Monitoring Methods of Crop Diseases and Pests Based on Hyperspectral Technology

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***Abstract*— It has important significance to improve monitoring the diseases and pest level and to maintain food security and ecological environment protection in China. There is a distinct difference on the chlorophyll content between the disease and health leaves after analyzing. Therefore the following bands, 470nm, 550nm, 635nm, 680nm, 800nm, sensitive to chlorophyll are used to monitoring the disease leaves. Combined with the measured chlorophyll content, the model for estimating chlorophyll content is constructed. The model can be used evaluating the extent of the wheat rust. The research of the canopy scale is based on the quantitative analysis on the first-order differential spectrum characteristics of the disease and health canopy. The following parameters, Db, Dy, Dr, Dinr, Rg, Ro, SDr/ SDb and SDinr/ SDb, are selected as hyperspectral characteristic parameters to diagnose the wheat yellow rust disease.**

Keywords- monitoring method;corp diseases; inspecting pests hyperspecrral technology

I. INTRODUCTION

As a large, fast, no damage, no pollution monitoring technology, remote sensing monitoring can realize the unity of the economy, society and environment. In Lucas's [1] paper, the author take Xiangfan district in Hubei province as a case, the method of the application of satellite remote sensing technology in pest monitoring was studied. The model can be used evaluating the extent of the wheat rust. The research of the canopy scale is based on the quantitative analysis on the first-order differential spectrum characteristics of the disease and health canopy. Through the correlation analysis between the average temperature, average maximum temperature, average minimum temperature and the rate of the winter-wheat yellow rust, the results indicate that: The main habitat factor influence the winter-wheat yellow rust occurrence is the month average maximum temperature in January, February, June and July, while the influence of the precipitation is less. Also causes a brief analysis. A forecasting model of the winter-wheat yellow rust occurrence is established according to the historical material, which can as the assistance method to monitoring the winter-wheat yellow rust. Remote sensing monitoring on the vegetation index is studied. The vegetation index NDVI was adopted for monitoring by comparison on various vegetation indexes. The TM image was selected on April 8th 2004 in Xiangfan Hubei province. First, winter-wheat is divided into three types using supervised classification method. Then the NDVI value is calculated. The winter-wheat health status can be determined. The results showed that NDVI can be used to identify the health and disease region. It is in accord with the occurrence area.

It has important significance to improve monitoring the diseases and pest level and to maintain food security and ecological environment protection in China. As a large, fast, no damage, no pollution monitoring technology, real time monitoring based on wireless sensor networks can realize the unity of the economy, society and environment. In this paper, we take rice diseases and pest monitoring as a case, the method of the application of WSN technology in pest monitoring was studied. In Stoddard's paper [2], WSN application in diseases and pest monitoring. There is a distinct difference on the chlorophyll content between the disease and health leaves after analyzing. Therefore WSN technology is used to monitoring the disease leaves. Combined with the measured chlorophyll content, the model of crop diseases and pest monitoring based on wireless sensor networks is constructed. The model can be used evaluating the extent of the diseases of rice. Through the correlation analysis between the average temperature, average maximum temperature, average minimum temperature and the rate of the rice, the results indicate that: the main habitat factor influence the diseases of rice occurrence is the month average maximum temperature in January, February, June and July, while the influence of the precipitation is less. Also causes a brief analysis. A forecasting model of the diseases of rice occurrence is established according to the historical material, which can as the assistance method to monitoring the diseases of rice. Hardware and software of WSN is discussed in Charles's paper [3]. According to the hardware architecture of WSN node, the processor module, wireless communication module, sensor modules and energy supply module of node have been designed. At the same time, according to the requirement of low cost, a new WSN node has been designed to optimize the performance of node. The agriculture remote monitoring system, using the nodes designed above, has run long-term in agricultural base of Hunan suburbs. The sensor nodes in this system have acquired the temperature, light, air humidity and other information. Through the analysis and evaluation of test data, time delay, network flux and other information in this system, this system has been proved feasibility and effectiveness. At last, it also summarizes the paper's main task and anticipates the more research aspects.

II. THE FRAMEWORK OF MONITORING METHOD OF CROP DISEASES AND PESTS

A rolling forecasting model of crop diseases and pests was studied using CBR theory with the time series and a system for diagnosis of wheat and rice diseases and insect pests of Anhui province was developed in Tamis' paper [4]. Impact factors and parameters of plant diseases and pests in Anhui province were optimized. Monitoring and prediction of crop pests and diseases is the basis of integrated pest management. A New method, based on case-based reasoning (CBR) in time series data similarity analysis, was studied used in the forecast of crop diseases and pests. The case-based reasoning method solves a new problem by searching the previous similar problems and comparing characteristics and the background between new and old problems to get knowledge and information. The CBR forecasting of main diseases and insect pests of rice and wheat was studied combining with weather characteristics of various ecological regions, geographical location and the happening situation of pest. First, established a time series data case, then constructed the similarity matching specifications and weight parameters according to the specified or preset factors function, and calculated the agreement rate of each historical case, finally selected the history case with the highest agreement rate as prediction conclusions. In addition, the future forecast data can also be added to the target case. CBR forecasting factors and parameters of Wheat scab, wheat powdery mildew, wheat sheath blight, wheat aphids, rice sheath blight, rice blast were optimized, with the percentage of the results' corresponding to historical data were above80%. And the agreement rate of Wheat scab of great outbreak was about 70%. The predicted parameters have certain reliability and can be used as the basis for CBR models to predict crop diseases and insect pests. Knowledge base of diseases and pests of rice and wheat in Anhui province was set up by means of Visual Basic6.0. Written materials and picture data of common diseases and insect pests of rice and wheat in Anhui province were collected, including symptom pictures of different diseases in different crops. Combine the written materials and symptom pictures by computer language to make the recognition and diagnosis easier. Running the system in properly condition, choosing the needed item or inputting necessary information, the users could achieve satisfactory running effect. The knowledge base can offer a reliable basis for the plant protection staff with its characteristics, such as complete types, easy to understand, simple operation, strong practicability [5].

The figure 1 shows the principle and model of crop diseases and pests (The wave filter tree a and tree b are real part and imaginary part of the transform. 2 means sampling every other one point.)

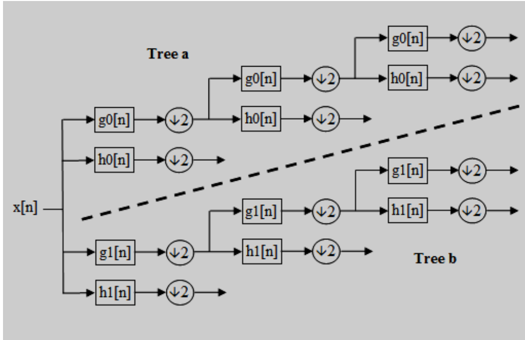

Figure 1. The principle and model of crop diseases and pests (The wave filter tree a and tree b are real part and imaginary part of the transform. 2 means sampling every other one point.)

It has important significance to improve monitoring the diseases and pest level and to maintain food security and ecological environment protection in China. As a large, fast, no damage, no pollution monitoring technology, real time monitoring based on wireless sensor networks can realize the unity of the economy, society and environment. Figure 2 shows the impulse response (Only the Real Pest).

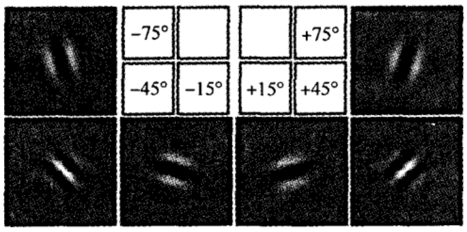

Figure 2. The impulse response (Only the Real Pest)

III. THE MODEL OF MONITORING METHOD OF CROP DISEASES AND PESTS AND HYPERSPECTRAL TECHNOLOGY

With the purpose of meeting the needs of the standardization of pest's data, and the demands of daily work of the plant protection, by using technology such as computer network, database and geographic information system, in order to mixing diseases and insect pests' survey, data transmission and management, prediction and control information publishing in the same system, a web-based universal platform for monitoring and early warning system of main diseases and insect pests was built by the open source software (Linux + Apache + PHP + MySQL), its purpose is to provide timely and accurate information service for agricultural disease and pest control, it contains data management module, expert system module, model library module, early warning module and user management module.

A Web-based data management system of agricultural diseases and insect pests was built by the latest network programming technology for the effective management and use of various diseases and pests' information. It is able to process the data submission, review, publish, and generate charts and statistics. Excel file can be efficiently used for import and export at the same time. It is convenient for plant protection worker, also has realized the centralized management of the information data, and provides a good prediction tool for agricultural diseases and insect pests [6].

The system uses dynamic and interactive web page technology and relational database technology; the user can interact with this system which stores several prediction expert knowledge bases by the reasoning machine. System maintenance is simple and clear. The system can add or change the dynamic data and has a good application prospect. A general model management system was built by object-oriented way. Each model in this system is described by PHP file. This system supports model description, operation and maintenance. And it can be used as a generic plant diseases and insect pests forecasting model management system. This system has realized the dynamic monitoring for data, according the model match result, warning information will send to the user when the forecasting has finished. The system design is flexible and easy to use. The system can be used as a general platform for the plant diseases and insect pests of early warning. This system can give each user or role different permissions, so that it can limit the sensitive data access behavior of the system for maximum protection. Development of this system solves the problems: management and information sharing difficulties, the areas scattered data and forecasting timeliness. It laid a foundation for development of decision support system for agricultural diseases and insect pests.

The agriculture remote monitoring system, using the nodes designed above, has run long-term in agricultural base of Hunan suburbs. The sensor nodes in this system have acquired the temperature, light, air humidity and other information. Through the analysis and evaluation of test data, time delay, network flux and other information in this system, this system has been proved feasibility and effectiveness.

Design and construction of regional integrated database system for CBW according to the national industry forecasting criterion of Helicoverpa armigera Htlbner [7], and characteristics of agricultural environment, the database of cotton bollworm(CBW) is developed based on Microsoft SQL server. Which contain fourteen sheets for CBW biological data and environment index. Five kinds of input-data ways are put forward based on database framework, a) based on Microsoft SQL server; b) based on heterogeneous database and processed for batch data (Excel, Foxpro, Access); c) based on Microsoft Web; d) based on CBWMIS (PC vision, CBW management information system) which is developed by our group; e) input data of farm environment index and CBW dynamic which are collected through GPRS (General Packet Radio Service) or telephone modem in automatic mode. Owing to the expensive cost of Internet communications, the system of CBWMIS is considered for inputting data and transmitting information. During forecasting system is used, it is necessary for old and new system to operate several years at the same time, and to modify new system and establish the relationship between the two systems. Additionally, those can provide key parameters for new system and guarantee the old system to displace with new system safely and successfully.

Written materials and picture data of common diseases and insect pests of rice and wheat in Anhui province were collected, including symptom pictures of different diseases in different crops. Combine the written materials and symptom pictures by computer language to make the recognition and diagnosis easier. Running the system in properly condition, choosing the needed item or inputting necessary information, the users could achieve satisfactory running effect.

IV. THE ALGORITHM

Every year crop diseases and pests bring huge losses to global food production. Field artificial measurement and identification are both time consuming and laborious, and it is lag and will easily miss the best control period. Monitoring the crops health status based on spectral data is fast, high efficient and nondestructive, which could provide a powerful support for solving the problems of crop production with depressiveness, territoriality, spatial and temporal variability. This paper summarized the theory of monitoring crop diseases and insect pests by spectrum, and reviews in detail the research progresses achieved in relevant technology from 2 aspects of imaging and non-imaging spectrum. It also introduced some vegetation indices for monitoring diseases and insects. Before ending, the paper discussed the algorithm to deal with the hyperspectral image. The algorithm is set to disposal and captures the basic data from the hyperspectral image. It is shown below [8].

Fix the sub-dictionary $\mathbf{D}_k$ to convert the full-waveband data of each cube $\mathbf{p}_m^{(k)}$ ($m = 1, 2, \cdots, M_k$) into minimization problem

$$\min_{\boldsymbol{\alpha}_m^{(k)}} \quad \frac{\lambda}{2}\left\|\mathbf{p}_m^{(k)} - \mathbf{D}_k \boldsymbol{\alpha}_m^{(k)}\right\|_F^2 + \left\|\boldsymbol{\alpha}_m^{(k)}\right\|_* \tag{1}$$

Then, the optimization problem is actually converted into minimization problem. After auxiliary matrix $\boldsymbol{\beta}$ is introduced, formula (1) is equivalent to

$$\begin{aligned} &\min_{\boldsymbol{\alpha}_m^{(k)}} \quad \frac{\lambda}{2}\left\|\mathbf{p}_m^{(k)} - \mathbf{D}_k \boldsymbol{\beta}\right\|_F^2 + \left\|\boldsymbol{\alpha}_m^{(k)}\right\|_* \\ &s.t. \quad \boldsymbol{\alpha}_m^{(k)} - \boldsymbol{\beta} = 0 \end{aligned} \tag{2}$$

The corresponding augmented Lagrange function is

$$\begin{aligned} L(\boldsymbol{\alpha}_m^{(k)}, \boldsymbol{\beta}, \mathbf{Z}) &= \left\|\boldsymbol{\alpha}_m^{(k)}\right\|_* + \frac{\lambda}{2}\left\|\mathbf{p}_m^{(k)} - \mathbf{D}_k \boldsymbol{\beta}\right\|_F^2 \\ &+ \left\langle \mathbf{Z}, \boldsymbol{\alpha}_m^{(k)} - \boldsymbol{\beta} \right\rangle + \frac{\mu}{2}\left\|\boldsymbol{\alpha}_m^{(k)} - \boldsymbol{\beta}\right\|_F^2 \end{aligned} \tag{3}$$

Then, the minimization problem of formula (4) is converted into the minimization problem of Lagrange function.

$$\min_{\boldsymbol{\alpha}_m^{(k)}, \boldsymbol{\beta}, \mathbf{Z}} \quad L(\boldsymbol{\alpha}_m^{(k)}, \boldsymbol{\beta}, \mathbf{Z}) \tag{4}$$

The rapidly converged alternating direction method (ADM) is used to solve the above corresponding optimization problem, with the specific steps as follows. The following iteration format of $\boldsymbol{\alpha}_m^{(k)}$ is solved through singular value thresholding (SVT):

$$\boldsymbol{\alpha}_m^{(k)} = \mathbf{U}\Gamma_{u^{-1}}(\mathbf{S})\mathbf{V}^T \tag{5}$$

Therein, $(U,S,V) = SVD(\beta - u^{-1}\mathbf{Z})$, $\Gamma_{1/u}(x)$ is:

$$\Gamma_{1/u}(x) = \begin{cases} x - 1/u & if\ x > 1/u \\ x + 1/u & if\ x < 1/u \\ 0 & other \end{cases}$$

Availably, the iteration formats of $\boldsymbol{\beta}$ and $\mathbf{Z}$ are

$$\boldsymbol{\beta} = \left(uI + \lambda\left(\mathbf{D}_k\right)^T \mathbf{D}_k\right)^{-1} \left(u\boldsymbol{\alpha}_m^{(k)} - Z + \lambda\left(\mathbf{D}_k\right)^T \mathbf{p}_m^{(k)}\right) \tag{6}$$

$$\mathbf{Z} = \mathbf{Z} - u\left(\boldsymbol{\alpha}_m^{(k)} - \boldsymbol{\beta}\right) \tag{7}$$

The coefficient matrix $\boldsymbol{\alpha}_m^{(k)}$ can be obtained through the iteration of formulae (5), (6) and (7).

Through coefficient matrix $\boldsymbol{\alpha}_m^{(k)}$, formula (7) is into:

$$\min_{\mathbf{D}_k} \left\|\mathbf{p}^{(k)} - \mathbf{D}_k \boldsymbol{\alpha}^{(k)}\right\|_F^2 \tag{8}$$

Therein, $\mathbf{p}^{(k)} = \left[\mathbf{p}_1^{(k)}, \cdots, \mathbf{p}_{M_k}^{(k)}\right]$ and $\boldsymbol{\alpha}^{(k)} = \left[\boldsymbol{\alpha}_1^{(k)}, \cdots, \boldsymbol{\alpha}_{M_k}^{(k)}\right]$. The analytical solution expression of above problem is:

$$\mathbf{D}_k = \mathbf{p}^{(k)}\left(\boldsymbol{\alpha}^{(k)}\right)^T \left(\boldsymbol{\alpha}^{(k)}\left(\boldsymbol{\alpha}^{(k)}\right)^T\right)^{-1} \tag{9}$$

The section will describe the detailed steps of the algorithm in the article, as shown in algorithm 1.

Algorithm 1: the algorithm based on nonlocal low rank dictionary learning

Algorithm input: noisy hyperspectral image $\mathbf{Y} \in R^{W \times H \times S}$;

Initialization: initial dictionary $\mathbf{D}^{(0)}$;

Step 1 Divide hyperspectral image into N mutually overlapped cube full-waveband data $\{\mathbf{p}_n\}$;

Step 2 Divide all $\mathbf{p}_n$ into K types through K-average value clustering algorithm;

Step 3 Solve the nonlocal low rank dictionary learning models (9) of K types to obtain the coefficient matrix $\boldsymbol{\alpha}_n$ of $\mathbf{p}_n$ and the corresponding sub-dictionary $\mathbf{D}_n$;

Step 4 Estimate the full-waveband data $\hat{\mathbf{p}}_n = \mathbf{D}_n \boldsymbol{\alpha}_n$ of each cube, joint them according to the positions thereof and average the overlapped parts of the cubes to recover the value $\hat{\mathbf{X}}$.

Output result: $\hat{\mathbf{X}}$.

Note of algorithm 1:

(a) Selection of initial dictionary $\mathbf{D}^{(0)}$: such rapidly realized data dictionary as DCT dictionary and wavelet dictionary shall be selected as initial dictionary $\mathbf{D}^{(0)}$.

(b) Selection of parameter λ : regard the nonlocal low rank dictionary learning problem as multiobjective optimization problem in order to obtain the parameter through α- method.

V. THE ALGORITHM

The experiment aims at showing the influence of the performance of monitoring the pests in full-waveband data (abbreviated as cube) on algorithm performance. The hyperspectral remote sensing image in Pest Experiment is added with Gaussian noise, the mean square errors are respectively as $\sigma = 20$ and $\sigma = 30$, the number of overlapped pests cube is changed from 0 to 7, and other simulation conditions are not changed. PSNR value (mean value of all waveband) of the algorithm in the article when the number of the overlapped pests is changed is as shown in Fig. 3. According to Fig. 3, along with the increased number, the algorithm performance is gradually improved, and when the number of pests index is more than or equal to 6, the algorithm performance is stable.

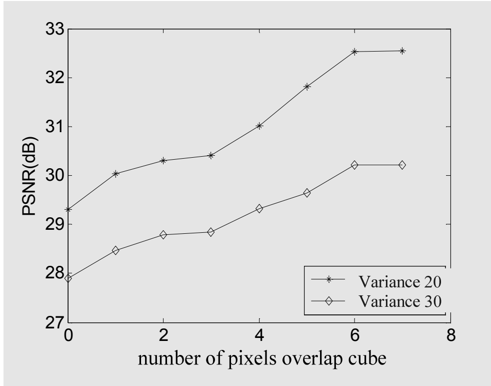

Figure 3. Influence of Overlapped Pests

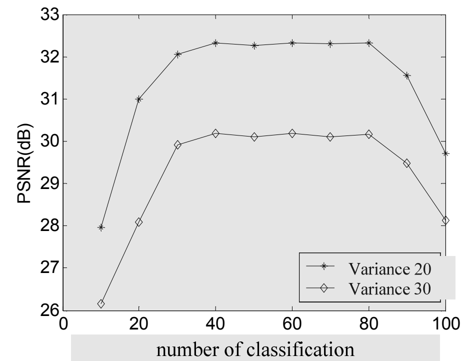

Figure 4. Influence of Number

VI. CONCLUSION

It has important significance to improve monitoring the diseases and pest level and to maintain food security and ecological environment protection in China. There is a distinct difference on the chlorophyll content between the disease and health leaves after analyzing. It has important significance to improve monitoring the diseases and pest level and to maintain food security and ecological environment protection in China. As a large, fast, no damage, no pollution monitoring technology, real time monitoring based on wireless sensor networks can realize the unity of the economy, society and environment. The model can be used evaluating the extent of the wheat rust. The research of the canopy scale is based on the quantitative analysis on the first-order differential spectrum characteristics of the disease and health canopy. The experiment result shows that along with the increased number, the algorithm performance is gradually improved, and when the number of pests index is more than or equal to 6, the algorithm performance is stable.

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