Modulation Recognition Method Based on Complex Neural Network

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Abstract. With the increasingly intensive communication environment and the indefinite appearance of signal modulation, it is more and more difficult to identify signal modulation. Modulation recognition technology is very important in both civil and military fields. In order to solve the problems of multiple signal styles and low signal-to-noise ratio, a modulation recognition method based on complex neural network is proposed, which involves the field of wireless communication technology. For the complex signal widely existing in the field of communication, this method proposes a new method, which uses the complex signal received in time domain. It does not need to extract any parameters from the received signal. It only needs to input the complex data into the complex neural network for training, and fully learn the characteristics of the real part and the imaginary part of the data. It can obtain higher accuracy than the traditional high-order accumulation method, the complex number has more abundant expression ability. The complex number neural network can learn the real part and imaginary part of the complex number, which is more suitable for most communication signals in the form of complex number. This method does not need to manually calculate and observe the differences between various signals or eigenvalues, and does not need to manually set the threshold to distinguish the modulation types of signals, so the neural network has the function of classifier.

Keyword: Neural Network, Modulation Recognition, Complex Number, Communication Field

1. Introduction

Automatic modulation recognition is basically divided into statistical image recognition and computer learning recognition. Zhu et al. Used a new nonparametric likelihood function to identify modulated signals with unknown dispersion and noise distributions. Ozemil et al. Proposed a new hybrid scheme, which was classified according to the maximum likelihood value of the maximized general expectation algorithm [1]. With the increase of machine learning research, more and more people use machine learning method to recognize modulation in academia and industry. K-nearest neighbor algorithm, neural network planning and support vector machine are all used as new attempts of communication signal modulation recognition [2]. Signal modulation is a process or processing method to change the specific characteristics of waveforms according to different waveforms or
signals. In wireless communication, information is usually a kind of transmission signal in the main frequency band, which has the characteristics of low frequency, wide band and mutual overlap [3]. Information about modulation is required for single channel transmission. The so-called modulation is the process of inputting the transmitted fundamental band signal into the high-frequency oscillator signal, which is basically the process of inputting the fundamental band signal into the fundamental band. High frequency carrier, which is the process of spectral shift. The purpose is to transmit analog or digital signals for transmission. The signal is converted into a high frequency signal suitable for channel transmission [4].

With the development of information age, modulation recognition technology is constantly updated, and modulation recognition is the key technology between signal detection and signal demodulation. The modulation method can be evaluated according to the received signal to realize intelligent receiving and signal processing modulation. The effective identification of signal modulation plays a very significant and important role in the subsequent processing of the detected illegal communication signal, including the demodulation and decoding of the signal [5]. Typical modulation recognition algorithms can be divided into two categories: one is based on decision theory, which uses likelihood function or approximation theory for recognition, also known as likelihood based (LB) method; the other is based on pattern recognition and machine learning theory, which extracts classification features from received signals for recognition, also known as feature-based (FB) method [6].

At the same time, in many scientific or engineering tasks, the unknown variable is a complex variable, and the task of optimizing complex variables is widely used in transportation, adaptive filtering, medical visualization, remote sensing and other fields. The main task is to find the value of the matching variable, and then solve the optimization task [7]. Complex field not only provides a brief view, but also maintains the physical characteristics of a given task, so it is better to use methods to solve problems. In the task of optimizing complex variables, scientists usually divide the complex into two parts, one is real number, the other is imaginary number. Then the task of optimizing comprehensive variables is turned into a real variable optimization task, and a method of optimizing the actual value is used to solve the problem [8]. In a complex neural network, variable state, vector state and activation function are complex numbers. Different from the actual neural network, there are many more complex methods to analyze the stability of complex neural network, such as Lyapunov function method and synthesis method [9]. Liu Xiaoyu, Kang Linfang, etc. used a comprehensive method to study a discontinuous and complex neural network model, and a standard for determining network parameters is established. Duan Chengjun and Song Qiankun studied the complex delayed linear discrete neuron threshold neural network, and obtained the finite degree evaluation standard [10].

2. Algorithm and Method

2.1 Complex Algebra Algorithm
As one of the most important algebraic operations of complex neural network is weighted summation, the difference between real and complex neural network can be determined by analyzing the algebraic operation of addition and the multiplication of real and complex numbers. It shows the advantages of complex neural network. First, we compare the algebraic operations of addition.Suppose there are four real numbers \(x_1, x_2, y_1, y_2\) and two complex numbers \(z_1 = x_1 + iy_1\) and \(z_2 = x_2 + iy_2\). The results are as follows:

\[
\sum x = x_1 + x_2 \\
\sum y = y_1 + y_2
\] (1) (2)
\[ \sum z = (x_1 + x_2) + i(y_1 + y_2) \quad (3) \]

From the above three formulas, we can see that in addition, there is basically no difference between the addition of real numbers and complex numbers, but there is a big difference in multiplication. Then compare the multiplication operations as follows:

\[ \prod x = x_1 x_2 \quad (4) \]
\[ \prod y = y_1 y_2 \quad (5) \]
\[ \prod z = (x_1 + iy_1)(x_2 + iy_2) \quad (6) \]
\[ (x_1 + iy_1)(x_2 + iy_2) = (x_1x_2 - y_1y_2) + i(x_1y_1 + x_2y_2) \quad (7) \]

From the above three expressions, it can be found that the multiplication of complex number is obviously different from that of real number. The multiplication of complex number is more complex in form, but if the expression of modulus and phase is used, the meaning of multiplication of complex number will be very clear. Suppose that there are two complex numbers: \( z_1 = a_1e^{i\theta_1} \) and \( z_2 = a_2e^{i\theta_2} \), then the multiplication algorithm of complex number can be expressed as:

\[ \prod z = a_1e^{i\theta_1}a_2e^{i\theta_2} \quad (8) \]
\[ a_1e^{i\theta_1}a_2e^{i\theta_2} = a_1a_2e^{i(\theta_1 + \theta_2)} \quad (9) \]

From equation (8) (9), we can find that the meaning of complex multiplication is the modular multiplication and addition of complex numbers. From this point of view, the multiplication of real numbers has no phase operation, but only modular multiplication, so the complex neural network is more effective in processing data than the actual digital neural network.

2.2 Modulation recognition

Modulation recognition based on BP neural network is mainly divided into four parts: signal preprocessing, feature parameter extraction, BP network training and BP network recognition.

1. Signal preprocessing includes signal re-acquisition, filtering and smoothing, which is used to improve the signal-to-noise ratio of the signal to be processed;

2. Feature parameter extraction, aiming at the differences of different signal style features, extracts relatively stable signal features with high recognition;

3. BP network training, through a large number of signal sample library, to train its characteristic parameters, obtain relatively stable training results, complete the training of BP recognition neural network. Save the training parameters;

4. BP network recognition, using the trained BP neural network parameters, on-line recognition of the input signal characteristics, get the signal modulation style, and output.

The core algorithm of this technology includes signal feature extraction, BP network training and BP network recognition.

2.3 Complex BP neural network algorithm

There are many learning rules in real neural networks, such as Hebb learning rule, perceptron learning rule, LMS learning rule and so on. The basic idea of these learning rules is also applicable to complex neural networks. For BP neural network, this kind of algorithm is often called gradient descent algorithm. The basic idea of BP algorithm is that the learning process consists of two processes: the forward propagation of signal and the reverse propagation of error. In the sequential propagation, the
input samples are transmitted by the input layer, and then processed by each hidden layer and transmitted to the output layer. If the actual output of the output layer is not consistent with the expected output (teacher signal), an error will be returned to the attribute phase. The error return attribute means that the output error returns to the input layer of each layer through the hidden layer, and all units of each layer have errors, so as to obtain the error signal of units of each layer. The error signal is used to modify the weight standard of each unit. The process of weight adjustment is the process of online learning and training. The process will continue until the level of network input error is allowed or the number of learning presets is reduced. Multi layer insight using BP algorithm (such as BP neural network) is the most widely used neural network so far.

3. Model establishment

3.1 Complex BP neural network model
Complex BP algorithm is the extension of real BP algorithm in complex field, but complex BP algorithm has more advantages than real BP algorithm. For example, complex BP algorithm can solve the XOR problem and symmetry problem only by two-layer neural network, and complex BP algorithm can deal with complex related problems, which real BP algorithm can't do. In terms of speeding up the learning speed, complex BP algorithm has great advantages.

The complex neuron model still refers to the actual neuron model, but the input, output, weight and threshold are all complex:

\[ O_j = f_c(Z_j) = f_c\left(\sum_i W_{ij} X_i - \theta_j\right) \]  

(10)

And each parameter can be divided into real part and imaginary part, so the complex \( Z_j \) can be written as follows:

\[ Y_j = x + iy \]  

(11)

In complex BP algorithm, the function of R-I neuron is as follows:

\[ f_c(Y_j) = f_R(x) + if_R(y) \]  

(12)

Among them,

\[ f_R(u) = \frac{1}{1 + e^{-u}}, u \in R \]  

(13)

Because the three-layer complex neural network can approach any nonlinear function in theory, the three-layer complex BP network is deduced on the basis of the three-layer real BP network, and its network structure is similar to that of the real BP network.

4. Evaluation Results
The understanding of complex neural network is investigated as follows:
From the data analysis in Figure (1), we can see that there are still some problems in the application of complex neural network, and nearly half of the students do not understand its application. Only a few students are familiar with the application of complex neural network. Most of them just know about it, but they don't know it in depth. From the data in the Figure, we can see that complex neural network is not very popular, so we should strengthen the optimization and update of it, so that complex neural network can be better applied and help students learn better.

From the data analysis in Figure (2), we can see that there are still some problems in the complex BP neural network algorithm. The existence of these problems affects the user's experience and makes these users have more opinions on the complex BP neural network algorithm. If the complex BP neural network algorithm wants to make users have a better use experience, it needs to overcome these problems, so that it can bring these users a good use experience, so that users can make better research.

We randomly selected 100 people, the ratio of male to female is 1:1, and did a survey on the understanding of the complex BP neural network algorithm as follows:
According to the data from the questionnaire survey in Table 1, there are gender differences in the understanding of the complex BP neural network algorithm between men and women. Boys know more about the complex BP neural network algorithm than girls, while girls know little about it. Therefore, gender will have a very different degree of cognition to the complex BP neural network algorithm, which is also an important factor we learned from the survey results. Therefore, when adjusting the complex BP neural network algorithm, we can ask more girls' opinions, so that girls can better understand, but we must also increase the dissemination efforts, which will be of great help to the development of complex BP neural network algorithm, so that people can understand it and support its development.

### 5. Conclusion

Today, with the continuous development of science and technology, our use of neural network modulation recognition method is increasing, and there are many kinds of classification methods, so we choose one method to study. This paper presents a modulation recognition method based on complex neural network. After training the selected characteristic parameters by modulation recognition, the preliminary parameters are obtained, and then the parameters are fine tuned by BP neural network to complete the modulation recognition. The modulation recognition method based on complex neural network is analyzed, and the recognition performance of modulation recognition based on BP neural network is analyzed. The results show that the modulation recognition algorithm based on complex neural network has great advantages in low SNR. It shows that this modulation recognition method based on complex neural network is an effective method to realize modulation recognition. In order to pursue the simplicity of the algorithm, the recognition speed is fast, the recognition range is wide, and the correct recognition rate is high, more and better research and discovery are needed.

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Research on complex neural network modulation (ky202003)

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