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Mining Method of Crop Spectral and Image Correlation ModelBased on Spatio-Temporal Information

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Abstract

Abstract: When crop disease occurs, it is often displayed in the leaf, and the appearance and internal structure of the crop are changed, and the growth environment also has a certain influence on the disease. The growth environment, leaf RGB images and spectral images are fused to study the sparse feature recognition method of crop diseases based on information combination of multi spectral images. *In this paper, a spatial-temporal information mining method for crop spectral and image correlation models is studied. The correlation between spectral reflectance characteristics of crop diseases and crop development, health status and growth conditions are analyzed from time dimension, space dimension and spectral dimension, and disease characteristics is established.* The experimental results show that the fusion method of image processing and spectral imaging technology can achieve fast, accurate and nondestructive diagnosis in the early stage of disease.

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Mining Method of Crop Spectral and Image Correlation ModelBased on Spatio-Temporal Information

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Abstract: When crop disease occurs, it is often displayed in the leaf, and the appearance and internal structure of the crop are changed, and the growth environment also has a certain influence on the disease. The growth environment, leaf RGB images and spectral images are fused to study the sparse feature recognition method of crop diseases based on information combination of multi spectral images. *In this paper, a spatial-temporal information mining method for crop spectral and image correlation models is studied. The correlation between spectral reflectance characteristics of crop diseases and crop development, health status and growth conditions are analyzed from time dimension, space dimension and spectral dimension, and disease characteristics is established.* The experimental results show that the fusion method of image processing and spectral imaging technology can achieve fast, accurate and nondestructive diagnosis in the early stage of disease.

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基于时空信息的作物光谱图像相关模型挖掘方法

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摘要：作物病害表现在叶片形态上，且外观和内部结构发生变化，生长环境也对病害有一定的影响。*将生长环境、叶 RGB 图像和光谱图像融合，研究并提出一种作物光谱图像相关模型的时空信息挖掘方法，从时间维度、空间维度和光谱维度分析作物病害的光谱反射特征与作物发育、健康状况和生长条件的相关性，建立典型病害特征模型。*实验结果表明，图像处理和光谱成像技术的融合方法可以在疾病的早期阶段实现快速、准确和无损诊断。

关键词：高斯滤波；光谱信息；时空信息；时间维；谱维数
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Introduction

In the process of crop growth, due to the adverse ecological environment, such as oligo, low temperature, high humidity, and so on, it causes the disease to occur easily, so as to affect the crop yield and quality. Disease is one of the most important factors that restrict the stable development of crop quality and yield. In the early stage of crop infection or early disease, it is necessary to quickly, accurately,

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real-time and nondestructively judge the species of crop diseases and carry out accurate pesticide application.

The technology of image processing and recognition[1-2] and spectral analysis[3-4] have been used in the diagnosis of crop disease. It provides a powerful technique and means for the rapid, accurate and nondestructive diagnosis of crop disease. When crop disease occurs, it is often displayed in the leaf, and the appearance and internal structure of the crop are changed. Meanwhile, the growth environment has a certain influence on the disease. It is significant to integrate the growth environment, RGB images of leaves and spectral images, to study the relationship between spectra and images, to realize the early diagnosis and recognition of crop diseases, and to improve the real-time and accuracy of disease monitoring.

Digital image processing technology obtains a large number of good adaptability and robustness information from the obtained object image and carries out analysis and discrimination. The application of the research on agricultural production began in the late 1970s. Its main applications include the analysis of crop growth and monitoring of crop nutrient[5] by extracting the color features of the image, and identifying crops and non-crop objects in farmland, such as weeds, soil, pests, and other[6-7] according to the morphological characteristics of the extracted objects. The research of crop disease monitoring is mainly based on computer vision technology to extract the edge of crop tissue damaged by disease or to extract the edge of plant disease spot, and then calculate the damage degree according to the injured area and the number of injured areas and take corresponding prevention measures.

After the disease was infected, the chloroplast was destroyed, the photosynthesis was weakened, the water absorption and other functions declined, resulting in changes in the characteristics of the leaf spectrum and image texture, which showed the symptoms of leaf roll, leaf blight, dwarf crop, leaf large area withering and so on. Spectroscopic analysis has been applied to the monitoring of crop physiological indices[8]. Many scholars also use spectral reflectance index to study the growth of plants, such as the study of vegetation index, normalized vegetation index and various improved vegetation index[9], chlorophyll pigment content index[10], and so on. Malthus and other[11] studied the reflectance spectra of soybean and Vicia speckled spores infected by the ground physical spectrometer and found that the first order reflectance of the speckled grape was high, which could be used to monitor the occurrence of infection of diseases and pests. Adams, et al. [12] studied the evaluation of the disease by using the yellow index of the two derivatives of the spectrum of soybean wilt disease. Muir, et al. [13] studied the spectral reflectance of potato tubers infected with disease but not yet observed at the naked eye to achieve early diagnosis. Wu Shuwen[14] studied the effect of rice leaf blast on the spectral characteristics of rice. It was found that the canopy spectral reflectance of green light area, red light area and near infrared region decreased, increased and decreased with the severity of the disease. Cao Xueren[15] detected and compared the canopy spectral reflectance and various spectral parameters of two kinds of winter wheat infected with powdery mildew, and found that the peak area of red edge was the most sensitive spectral parameter for powdery mildew detection.

In order to analyze the physiological status of each part of the infected crop more accurately and

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deeply, in this paper, a method of mining the correlation model of crop spectrum and image based on spatio-temporal information is studied. The correlation between spectral reflectance characteristics of crop diseases and crop development, health status and growth conditions are analyzed from time dimension, space dimension and spectral dimension, and the correlation model between spectral characteristics, environmental perception data and disease characteristics is established.

1 Analysis of spectral and image association rules of crop disease

According to the characteristics of disease data, multi-dimensional, multi-scale, non-stationary, uncertain and cyclical models are combined. In this paper, the spectral information and the sparse feature related to the disease are excavated on different time axes, and the pixel features and spectral bands of the disease parts are extracted, and the correlation model of the monitoring time, spectrum and image of different types of crop disease infection is established. Different kinds of diseases are classified and studied, and "self-learning" of various index data of crop diseases are "self-learning", and the fuzzy matrix calculation method of different dimensions is used to reduce the influence of redundant information.

1.1 Image set description of crop disease

Most of the disease symptoms are more or less displayed on the leaf of the crop, changing the color, shape and texture of the leaves, and the distribution of the disease spots and markings. Using this feature, the computer vision technology has been widely used in the nondestructive testing of crop diseases.

In this paper, the disease image recognition technique based on the significant area and hierarchical index as an example. This technique can extract color, texture and shape features in key disease areas of crop images. It makes full use of similarity searching of clustering index and can provide quick crop disease recognition.

As an algorithm based on local autocorrelation function analysis of images, Harris operator has good robustness in image rotation, brightness variation, change of view and noise reduction. Angular point is determined by analyzing the autocorrelation matrix of eigenvalue autocorrelation function surrounding pixels. To increase the detection sensitivity of interest points, image seems as three-dimensional image, so it calculated gradient on z direction of the image while maintaining same gradients on x and y directions. Next, Gaussian filtering of image was implemented to define the autocorrelation matrix between the disease region and surrounding background (M).

$$M = G(\partial) \otimes \begin{bmatrix} g_x^2 & g_x g_y & g_x g_z \\ g_x g_y & g_y^2 & g_y g_z \\ g_x g_z & g_y g_z & g_z^2 \end{bmatrix} \tag{1}$$

$$g_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} g_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} g_z = \begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{bmatrix} \tag{2}$$

where $G(\partial)$ is Gaussian weighting marks; g_x, g_y and g_z are gradients on x, y and z directions, respectively. The eigenvalue of M is the first-order curvature of the autocorrelation function. Eigenvalues of adjacent pixels in the crop disease image were calculated and viewed as the evaluation index of salient points has sudden change between scab and surrounding background. If eigenvalues of two adjacent pixels are small, no salient point exists. If one eigenvalue is large, pixel only changes greatly on one direction. If both eigenvalues are large, gradients on x, y and z directions all change significantly, and the corresponding point shall be marked as salient point. The measurement formula of

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salient point is:

$$H = \det(M) - \frac{\det(M)}{trace} \bullet trace^2(M) = [I_x^2 I_y^2 I_z^2 - (I_x I_y I_z)^2] - \frac{[I_x^2 I_y^2 I_z^2 - (I_x I_y I_z)^2]}{I_x + I_y + I_z} \bullet (I_x^2 + I_y^2 + I_z^2) \quad (3)$$

where H is the significant pixel; det is the determinant of a matrix; trace is the trace of matrix on x, y and z directions.

Red points in Fig. 1 are salient points determined by improved Harris operator. Experiment demonstrates that not more salient point is better. As salient point increases, some less salient points will be involved in computation, which will lower recognition efficiency and accuracy.

Fig. 1 Image set description of crop disease

1.2 Spectral description of crop disease

The spectral technology can collect the unperceived band of the naked eye. After the crop is infected, the chloroplast is destroyed, the photosynthesis is weakened, the water absorption and other functions decline, which leads to the changes in the characteristics of the leaf spectrum and image texture, and presents the symptoms of leaf roll, leaf blight, crop dwarf, leaf large area withering and so on.

In this paper, the wavebands which can best reflect the differences between different diseases are analyzed, and the optimal values corresponding to disease types are selected. First of all, according to the corresponding bands of different diseases, an unstable index is calculated in the same band of the 1 day and 24 hours of crop spectral samples. If the samples involved in the operation belong to two kinds of diseases, the inter class instability index is:

$$C_i = \frac{\Delta within, i}{\Delta between, i} = \frac{S_{1,i} + S_{2,i}}{|m_{1,i} - m_{2,i}|} \quad (4)$$

Among them, C_i is the class of instability index of two kinds of diseases in i band. $\Delta within, i$ is intra class deviation, $\Delta between, i$ is inter class deviation, $S_{1,i}$ and $S_{2,i}$ are the first diseases and the standard deviations of the second diseases at the i band. $m_{1,i}$ and $m_{2,i}$ are the mean values of spectral reflectance of the first category of diseases and second kinds of diseases at the i band. It can be seen from the formula that the smaller the intra class deviates , the greater the inter class deviates and the smaller the inter class instability index.

1.3 Correlation analysis of spectrum and image

The association rules of the image set I are defined as:

$$P_1 \Lambda P_2 \Lambda \cdots \Lambda P_n \rightarrow Q_1 \Lambda Q_2 \Lambda \cdots \Lambda Q_m (c\%) \quad (5)$$

Among them, $P_1, P_2, \cdots P_n$ are the description words of I respectively, including image size, color, texture, object, spatial location, spectral wavelength, sampling environment and so on. $Q_1, Q_2, \cdots, Q_m$ are typical disease characteristics of greenhouse vegetables respectively , $c\%$ indicates the credibility of the rules. When $P_1, P_2, \cdots P_n$ happens, $Q_1, Q_2, \cdots, Q_m$ will occur. The probability of each description in the description word $\{P_1, P_2, \cdots P_n\}$ in the whole image set is $\sigma(P_i / D)$. Take $M = \max\{\sigma(P_i / D)\}$, $N = \min\{\sigma(P_i / D)\}$, according to the maximum and minimum of the probability of the description word, select the minimum correlation degree of multiple description words, and the corresponding rule of the description word that the resume satisfies the minimum correlation degree.

$$\begin{aligned} &P_1 \to P_2 \wedge P_3 \wedge P_4 \\ &P_1 \wedge P_2 \to P_3 \wedge P_4 \\ &P_1 \wedge P_2 \wedge P_3 \to P_4 \\ &\ldots\ldots \end{aligned} \quad (6)$$

The rule reliability is calculated by conditional probability:

$$C = p(P_1 \mid P_2 \wedge P_3 \wedge P_4) = \frac{\sigma(P \wedge P_2 \wedge P_3 \wedge P_4)}{\sigma(P_1)} \quad (7)$$

According to the above association rules, the correlation model of crop growth period, sampling time and disease characteristics was established in time dimension, according to the disease characteristics of different crop growth period, the dynamic monitoring of crop growth, and the extraction of spectral index time series. In spectral dimension, the similarity between one pixel and its adjacent pixels in each spectrum is analyzed, and the correlation model of disease type, disease degree and spectral band is constructed. In space dimension, the mining of multi-source and heterogeneous information, such as real-time environmental perception data, disease RGB image data, etc., is used to construct the association model of environmental parameters and disease characteristics. Ref Fig. 2 the correlation model of time dimension, space dimension and spectral dimension is fused, the spatial relation of environment / image / spectrum is extracted, spatial knowledge of the disease type and the influence of spectral redundancy are reduced, and the important gray image information of crop disease recognition is preserved to the maximum, and it is used for the establishment of crop disease decision model.

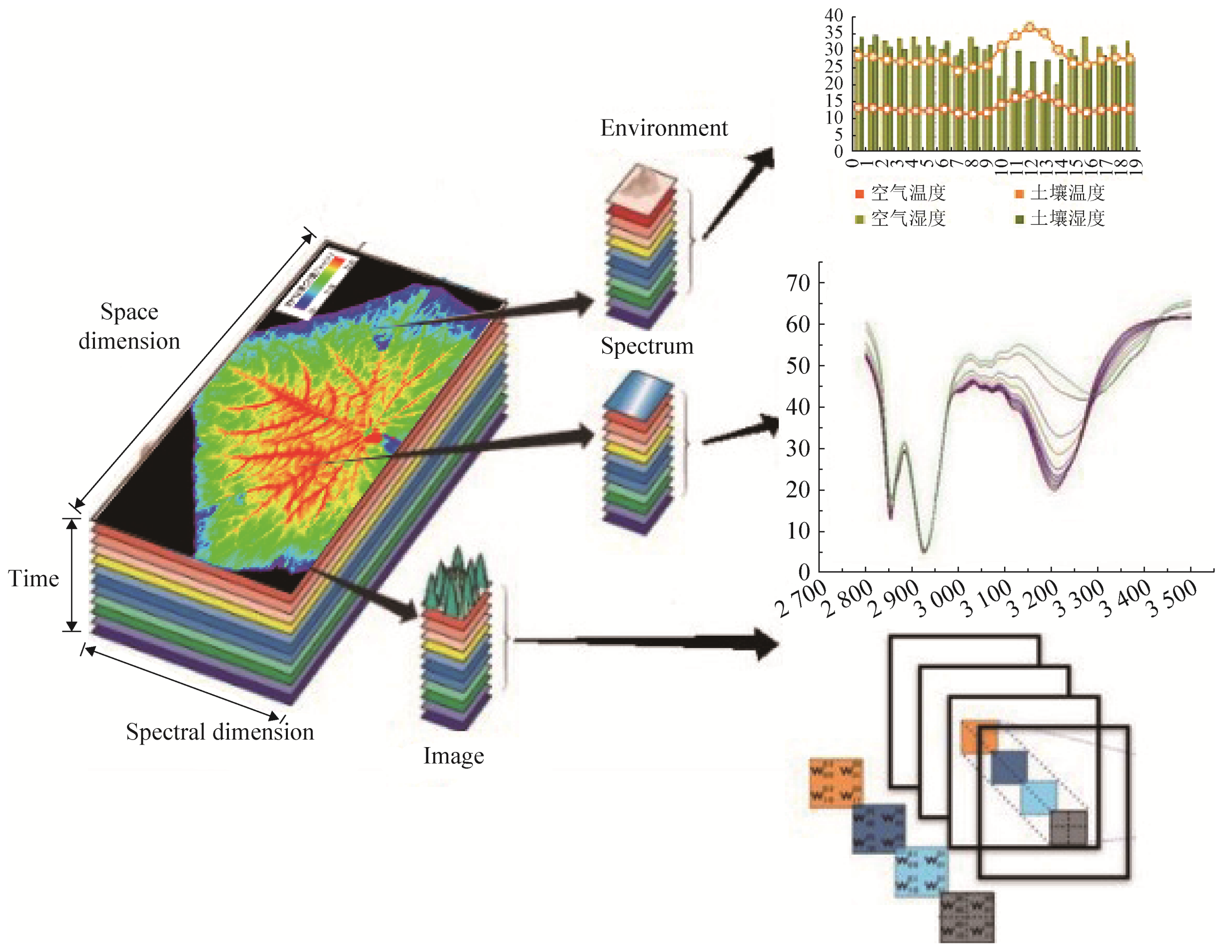

Fig. 2 Association rules of crop spectrum and image information

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2 Experimental results and analysis

The most typical diseases were green leaves, yellow leaves and disease leaves. The spectral reflectance values of different wavelengths were calculated as flowing in Fig. 3. All leaves were collected by ADC digital agricultural multispectral imager. ADC can obtain visible and 920 nm near-infrared rays with wavelengths above 400 nm.

Fig. 4 is the spectral reflectance curve of the leaf spot data. It can be seen that the overall shape of the spectral reflectance curves of different bands is similar, and the spectral noise is larger in the range of 400 nm-450 nm, so only 55 bands between 450-750 nm are analyzed.

For training samples, 200 samples are in the range of 450 nm-720 nm. The characteristic wavelengths of yellow leaves, disease leaves and green disease-free zones were discriminated and analyzed, and the spectral reflectance values of different bands were obtained as shown in Tab. 1.

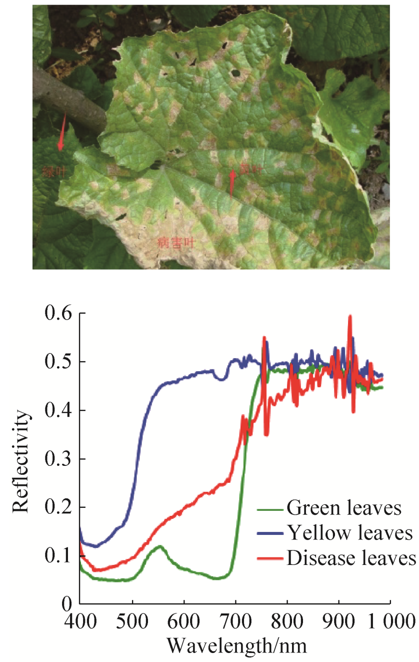

Fig. 3 Spectral reflectance of green, yellow and disease leaves

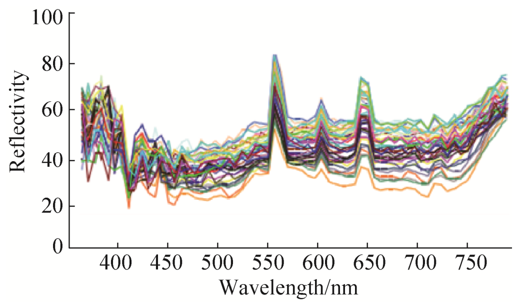

Fig. 4 Spectral reflectance of cucumber angular leaf spot

Tab. 1 Reflectance of the sample in characteristic bands

sample	name	Characteristic bands (nm)					
		460	540	620	700	705	720
Training sample	Yellow leaves	40.81	40.51	45.01	54.16	55.93	63.56
	Disease leaves	33.3	37.91	38.45	51.95	52.61	66.92
	Green leaves	27.66	20.23	11.19	25.45	31.70	56.82
Test sample	Yellow leaves	36.73	37.30	38.83	51.09	54.82	65.13
	Disease leaves	43.08	46.69	54.15	55.35	61.07	67.35
	Green leaves	31.31	19.03	12.08	23.67	32.86	48.01

3 Conclusion

Early, rapid and accurate diagnosis of disease is the key to effectively control the occurrence of disease. The characteristics of crops are diverse and complex, and the growth process is a dynamic process. The dispersion of single characteristics is large, so it is difficult to make an ideal judgement of the disease species. At the same time, the growth

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process is affected by the change of illumination, which is not conducive to image acquisition. When using artificial light source, it will also cause disturbance to crop growth. Especially when the intensity of illumination is high, it is difficult to obtain good quality images. Unstructured disease detection, it is difficult to meet the actual requirements of production simply by spectral technology or image processing technology. In this paper, the combination of time series representation and classification learning is used to analyze the spectral data of crops and to excavate the spectral information and image information related to the disease from different dimensions. The integration of image processing and spectral imaging technology is applied to the diagnosis of crop diseases to achieve rapid, accurate and nondestructive diagnosis of vegetable diseases.

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