

The BP Network Classification Leafminer-infected Leaves Based on the Fractal Dimension

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Keywords: fractal dimension, BP Network, image processing, leafminer

Abstract. Leafminer is one of pest of many vegetables, and the damage may cover so much of the leaf that the plant is unable to function, and yields are noticeably decreased. In order to get the information of the pest in the vegetable before the damage was not serious, this research used a BP neural network to classify the leafminer-infected tomato leaves, and the fractal dimension of the leaves was the input data of the BP neural network. Prediction results showed that when the number of FD was 21 and the hidden nodes of BP neural network were 21, the detection performance of the model was good and the correlation coefficient (r) was 0.836. Thus, it is concluded that the FD is an available technique for the detection of disease level of leafminer on tomato leaves.

I. INTRODUCTION

The fractal dimension (FD) provides a quantitative index of the roughness of natural surfaces, and many other natural phenomena. It has been applied to many different areas in science and engineering such as graphical simulation of clouds or trees^[1], texture analysis of some images and material surfaces^[2], detection the brain MRI^[3], et al. Automatic ways, such as machine vision^[4] and artificial neural networks^[5] have been used to detect and recognise the parameters of agricultural pests and diseases.

Leafminer (*Liriomyza sativae* Blanchard) is a pest of many kinds of vegetable and ornamental plants, such as tomatoes, beans, peas, and various cucurbits. It had been spread out of the country since the first outbreak in China occurred in 1993^[6]. The damage may cover so much of the leaf that the plant is unable to function, and yields are noticeably decreased. In 1995, the leafminers caused a 30%~40% reduction of output in somewhere of China^[7]. In the past, many researches were found that the spectral range from 737 to 925 nm was useful for discriminating levels of infestation, especially at wavelengths 755 and 1400 nm, where the differences in reflectance between levels were the largest. Wu et al found that the wavelengths (771, 821, 891, 945, 1026, 1121, 1256, 1674, 1687 and 1933 nm) related with the damaged degree of the leafminer-infected leaves^[8, 9], and Wu et al. used the vis-near infrared spectra to detect gray mold of tomato leaves, they find when the number of primary PCs was 8 and the hidden nodes of BP neural network were 11, the detection performance of the model was good as correlation coefficient (r) was 0.930^[10].

In the past, chemical sprays have always been used against leafminers due to their protection within the plant. However, the layman often confuses leafminer damage with other leaf diseases and also does not know how bad the damage is. Thus, our objectives were to use leaf image data to determine the leaf damaged degree and the FD in diseased plants, and use the BP network to classify FD data of the tomato leaves.

II. MATERIALS AND METHODS

2.1 The BP network

The BP network, due to their excellent ability of non-linear mapping, generalization, self-organization and self-learning, has been proved to be of widespread utility in solving complex problems like pattern recognition and adaptation. The training of a BP network usually adopts a back-propagation algorithm, which is a kind of generalized form of the least-mean-squares

algorithm usually used in engineering. By using the algorithm-generalized gradient descent search technique, the back-propagation algorithm adjusts the weights of the network and the threshold of each neuron recurrently according to the criterion that the cost function is minimized.

2.2 Calculating the FD of the tomato leaves

Fractal feature is based on the fractional Brownian motion (FBM) model, which is a technique that combines both fractal and multi resolution image decomposition. The FBM is a part of the set of $1/f$ processes, which are the generalization of the ordinary Brownian motion $X(0)$. The FBM is non-stationary, zero-mean Gaussian random functions, which are defined as:

$$X(0) = 0 \quad (1)$$

$$P(X(t + \Delta r) - X(t) \leq x) = (2\pi)^{-\frac{1}{2}} (\Delta r)^{-H} \int_{-\infty}^x \exp\left[\frac{-u^2}{2(\Delta r)^{2H}}\right] du \quad (2)$$

Where $0 < H < 1$ is the Hurst coefficient that characterizes the FBM. t represent different observation times of the process X .

From the Eq. (2), the increment $X(t + \Delta r) - X(t)$ is steady, and its variance between the Δr^{2H} is in proportion, that is:

$$E[(X(t + \Delta r) - X(t))^2] = k\Delta r^{2H} \quad (3)$$

Where the H is the Hurst coefficient. Falconer^[11] had proved that the Hurst coefficient is $2 - H$ when the FBM is curve and $3 - H$ as the FBM is the curved surface. So, in order to compute the FD successfully involves estimation of H . Wu et al.^[7] used a novel computational modeling for estimating H . This paper also used this method to estimate the H value, and hence the FD,

2.3 Materials

The larvae of the leafminers were collected at the suburb, Beijing, China. And reared on potted tomato seedlings and honeys placed in cages (50cm length×50cm width×50cm height) fitted with 0.4×0.4mm mesh size insect-proof screens, at $T = 27 \pm 1^\circ\text{C}$, $\text{RH} = 70\% \pm 5\%$. Tomatoes were seeded in the 72-cell plug tray, and transplanted in plastic pots of 12 cm diameter and 10 cm height with one plant per pot, when the first leaf outspreaded. The pots were placed in a greenhouse (Greenhouse conditions were kept at: 25/20°C (winter), 30/25°C (summer); 70% RH; a photoperiod of 14 h light: 10 h dark.) to culture, watered and fertilized regularly to guarantee the plants to growth well. After the third leaf had outspreaded, the plants were placed in the screen cages containing a colony of adult leafminers which had hatched out already one day to infect leaves. 10 seedling pots were placed in the screen cage. After 12 hours, the pots were moved in the greenhouse to culture. 10 infected leaves were collected every time.

2.4 Computing the damaged degrees and the FD

The leaf image was taken by the Casio EX-Z3 camera in the natural light, and then processed to grey image, segmented and calculated the total leaf areas and the damaged leaf areas (it is shown in Fig. 1). At last, the damaged degree (DD) of the leaf was worked out by using the followed equation:

$$\text{DD} = (\text{The total leaf areas} - \text{The damaged leaf areas}) / \text{The total leaf areas} \quad (4)$$

The software Matlab 6.5 was used to compute H values with self-written programs, and then the FD. Then the FD values of different leaves were classified by the BP neural network.



Fig. 1 Tomato leaf image segmentations

(a. Original image; b. Image after segmented (the threshold was 137); c. Image excluded the damaged areas (the threshold was 75))

III. RESULTS AND DISCUSSIONS

3.1 H values and the FD of the leafminer -infected tomato leaves

When the leaves were infected by the leafminers, the leaf surface was damaged because they ate leaf mesophyll tissues (the leaf lost its chlorophyll, water, and other materials). From the Fig. 2, it is found that the H values are different with different computing steps. At some computing steps, the H values of the leaves are significantly different, so we can use the H values to classify the damaged leaves.

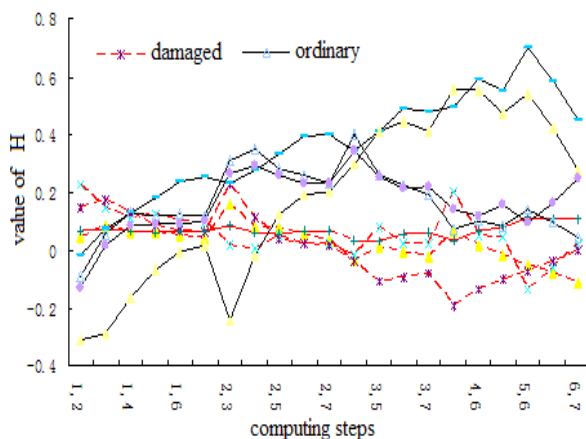


Fig.2 Hurst values of the tomato leaves with different computing steps

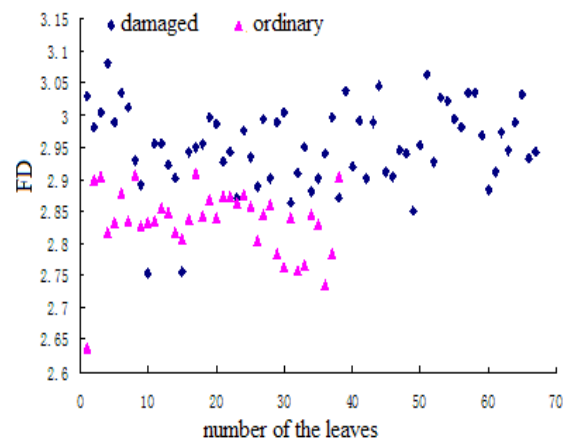


Fig.3 Fractal dimensions of tomato leaves

It is showed that the FD of the leafminer-infected leaves is different from the Fig. 3. The FD between the ordinary and the damaged leaf images has many intersections, so it is hard to classify by using the TM, while the TM can classify the leaves at some computing steps.

3.2 Thresholds classification (TM) based on the FD

The TM is good at the linear problem. From the table 2, the classification precision of the TM is the best (75%) at the (3,7) computing steps, and is the worst (35%) at the (3,4) computing steps. In a word, the classification precision is very low. So, at that step, the leaves can not be classified. Therefore, the nonlinear methods must be used to classify.

Tab. 2 Classification results of threshold methods based on the tomato leaf fractal dimensions

Steps	Thresholds H values	Correct number	Error number	Classification Precision%
2, 4	0.1494	66	9	50
2, 5	0.1561	66	9	63
2, 6	0.1823	69	6	63
2, 7	0.1832	70	5	50
3, 4	0.2297	70	5	25
3, 5	0.2067	68	7	50
3, 6	0.2349	67	8	63
3, 7	0.2267	69	6	75

3.3 The BP network classification based on the FD

The BP network is a powerful method for pattern recognition and is good at the nonlinear problems. The BP network has been applied as the recognising and classifying system. Fig. 4 was showed the results of the performance of the square errors of the BP network, and the NMSE is convergent. When the number of FD was 21 and the hidden nodes of BP neural network were 21, From the Fig.5, it was found that the recognition provisions were higher (the precisions were 83.6%) than the TM's.

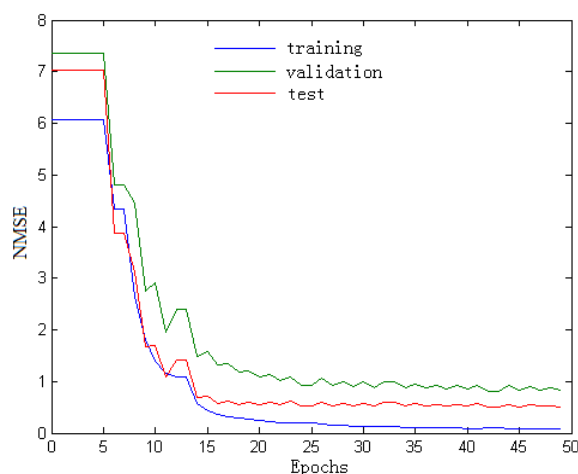


Fig. 4 The square errors of the BP network

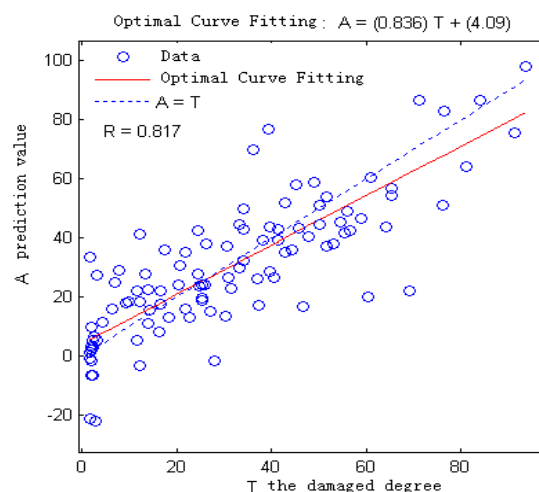


Fig. 5 The output of the BP network

IV. CONCLUSIONS

The paper has presented the FD of the leafminer-infected leaves recognising applications based on the TM and the BP network.

The proposed method has been tested on the samples. Two different kernel functions have been considered to set up the classifying models, and the FD of the damaged tomato leaf image was applied to the TM and the BP network performing of the recognition and classification. The classification precision of the TM is the best (75%) at the (3,7) computing steps, and is the worst (35%) at the (3,6) computing steps. The precisions of the BP network were 0.836 when the number of the FD was 21 and the hidden nodes of BP neural network were 21. From the experiment, we can use the BP network-based FD models to classify the tomato leaves infected by the leafminers.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial supported by the Fundamental Research Funds for the Central Universities (Grant No. XDJK2009C141 and XDJK2010C048).

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