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The Application of Wavelet Transform In The Feature Extraction of Plant Electrical Signals

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Abstract: A method of feature extraction in non-stationary signals is proposed to improve the correct classification rates of plant electrical signals. The samples are composed of plant electrical signals datum which includes the period of four circumstances. For wavelets have the trait of arbitrary distinction and decomposition, eigenvector which reflect different state of plant electrical signals are extracted from different frequency segments with the technology of wavelet decomposition. Then we take them input neural network as samples to establish the model of BP neural network. Experimental results demonstrate that the classification accuracy of the proposed feature extraction method for experiment plant electrical signals is high.

Keywords: plant electrical signals, wavelet transform, feature extraction, BP neural network

1 Introduction

Plant electrical signal, the transmitted information related to the processes of plant physiology is an important physiological signal. It is the plant in response to environmental change stimulation. Scientists from verify the presence of radio signals of the plant to ascertain the characteristics and electrical transmission mechanisms of the plant, and development to the current model for establishing electrical plants and related physiological effects study[1-5]. With the development of weak signal detection processing technology and computer information collection and data processing system realization, the extraction and analysis of weak plant electrical signal will be more scientific; feasibility and quantitative analysis of the wave signals of the plant is also possible. There are commonly used methods [6,7]: plants wave signals in time domain, frequency domain analysis, wavelet analysis and time series analysis, electrical plants AR model and neural network prediction, and so on.

Wavelet transform signal projected onto a set of mutually orthogonal wavelet function sheets into space, which can be decomposed into two parts: low frequency part and high frequency part. In the next layer decomposition, the low frequency part was conducted re-decomposition, while the high frequency part was not conducted re-decomposition, which is very suitable for the weak low-frequency electrical signal

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feature extraction of the plant. Based on wavelet transform, this paper presents a method, which is suitable for non-stationary signal feature extraction, and wavelet coefficients energy eigenvalues as BP neural network classifier for automatic identification, achieving good recognition effect.

2 Basic Principles

2.1. Wavelet decomposition principle

It is an effective tool for signal processing because wavelet transform can localize in both time and frequency field. In practical, we often use Mallat fast algorithm. Here will be described with three-layer decomposition, and wavelet decomposition tree shown in Figure 1.Where, S is the signal to be decomposed, representing the decomposed approaching signal of $A_n(n=1,2,3,\mathrm{L})$. $D_n(n=1,2,3,\mathrm{L})$ represents the details of the decomposed signal[8].

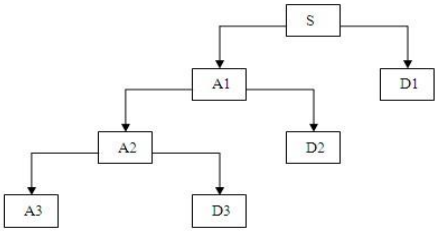

Fig.1 Three-level structure of the wavelet decomposition tree

As can be seen in Figure 1, the low frequency part was further decomposed, but the high frequency part will not be decomposed. Decomposition has relation S=A3+D3+D2+Dl. In addition, there is just explaining three-layer decomposition. If we want to further decompose, the low-frequency part of the A3 can be decomposed into low frequency A4 and high frequency D4.The following further decomposition, and so on.

2.2. Electric signal of the plant

The electric signal of the plant is weak low-frequency. Studies [9,10] showed that the amplitude of electric signal of the plant is only a few pV to a few mV range. Experimental data is the electric signal of aloe Vera collected under the darkness, broken branches, smoke, and burning conditions or stimuli condition. In this study, We used the biological function experiment system to measure electrical signals. The measuring system is shown in [11-12].

The sampling frequency of the original data is $F_s = 5000$ Hz. After wavelet decomposition, the n-lever detail coefficients corresponding to frequency range is

$(F_s / 2^{n+1}, F_s / 2^n)$; the n-lever approximation coefficients corresponding to frequency range is $(0, F_s / 2^{n+1})$. Thus, we can calculate the details of the wavelet decomposition of the signal and the approximation signals' the frequency range, which are shown in table 1.

Table 1. Frequency range after wavelet decomposition

Signals	D5	d4	d3	d2	d1	a5
Frequency range (HZ)	156.75~ 312.5	312.5~ 625	625~ 1250	1250~ 2500	2500~ 5000	0~ 156.75

2.3. BP neural network establishment and training

BP neural network has been successful in many applications of recognition and classification problems. BP network is a former propagation multilayered network, in addition to the input layer and the output layer, there are one or more hidden layers. The network training method is called error back propagation method (Back Propagation, BP),which uses the minimum error between the actual network output and the desired output(target vector) to correct the multilayer network connection weights layer by layer from back to front. This successive constantly modify the weight vector method called successive correction method [13].

3 Energy characterization extraction algorithm

The original signal is denoted as A_s , according to the principle of wavelet decomposition, A_s can be decomposed as:

$$A_s = A_1 + D_1 = A_2 + D_1 + D_2 = \cdots \quad (1)$$

The decomposition of the reconstructed signal, which includes the time-domain of the original signal in different bands, Research under different frequency bands signal characteristics, and then extract the character frequency ranges, which can most express the fault features. The expression for the total energy of the signal is:

$$E = EA_j + \sum ED_j \quad (2)$$

The approximation signal of the j-th layer and the layers' detail signal energy can be selected as are preventatives to analyze the characteristics of the signal. The

feature vector is constructed as following: $T=[ED_1, ED_2, \mathrm{L}\ , ED_j]$. Feature extraction algorithm of the plant electric signal based on wavelet analysis is described as follows:

1) Conduct five-layer wavelet decomposition after de-noising a long period of time about 20s plant's electric signal, extracting the detail coefficients of wavelet band division, using S_{ij} to represent wavelet coefficient of the i-th layer j-th node.

2) Calculate the variance and the norm of wavelet coefficients, according to the calculated results to class the experimental data.

3) Calculate the energy [14] of the wavelet coefficients, set the signal S_{ij} corresponding to the energy is E_{ij}, then,

$$E_{ij} = \int \left|S_{ij}(t)\right|^2 dt = \sum_{k=1}^{n} \left|d_{ij}^{k}\right|^2 \tag{3}$$

Where, d_{ij}^{k} represents sequence value of the i-th layer j-th node's wavelet coefficient.

4) Structure feature vector. Using five-layers of the wavelet decomposition energy value of detail wavelet coefficients as elements to structure feature vector T, which can be described as follows:

$$T=[E_{5,1}, E_{5,2}, E_{5,3}, E_{5,4}, E_{5,5}] \tag{4}$$

Input the obtained feature vector to BP neural network to testing.

4 Experimental results and analysis

Four groups of plant electrical data referenced in this study are the aloe plant electrical signals from Xi'an University of Technology Laboratory collected. We'll represent the plant electrical signals collected under the darkness, smoke, broken branches and burning conditions using symbols: A, B, C, and D. Adopting db5 wavelet to conduct five layers wavelet decomposition for each plant electrical signal, extracting the wavelet coefficient of each node, calculating the norm and variance of wavelet coefficients as a kind of feature to analyze the signal. Because the sample data are more, so only 2 set of values of each characteristic group are listed in this paper, which are shown in Tables2-3.

By contrast, it can be found that the characteristics of the data set A and B are in an order of magnitude, the characteristics of the data set C and D are in the other an order of magnitude, which usually higher than the previous. the stimulation of aloe under the darkness and smoke conditions is weaker than it under the conditions of broken branches and burning. In order to make the classification accuracy of the plant electrical higher and the simulation experiments easier, we divided the experimental

data into two categories: the signal under the conditions of darkness and smoke is a kind of class, under the conditions of broken branches and burning is a kind of the other class. Through a lot of experimental results, it can easily distinguish these two categories.

Table 2. The normal of wavelet coefficients

Data Set	Number	T1	T2	T3	T4	T5	T6
A(Darkness)	1	267.4	3999	957.6	1202.2	1379.0	928.6
	2	325.1	574.0	1177.3	989.4	558.0	718.5
B(Smoke)	1	198.7	396.5	764.8	845.2	1144.2	1786.7
	2	271.3	596.5	836.0	1024.3	1282.2	636.9
C(broken	1	10069	15992	16187	12882	7934	12275
branches)	2	1906	6186	16181	8425	5348	7110
D(Burning)	1	7215	11008	12708	15475	8101	15934
	2	7838	8664	9628	13027	10287	13521

Table 3. The variance of wavelet coefficients

Data Set	Number	T1	T2	T3	T4	T5	T6
A(Darkness)	1	18.955	28.342	67.880	85.223	97.631	63.308
	2	23.043	40.684	83.453	70.138	39.549	47.709
B(Smoke)	1	14.083	28.107	54.211	59.913	80.985	125.436
	2	19.231	42.284	59.259	72.551	90.658	45.037
C(broken	1	713.8	1133.7	1147.4	913.1	562.3	870.1
branches)	2	135.1	438.5	1147.1	596.7	379.1	449.2
D(Burning)	1	511.5	780.3	900.9	1096.8	574.3	1129.5
	2	555.62	614.15	682.48	923.43	729.16	955.04

BP neural network achieved successfully applied in many recognition and classification problems. In this paper, we adopt three-layer BP neural network to classify [15], which is widely used in the current. And input T to the BP neural network for testing. Each category of data contains two the plant electrical, namely category vector includes two categories. Because the energy extracted feature vector dimension is 5, so the BP neural network input layer nodes is 5. Based on empirical formulas and specific experimental results set the nodes of hidden layer is 12 and the nodes of output layer is 2.

Neural network is an intelligent algorithm, each time the results are not necessarily able to achieve the set parameters. Setting the maximum number of training steps is 20000, training target is 0.06, and the program successfully reaches to set parameters denoting process efficiency. Training results are shown in Figure 2.

In the experiment, the plant electrical were conducted on 6-layer, 5-layer and 4-layer wavelet decomposition and obtaining each feature vector.

Input the feature vector, which was obtained by 6-layer wavelet decomposition, into BP neural network. Although the signal recognition rate is relatively higher, yet the program efficiency is relatively lower. Input the feature vector, which was obtained by 4-layer wavelet decomposition, into BP neural network. Although the program efficiency is relatively higher, yet the signal recognition rate is relatively lower. The results are shown in table 4.

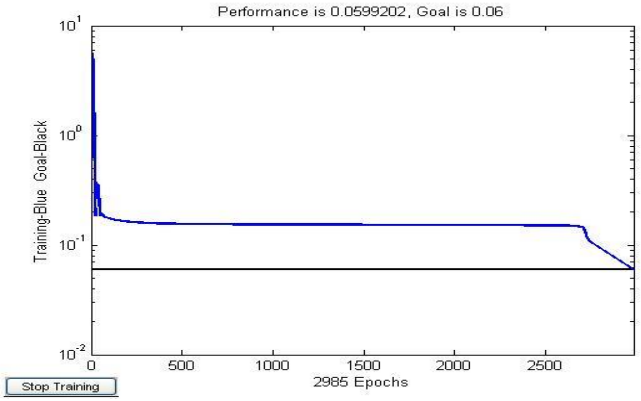

Fig.2 Training results

Table 4. The experimental results of BP Neural Network

The layers of Wavelet decomposition	Signal recognition rate	Program Efficiency
6	96%	50%
5	91%	83%
4	77%	100%

Therefore, considering the experimental results, we selected the plant signal recognition method, which is based on the energy feature of 5-layer wavelet decomposition. The experimental results show that the plant electrical signal recognition rate of the proposed method reaches 91%.

5 Conclusion

In this paper, the wavelet transform was carried out on the plant electrical signal decomposition. Choose the extracted norm and variance which include in different

frequency bands of the signal, as the characteristics of preliminary identification of the plant electrical signal. Finally, a feature vector was input into BP neural network. The feature vector which was constructed by the energy values of the wavelet packet coefficient. The proposed method is only exploratory research in plant electrical aspects. In our further research work, other feature extraction methods and the improved BP neural network will be tried. Therefore, the plant weak electrical signals study will play an increasingly important role in facility agriculture, the agricultural aspects of information technology.

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