using neural network classifiers [8-9] to classify four radar signals under the instability signal to noise ratio. Using the good robustness characteristic parameters combines with the neural network classifiers which has strong adaptive ability, even if the signal to noise ratio changes in the environment, it can still sort of radar signals with good recognition results.

2. Basic Theoretical Knowledge

2.1. Theory of Fractal Dimension

Fractal dimension [10] is the main parameters in fractal theory. It can quantitatively describe the complexity of fractal sets; measure the extent of irregular signals. Among them, Hausdorff dimension is the basic fractal theory of fractal dimension. In practice, the calculation of the Hausdorff dimension is very difficult, so many people usually use fractal box dimension to describe the measure of the signal information.

Fractal box dimension is defined as follows: Make a metric space (X, d), H is a non-empty compact set of X, $B(x, \varepsilon)$ is a closed ball with the center of x and the radius of ε. Let A be a non-empty compact set of X, for every positive number ε, let $N(A, \varepsilon)$ be the number of the smallest closed ball covering A, the radius of the closed ball is ε, so:

$$N(A, \varepsilon) = \left\{ M : A \subset \sum_{i=1}^{M} N(x_i, \varepsilon) \right\} \quad (1)$$

Where $x_1, x_2, \cdots x_M$ are the different points of X. So the definition of box dimension can be described as follows:

$$D_b = \lim_{\varepsilon \to 0} \frac{\ln N(A, \varepsilon)}{\ln (1/\varepsilon)} \quad (2)$$

The fractal box dimension can depict the variation of signals, and it has the characteristics of not sensitive to noise. Therefore, it will have good recognition results for radar signal feature extraction.

2.2. Basic Theory of Neural Network

ANN (Artificial Neural Networks, ANNS), also known as Neural Networks (NNs), is a mathematical model which simulation the biological neural networks for information processing. Among them, the artificial neuron is the basic information processing unit of artificial neural network. The artificial neuron model is shown in Figure 1, which is the basis of artificial neural network design.

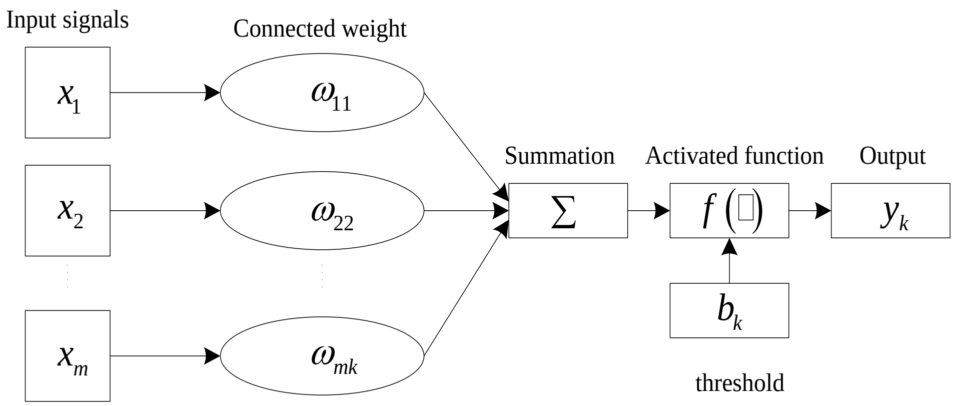

Figure. 1. The Unit of Artificial Neuron Model

The work process of neural network can be summarized as follows:

Suppose the input pattern vector is expressed as follows:

$$A_k = (a_1, a_2, \cdots, a_n) \tag{3}$$

Where $k = 1, 2, \cdots, m$. m is the number of learning patterns and n is the number of input layer units.

The output corresponding for the input mode is:

$$Y_k = (Y_1, Y_2, \cdots, Y_q) \tag{4}$$

Where q is the number of output layer units.

First, calculate the middle layer of each input unit:

$$S_j = \sum_{i=1}^{n} \omega_{ij} \cdot a_i - \theta_j \tag{5}$$

Where $j = 1, 2 \cdots, p$, ω_{ij} are the connection weights between input layers and middle layers, θ_j is the threshold of middle layer unit, and p is the number of middle layer unit.

Suppose S_j as a function (Sigmoid function), calculate the output of each middle layer unit:

$$b_j = f(S_j) = \frac{1}{1 + e^{-S_j}} \tag{6}$$

Where b_j are the activation values of middle layer units.

Calculate the input and output of each output layer units similarly to equation (7), (8):

$$L_t = \sum_{j=1}^{n} \upsilon_{jt} \cdot b_j - Y_t \tag{7}$$

$$C_t = f(L_t) = \frac{1}{1+e^{-L_t}} \tag{8}$$

Where $t = 1, 2, \cdots, q$, and υ_{jt} are the connection weights between middle layers and output layers. Y_t is the threshold of output layer units.

Currently two categories of classifier design have been widely used. One is based on the theory of classification decisions, and one is the neural network classifier. Compared with the decision theory, ANN algorithm does not require pre-determined threshold characteristics, and the whole identification process is a comprehensive analysis and determination using global features. There is no global impact or other defects due to the features without order as well as some of the features are distorted which will bring to inaccurate identification. So the ANN algorithm has better performance, and it improves the probability of correct identification in greater extent.

3. System Identification Block Diagram based on Fractal and Neural Network

Based on the above theoretical analysis, radar signal identification system block diagram is shown in Figure 2.

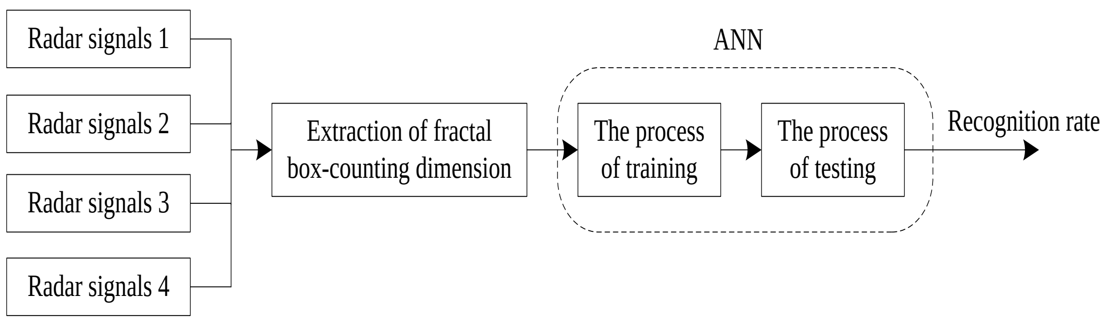

Figure 2. Radar Signal Identification System

First pre-process the four intercepted radar signals, then extract their fractal dimension features, and calculate the fractal box dimension of different radar signals. As the fractal dimension has good anti-noise performance, therefore, it can extract relatively stable feature vectors as the input of neural network. Put one part of the extracted signal characteristics as training samples to the input of neural network system to train. And after accommodating the weights of each hidden layer of neural network, put another part of the extracted signal characteristics as the test sample into the trained neural network system to test the performance of the recognition classification system. Finally, calculate the recognition rate.

4. Simulation Results and Analysis

Select four radar signals FSK, PSK, LFM, CSF, which all have 1024 samples. Extract the fractal box dimension characteristics of four kinds of signals. The range of SNR is -20dB~ 20dB, calculate the fractal dimension characteristics values of four kinds of signals which is shown in Figure 3.

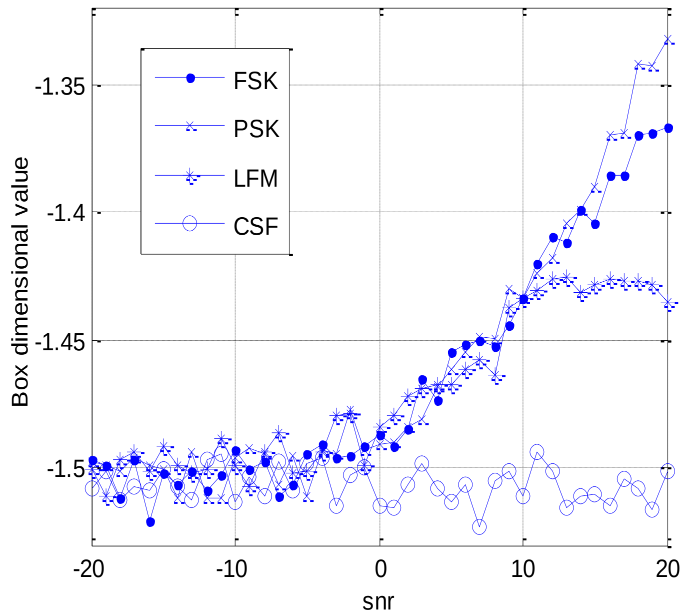

Figure 3. Fractal Dimension Characteristic Values of Four Signals under Different SNR

From the curve in simulation graph, the following conclusions can be drawn:

1. The fractal dimension characteristics of CSF signal is in a steady state with the changes of signal to noise ratio;

2. When the SNR is 0dB, the box dimension values of CSF signal curve gradually began to have a clear gap contrast to the other three kinds of radar signals,;

3. Observe the vertical axis of simulation graph, the fractal dimension values of different signals have little change with the variety of signal to noise ratio. When the signal to noise ratio is relatively in small fluctuations, it also has good stability.

Based on the fractal dimension feature extraction, 200 samples of each signal are get, put the value of the extracted features as input of neural network, 100 signals as the training samples and 100 samples as the tested samples. Get the classification results as the output. Calculate the radar signal recognition rate in different SNR, compared the recognition rate under different SNR which is shown in Table 1.

Table 1. The Radar Signals' Recognition Rate under Different Changing SNR

The range of SNR	10~15	12~17	14~19	16~21	18~23
Recognition rate（%）	77.5	92.5	100	100	100

In order to adapt the changing and instability of actual SNR environment, this experiment calculates the recognition rate of different signals in a certain changes range of SNR. Therefore, compare with the recognition rate calculating under stable SNR conditions, the recognition results is relatively low. However, from the statistical results and the observation shown Table 1, with the SNR changing in the range of 5dB, it already reached a high recognition rate when the SNR is greater than 12dB.

The eigenvalue of fractal box dimension has strong anti-noise performance, stability and good features. The neural network has the characteristics of adaptive capacity. Combined with the advantages of both methods, it can achieve good recognition results. The Recognition method of this article is more adaptive using in unstable environment compared with the traditional classification methods. So it can be used more widely in practical applications.

5. Conclusion

Fractal box dimension is an important parameter of fractal theory. It has the characteristics of good anti-noise performance, low complexity, and it can well describe the complexity of the signal. Neural network classifier has powerful pattern recognition ability. It can adapt the changes in the environment, and it can well handling the nonlinear problems. It also has better robustness and potential fault tolerance, so it has high recognition rate in practical.

Extract the signals' characteristics using fractal box dimension, and using neural network classifiers to classify and identify the radar signals, design the radar signal recognition system combined with the advantages of both, it will have good recognition results under a range of changing SNR. So it has wider application in engineering.

Acknowledgements

This work is supported by the Nation Nature Science Foundation of China No.61301095 and 61201237, and the Fundamental Research Funds for the Central Universities No. HEUCFZ1129, No. HEUCF130810 and No. HEUCF130817.

References

[1] Y. Shi and X.-D. Zhang, "A Gabor atom network for signal classification with application in radar target recognition", Signal Processing, vol. 49, **(2001)**, pp. 2994-3004.
[2] K. Banasiak and A. Pieniezny, "Radar pulse repetitive patterns' detection", 2010 11th International Radar Symposium (IRS), Vilnius, Lithuania, **(2010)** June 16-18.
[3] C. Zhao, Y. Zhao and J. Lu, "Radar Signals Sorting with Kohonen Neural Net", International Conference on Signal Processing, Guilin, China, **(2006)** November 16-18.
[4] J. Zhang and Y. He, "A Novel Method for Recognising Radar Emitter", 2010 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM), Chengdu, China, **(2010)** September 23-25.
[5] N. Sarkar and B. B. Chaudhuri, "An efficient differential box-counting approach to compute fractal dimension of image", Systems Man and Cybernetics, vol. 24, **(1994)**, pp. 115-120.
[6] M. D. Prieto, A. G. Espinosa, J.-R. R. Ruiz, J. C. Urresty and J. A. Ortega, "Feature Extraction of Demagnetization Faults in Permanent-Magnet Synchronous Motors Based on Box-Counting Fractal Dimension", Industrial Electronics, vol. 58, **(2011)**, pp. 1594-1605.
[7] R. Kosara, F. Bendix and H. Hauser, "Parallel Sets: interactive exploration and visual analysis of categorical data", Visualization And Computer Graphics, vol. 12, **(2006)**, pp. 558-56.
[8] V. N. Ghate and S. V. Dudul, "Cascade Neural-Network-Based Fault Classifier for Three-Phase Induction Motor", Industrial Electronics, vol. 58, **(2011)**, pp. 1555-1563.
[9] N. Perera and A. D. Rajapakse, "Recognition of Fault Transients Using a Probabilistic Neural-Network Classifier", Power Delivery, vol. 26, **(2011)**, pp. 410-419.
[10] J. S. Andrade and S. D. S. Reis, "Ubiquitous Fractal Dimension of Optimal Paths", Computing in Science and Engineering, vol. 13, **(2011)**, pp. 74-81.