Studies on the plant electric wave signal by the wavelet analysis

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Abstract. In this study, we choose that the ‘db3’ wavelet as the basis function to decompose the electric wave signal in 5 levels and a low and high frequency coefficient of 6 species plants are obtained, and coefficients after denoise are reconstructed for the first time. A result of the analysis of the wavelet in plant electric wave signals indicates that plant electric wave signals are of changing of characters in the each frequencies scale. In the low frequency level, the main character of the plant electric wave signal is reflected; in the high frequency level, the noise of the determined signal and also the mutation of the signal are reflected respectively. That the denoised signal of plants by wavelet analysis is similar with the original one indicates that the wavelet analysis is fit for studies on the plant electric wave signal. There are -200~500μV of the electric wave signals in growing plants.

Keywords: wavelet transform, plant electric wave signal, signal processing

1. Introduction

The plant electric wave signals are the reflection of plants to the stimulation and changes of environments, and the informations it carried reflect the physiological activities of plants [1-21]. But, the plant electric wave signal is of rather strong randomicity and background noise, and it is also a kinds of non-stable micro-signal. How to obtain main character of plant electric wave signals is a difficult problem in the field of the signal processing of plant electric wave signals. Multiresolution wavelet analysis as a kind of the signal processing technology is already widely applied to many field, especially to biomedical signal, such as, brain wave signal [22-24], electrocardiosignal [25-28], electromyographic signal [29,30]. But it is seldom to use for the processing of electric signals of plants. The wavelet analysis is of excellent characteristic in time-frequency localization, and is fit for the analysis on the transient characteristic and the time varying characteristic of the non-stable signal. The wavelet transform is of the ability to processing the non-stable random signal of plant electric wave. It is a rather perfect mathematical tool for signal processing. We intend to use the wavelet transform theory to analyze the plant electric wave signal in this article.

2. Materials and methods

2.1. Testing apparatus

BL-420E biological enginery testing system was purchased from the Chengdu Taimeng Science and Technology Limited Company. The basic principle is: firstly, introducing the plant electric wave
signal by leading electrode; secondly, magnifying and filtering the signal; then, digitizing it by analog-to-digital converting, and imputing the digitizing signal into the computer to analyze it.

2.2. Plants
6 plants, that is, Crassula portulacea, Jasminum sambac, Aloe vera var. chinensis, Scindpsus aureus, Catharanthus roseus and Celosia cristata were bought from the flower market and cultivated in the lab.

2.3. Wavelet transform analysis
Basing on such characteristic, applying wavelet transform to the analysis of the plant electric wave signal to discuss the character of it. The wavelet transform comes from the analysis of signal, and has the ability of giving expression to time domain and frequency domain information at the same time [31-34]. The function (basic wavelet), which satisfies some conditions, is used to decompose original signal. And the wavelet function make up of the wavelet basis by extending and contracting in frequency domain and translating in time domain. The definition of wavelet transform as follows:

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WT_f(a, \tau) = \left( f(t), \Psi_{a,\tau}(t) \right) = \sqrt{a} \int_{-\infty}^{\infty} f(t) \Psi \left( \frac{t-\tau}{a} \right) dt, \quad \text{in the formula: } a, \ \text{denoting the scale frequency factor; } t, \ \text{denoting the time parameter; } \Psi(t), \ \text{denoting the wavelet generating function. The wavelet transform } WT_f(a, \tau) \ \text{is the two variable function, which was composed of the scale variable } a \ \text{and the variable } \tau. \ \text{The variable } a \ \text{and variable } \tau \text{defined the scale/ time plane. So, when we expand the function by the wavelet basis, it means that project a time function on the scale/ time plane. In this plane, we can sharply get the feature description of the signal we analyzed, in different scale and time. The most important application of the wavelet analysis is the denoising to the signal. The model of the noisy signal can be expressed as follow: } s(i) = f(i) + e(i), \quad i = 0, \ldots, n-1, \ f(i) \ \text{is the actual signal, } e(i) \ \text{is the yawp, } s(i) \ \text{is the noisy signal.}
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The useful signal of plants usually is a low frequency signal, and the noisy signal usually is a high frequency signal. So, the denoising course can be done by the following methods: firstly, decomposing the signal and the noise contain in the high frequency coefficient; secondly, processing the wavelet coefficient by the threshold value; then, reconstructing the signal to denoise. In this study, we choose the ‘db3’ wavelet as the basis function to decompose the plant electric wave signal in 5 levels, and obtained the low and high frequency coefficient, and reconstructed the coefficient to denoise.

3. Results and discussions

3.1. The time domain waveform of electric wave signal
Figure 1–3 is the time domain waveform of 6 plants electric wave signal respectively. An appearance of the action wave from the first to second time in Crassula portulacea is about 60s and the action wave appears 5 times in 180s, and the maximum value of the electric wave signal is about 80 μv (figure 1 left s). An appearance of the action wave from the first to second time in Jasminum sambac is about 65s and the action wave appears 2 times in 100s, and the maximum value of the electric wave signal is about 190 μv (figure 1 right s). An appearance of the action wave from the first to second time in Aloe vera var. chinensis is about 260s and the action wave appears 2 times in 500s, and the maximum value of the electric wave signal is about 310 μv (figure 2 left s). An appearance of the action wave from the first to second time in Scindpsus aureus is about 100s and the action wave appears 2 times in 400s, and the maximum value of the electric wave signal is about 550 μv (figure 2 right s). An appearance of the action wave from the first to second time in Catharanthus roseus is about 60s, but it takes very long time that an appearance of the action wave from the second to third time is about 310s and the action wave appears 3 times in 500s, and the maximum value of the electric wave signal is about 590 μv (figure 3 left s). An appearance of the action wave from the first to second
time in *Celosia cristata* is about 40s and the action wave appears 2 times in 100s, and the maximum value of the electric wave signal is about 200 μv (figure 3 right s). These results show that signals are different and it is difficult to distinguish the noise and signal itself of 6 plants interweaved together. It is the significant and representational plants that we selected *Crassula portulacea*, *Jasminum sambac*, *Catharanthus roseus* and *Celosia cristata* belong to the dicotyledon and *Aloe vera* var. *chinensis*, *Scindpsus aureus* belong to the monocotyledon. But it is -200~500μV and never “mV”, of the testing electric wave signals in 6 plants, which is quite difference with other publications’ [1-14].

### 3.2. The wavelet decomposing of 6 plants electric wave signal

The low and high frequency coefficient of 6 species plants are obtained and their decomposing results respectively show in figure 1-3. With the level changing from the low to high, it evidently displayed the detail component of each level, which represent the high frequency component of the plant electric wave signal. Through analyzing the high frequency coefficient, we can accurately detect the arisen position of the action electric wave, which was one type of the plant electric wave, just like the brain wave of animals.

### 3.3. The denoised signal of the six plants electric wave signal

The high frequency level also reflects the noise component of the plant electric wave signal, so, quantizing the high frequency coefficient of the wavelet decomposing of the plant electric wave by a threshold. In this article, the denoising threshold value is estimated by the standard deviation of the coefficients of the wavelet decomposing. Then it has been reconstructed of the quantized high frequency coefficient and the low frequency coefficient of the fifth level of wavelet decomposing for denoising plant electric wave signals. The denoised plant electric wave signal is shown in figure 4-6. Results indicate that the denoised signals can keep the pinnacle and the mutational site of the useful signal of plants well, and is of high degree of similarity with the original one.

![Figure 1](image1.png)

Figure 1. The three-dimensional diagram of 5 scale wavelet decomposing of *Crassula portulacea* (left) and *Jasminum sambac* (right) (original s, low frequency a5, high frequency d5, d4, d3, d2, d1).

![Figure 2](image2.png)

Figure 2. The three-dimensional diagram of 5 layer decomposing of wavelet of *Aloe vera* var. *chinensis* (left) and *Scindpsus aureus* (right) (original s, low frequency a5, high frequency d5, d4, d3, d2, d1).
Figure 3. The three-dimensional diagram of 5 layer decomposing of wavelet of *Catharanthus roseus* (left) and *Celosia cristata* (right) (original s, low frequency a5, high frequency d5, d4, d3, d2, d1).

Figure 4. The denoising plant electric wave signal of *Crassula portulacea* (left) and *Jasminum sambac* (right).

Figure 5. The denoising plant electric wave signal of *Aloe vera var. chinensis* (left) and *Scindpsus aureus* (right).

Figure 6. The denoising plant electric wave signal of *Catharanthus roseus* (left) and *Celosia cristata* (right).
4. Conclusions

Our research result shows that the waveform of the ‘db3’ wavelet is the most similar with the plant electric wave signal. It is not the higher decomposing level, the better decomposing effect. If the decomposing level is too high, there is perhaps distortion in the waveform. Through calculating and trying, the fifth level decomposing is the best. So, that is why we choose the ‘db3’ wavelet as the basis function, to decomposing 6 plant electric wave signals in 5 levels.

The wavelet analysis result of plant electric wave signals indicates that the signal is of the character changing in all frequency scale. The wavelet analysis is of the ability to express the local characteristic of the signal in both time and frequency domain, namely, there is of higher frequency resolution and lower time resolution in low frequency, there is of the higher time resolution and lower frequency resolution in high frequency. So, in the analysis of the plant electric wave signal, the wavelet analysis can evidently display the detailed component of it, and can express the character of it better in time and frequency domain, and can accurately detect the arisen position of the action electric wave. Through studying the frequency and the variation instance of the action electric wave, we can ascertain cases of the plant growth or disease. So, the wavelet analysis can be applied to the analysis of the plant electric wave signal as well.

There are -200~500μV of the electric wave signals in growing plants, that is, a measure of μV. After the wavelet analysis it will be become a significant signal for the physics research, and also to analyse physiological characters of plants.

Acknowledgments
We thank Mr. Leslie Chason, who teaches English at China Jiliang University for revising conscientiously this manuscript.

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