Research of the Early Warning Analysis of Crop Diseases and Insect Pests

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Abstract. The early warning technology of crop diseases and insect pests is a strong guarantee to respond to the increasingly dire situation of major pests and diseases and ensure national food security. At present, the method of the monitoring data collection about the information of diseases and insect pests mainly relies on a field visit carried out by the plant protection staff, sampling and analysis, which directly impacts on the accuracy of early warning analysis. Firstly, the research status of the early warning analysis technology of crop diseases and insect pests in the field of agricultural are investigated and studied thoroughly and deeply, and then the comparison and analysis of the mainstream technology for pest and disease warning and algorithms are done in detail. The final combination of the technology of the Internet of things, a better pest early warning solution of the facility agriculture is put forward in order to provide a useful reference for the study of the early warning of crop pests.

Keywords: diseases and insect pests, early warning, facility agriculture, Internet of things, plant protection

1 Introduction

There are more than 1400 species crop diseases and insect pests in China. China is one of the countries that the plant diseases and insect pests occur frequently. The crop diseases and insect pests occur frequently each year and bring huge economic losses. At the same time, the problems of crop diseases and insect pests also exacerbated environmental pollution, food safety and other issues. Therefore, it is a particularly important work that ensuring the safety of China's agriculture to timely and effective monitoring, early warning and prevention and management. At present, China still lacks qualified experts and the traditional methods are still used by a majority of plant protection departments to detect the diseases and insect pests, manually fill in the survey data about crop diseases and insect pests, don not report to the higher authorities until the occurrence of diseases and insect pests and then the management work is begun. Most traditional approaches are inefficient, timeliness poor and can not make maximum use of existing data[1]. It has become an urgent problem to apply existing computer technology and communication technology in the field of detecting the crop diseases and insect pests to build an early warning system of the crop

diseases and insect pests. Combined the real-time data and historical data, the system will be able to make advance warning when the crop diseases and insect pests occur. And then the necessary protective measures are carried out in time, controlling the crop diseases and insect pests in the embryonic stage.
The paper summarized the existing theories and methods of early warning analysis for the crop diseases and insect pests, generalized existing early warning analysis algorithms and models and then made comparison and analysis in detail. Against a background of Internet of things, big data, cloud computing and other information technology, crop pest early warning analysis scheme based on real-time sensing data is put forward. The paper summarized various research methods to early warning analysis of the crop pests, providing a reference for the research and development of the early warning technology of the crop pests.

2 Warning analysis theory

2.1 The basic concept and theory

Early warning technology of the crop diseases and insect pests relies on the principles of the biology, ecology and mathematics, and it analyzes a variety of correlative factors collected from the historical figures and the present figures about the diseases and insect pests and estimates theirs future changes and development trend to achieve the purpose of reduce the catastrophic losses. It is the cornerstone of pest diagnosis and treatment to make accurate and timely pest early warning and early warning can improve the ecological environment[2]. Pest warning is to test the environment, pathogeny, individuals themselves, analyze the monitoring data obtained from the test and then predict the incidence according to the relationship between the impact factors. The system will send out warning information if there is a possibility of disease or the forecast data exceeds a certain threshold value.
In accordance with the warning category pest early warning can be divided into several aspects crop warning, livestock and poultry warning, aquatic product warning and forestry warning. The paper focuses on the research methods of the crop warning.
The process of the pest early warning can be divided into several stages: Firstly it is to determine the alarm, which can be inspected from two aspects. One is alarm pheromones that are the component of the early warning indicators. The emergence period, the prevalence rate, the order of severity and the state of an illness are generally as the alarm pheromones of the crop pests. The other is the extent of the warning situation, which usually be divided into five levels that are without warning situation, light warning situation, moderate warning situation, Severe warning situation, the serious warning situation. The second is to look the police sources. Each police source can be subdivided and that a police source will be picked out as the analysis focus should be in accordance with specific conditions. The third is to analyze the warning signs. Different alarms are corresponding to different warning signs. The warning signs can be understood as the proliferation of warning situation and the phenomena generated during the period of the proliferation. Fourthly, forecast the warning degrees, which is the purpose of the early warning. For improving the

warning degrees we should combine empirical methods and expert methods. Finally, it is to overcome the warning situation. Based on the principles of prevention first, integrated control and protection of the environment there are some recommendations of prevention for users.

2.2 Early Warning Methods

The early warning methods are a process logical thinking that is to collect data, sort out the data, generate the early warning information and then realize the early warning function. According to the statistical data there are more than 200 kinds of warning method so far.

On the basis of the methods and means of the early warning the methods can be divided into the expert experience method, the model method and the index method. The expert experience methods are mainly based on the past experience, adopt some mathematical models such as simulation experiments, the optimistic and pessimistic methods, competition theory and make use of the analogy methods to deduce the trend of development[3]. The model method is according to the dependent variables that are the state of an illness and the independent variables warning signs to establish early warning model. That is to say it processes the original data and gets the early warning information and expresses it.

According to the content of the early warning, the early warning method can be divided into the occurrence warning, the occurrence amount warning and the disaster degree warning .etc. The occurrence warning mainly alert the patent period or the dangerous period of the state and the level of plant diseases and insect pests. For the long-distance migratory pests and the pests which have the ability of diffusion behavior, it can alert the period when the pests move out and move in this locality and takes the date as the basis of determining the prevent periods.

The occurrence amount warning method estimates that whether the tendency of pests appeared in the future reaches the threshold which indicates that it is the time to prevention and cure through the means of forecasting the quantity of the vermin and the pest density in the field. However, it will not be credible if there does not exist a large number of data collected for many years.

The disaster degree warning method relies on the two methods in front. Combined arable farming and the outbreak of the pests to early warning the most sensitive period one crop to the pests, it judges whether the period absolutely coincides with the destructive power of the pests or not and estimates whether the invasiveness of the pests is identical to the period that there emerge more and more pests or not and finally deduce the degree of the plague and the size of the loss caused by the pests[4,5].

According to the timeliness of early warning, the early methods can be divided into four methods. They are short early warning, mid-term early warning, long-term early warning and extra long range early warning. Short Warning happens and warning the state after a few days when the pests emerge. The Mid-term early warning alerts the dynamics about a month later. Long-term warning makes warning about the dynamics of pests a few months later. Relying on the research of the law of development of the diseases and insect pests, Ultra-long warning explores the occurrence trend in the next year and ultra-long warning.

On the basis of the fundamental theory and early warning method of the agricultural pests and diseases, the paper builds the general framework[6] for early warning of the agricultural pest.

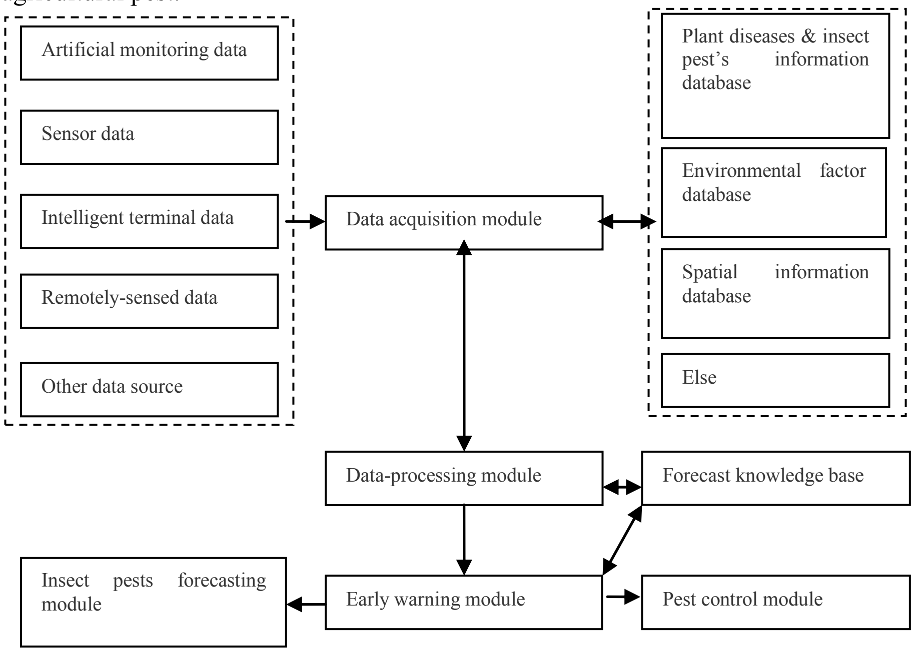

Fig. 1. the Overall Frame of the plant diseases and insect pests Warning

3 The algorithm and model of the warning analysis

3.1 The main early warning analysis algorithm

There are many algorithms for the pest warning analysis, such as the genetic algorithm, BP neural network, radial basis function neural network, rough set theory algorithm, information fusion algorithms and statistical algorithms. The warning models are built on the basis of these algorithms[7]. The following content gives a very brief overview of the several typical algorithms.

3.1.1 Rough set theory algorithm

Rough set theory algorithm is a new mathematical tool processing the vague and imprecise issues. For the border area thought the rough set is proposed and the individual that can not be confirmed are all belonged to the boundary line area. The area is defined as the difference set of the upper approximation set and the lower approximation set. Rough set theory processes and analyzes large amounts of data in the sets contained finite elements, gets rid of the compatibility information in accordance with the dependency relationship between two equivalence relations on the domain and then extracts potential and valuable rules and knowledge. Among them, the simplification and nuclear are two important concepts. The definitions of these basic concepts are given in the following.

Let U be the discourse domain, R is a indistinct relationship on the domain U. $X \subset U$, $R^*(X)$ shown in the formula(1)represents the upper approximation set of x and the lower approximation set $R_*(X)$ is shown in the formula (2).

$$R^*(X) = \{x \in U, R(x) \cap X \neq \phi\} \tag{1}$$

$$R_*(X) = \{x \in U, R(x) \subseteq X\} \tag{2}$$

ϕ is null set and $BN_R(X)$ represents the boundary of X and it is defined as formula (3).

$$BN_R(X) = R^*(X) - R_*(X) \tag{3}$$

For knowledge R, $R_*(X)$ is a set whose elements are not only contained in the domain U but must be included by X, $R^*(X)$ is a set whose elements are not only contained in the domain U but may be included by X and $B_{NR}(X)$ is a set composed of the remainder elements that not exit in the set X and $\overline{X}$ .The positive region of X is defined in the formula (4).

$$_{posR}(X) = R_*(X) \tag{4}$$

R is a equivalence relation and r represents any one element, $r \in R$. R can be simplified through formula (6) if the formula (5) is true. The function of ind() expresses indistinct relation. If R can not be simplified further, the simplification of R can be expressed as red(R).

$$ind(R) = ind(R - \{r\}) \tag{5}$$

$$ind(R) = ind(R - \{r\}) \tag{6}$$

The R's nuclear core(R) is defined ass the intersection of all the red(R), such as (7).

$$core(R) = \cap red(R) \tag{7}$$

Nuclear is included in all simplified clusters and it is the characteristic set that is can not be eliminated. R and U is an equivalence relation on the domain U and the positive region R of the Q is defined as the formula (8). The equivalence relation is shown in formula (9).

$$P_{OSR}(Q) = \cup R_*(X) \quad X \in Q \tag{8}$$

$$_{rR}(Q) = card(_{POSR}(Q)) / card(U) \quad 0 \leq _{rR}(Q) \leq 1 \tag{9}$$

Among them, the radix of B is defined as card (B).Taking advantage of the dependency relationship $_{rR}(Q)$, we can determine the compatibility of equivalence classes R and Q. R and Q are compatible if the value of $_{rR}(Q)$ equals 1. Otherwise, they are incompatible.

Information Fusion steps[8] through rough set theory are as follows

1) Draw up an information sheet contained condition attribute and conclusions attribute according to the collected sample information.
2) Taking advantage of the concepts such as simplification and nuclear, remove redundant condition attributes and duplicate information and finally draw s simplified information table.
3) Calculate the nuclear value table.
4) Obtain the simplified form of the information table according to the nuclear value table
5) Gather the corresponding minimum rules and educe the fastest fusion algorithm.

3.1.2 Neural Network Algorithm

BP neural network prediction model[11] makes use of the self-adaption and self-learning ability owned by BP neural network to study and analyze the data samples, and then it finds out the inherent laws and determines the connection weights and thresholds in the network. In the plant pests and diseases prediction method and an agricultural pest's prediction method, the optimization capability of a single BP neural network is weak. There are also studies that the genetic algorithm was introduced to BP neural network optimization and achieved good results. However, genetic algorithm makes arithmetic operators such as crossover, mutation, selection. Therefore, its convergence rate is slow and optimize efficiency is not high and it often expenses a lot of learning time to establish connection weights and thresholds.
The PSO optimization algorithm is good at handling optimization problems[10], and the study sets the connection weights and thresholds of the BP neural network as the position vector elements in the PSO optimization algorithm and uses it to achieve the initial optimization of the PB neural network, which improves optimization speed and accuracy of the connection weights and thresholds in PB neural network.
The idea of the PSO optimization algorithm is as follows:
1) It multiple calculates and optimizes position vector of itself until the fitness approaches the optimal. Solutions group tends to be stable if there are no significant changes. At this time, the position vector element is closer to the needs of the application;
2) Based on this, optimize the elements of the position vector further using of BP algorithm until the optimal connection weights and thresholds are found out.

3.2 Early warning Model

Firstly, we usually establish pest warning indicator system and then combine some appropriate algorithms to build pest early warning model. The specific steps are as follows.

3.2.1 Establish a Warning Indicator System

(1) Determine the early warning indicators

Under the guidance of the experts in related fields, the early warning indicator whose affect is small and not easy to be detected is removed and several or a dozen indicators that are more important for pest control and prevention are selected as warning factor that is used to level evaluate police level.

(2) Sort the important degree of the early warning indicators

It is an important part to determine alarm level. Whether the indicators selected are appropriate or not directly affects the early warning results. The expert investigation method, matrix analysis method and the Delphi method are generally selected to sort.

(3) Identify the Warning limit of the warning indicators

According to the indicators and the order of the importance, the appropriate number of key indicators is selected as the basis for pest warning. For example, the formula of the police limits are determined using of the expert investigation and it is shown in formula (10).

$$D = \frac{\sum\left(Q(w_i) \times d_i \right)}{N \times Q} \tag{10}$$

D represents the alert level, Q is the expert weight and its range interval is from 1 to 10, d represents the alarm level set by experts, N represents the number of experts.

3.2.2 Build the early warning Model

There are some common forecasting models at home and abroad such as univariate decision judgment model, multivariate linear judgment model, multiple logical model, multivariate probability ratio regression model, artificial neural network model and combined forecasting model[11,12,13]. BP neural network model firstly predict the warning factor under the existing situation, and then identify the alarm size, according to the change speed of the monitoring value for a period predict whether the current state is abnormal or not.

Studies show that two hidden layer BP neural network can approximate any continuous function and it's any derivative with any precision and it can better approximate nonlinear function than the BP neural network that contains many hidden layer neural networks[11]. For BP neural network, fewer layers can also achieve good effect if the number of nodes in the hidden layer is designed reasonably. In order to reduce the computational complexity we design three-layer BP neural network and it is shown in the following picture 2.

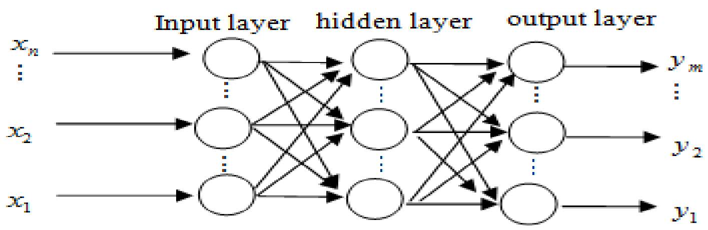

Fig. 2. three-layer BP neural network

The early warning of the plant diseases and insect pest's three-layer BP neural network contains input layer, hidden layer and output layer. The number of neurons in input layer is determined by the input indicators. The BP neural network model needs optimizing through certain methods, the model needs training through the sample data and finally the prediction model is determined.

3.3 Early Warning Analysis based on Real Sensory Data Analysis

Internet of things[9] is a constituent part of new generation of information technology. It makes real-time acquisition through the technology such as the sensor, radio frequency identification technology and global positioning system. The collection content includes any objects or process that needs monitoring, connecting and interacting and various information such as temperature, humidity and light. It can achieve the ubiquitous link among things and things, things and people through accessing to various possible networks and then realizes intelligent perception, identification and management to the objects and the process.

It will achieve the desired effect to apply the modern communications technology and the Internet of things technology to the field of agriculture and use of artificial neural network model to analyze the pest early warning. It takes advantage of varieties of sensors to accurately monitor facility environmental factors, which makes the facility environment be in real-time monitoring. Meanwhile, it collects and processes various data[14,15]. Therefore, the paper put forward real-time sensing data-based early warning analysis and its treatment flow is shown in Figure 3.

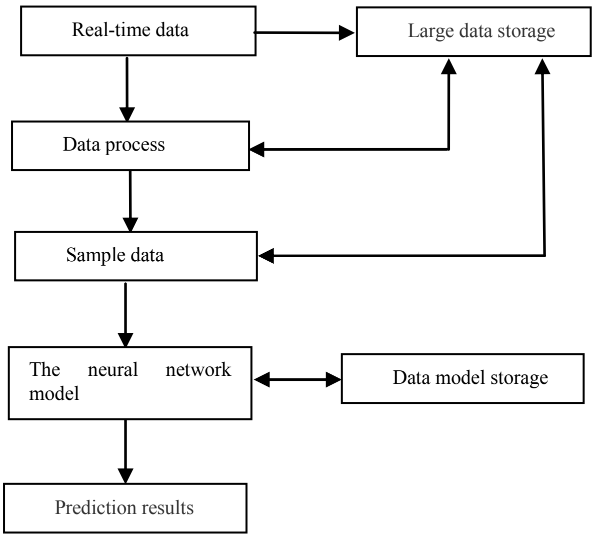

Fig. 3. the process flow of the early warning analysis based on real-time sensing data

4 Comparisons and Analysis

Based on the research of the pest warning algorithm model we make a contrastive analysis of various model and summarize their excellences and weaknesses. They are shown in the table 1.

There are many algorithm for pest early warning analysis, such as genetic algorithm, BP neural network, radial basis function neural network, rough set theory, information fusion algorithm and statistical algorithms. The pest early warning model is built based on these algorithms. At present, common forecasting model at home and abroad are univariate decision judgment model, multivariate linear judgment model, multiple logical model, multivariate probability ratio regression model, artificial neural network model and combined forecasting model.

Table 1. the Result of the Comparison and Analysis

the early warning algorithm	advantages	shortcoming
genetic algorithm	The global search capability is Strong.	Local search ability is weak.
BP neural network algorithm	Local search ability is strong.	Convergence speed is slow; local minimum; point instability.
Joint Algorithm	These algorithms complement each other.	There is not defect.

5 Conclusions

At present, pest warning technology of high intelligence and precision in the field agricultural is till in the research and development stage and needs constantly adding new practices and technologies during the process of the early warning research. The early warning of the crop diseases and insect pests will become an effective way to solve the problems emerging in the process of insect control .It takes Internet of things as its core and combines the communication technology, cloud computing, as well as the big data technology. So this early warning method will be more accurate and timely for the diseases and insect pests forecast and improve the overall level of the agricultural disaster prevention and counter-disaster.

Acknowledgment

This research was supported by National Science and Technology Support Project of China (Grant No. 2013BAD15B05) and the National Science Foundation Scientists of China (Grant No. 2012BAH20B02), Beijing Natural Science Foundation (4121001), all support is gratefully acknowledged.

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