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# The Research of Control Method of Greenhouse Based on Global Variable Prediction Model

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The paper deals with the problem of control of greenhouses inside climate based on the global variable prediction model. A mathematical model of greenhouse climate was established. Confronted with problem of greenhouse climate control existed in conventional controller such as control system is reactive, the adjustment of the actuators is not synchronized, control scheme is not optimal. In the method, inside the greenhouse temperature, humidity, radiation values, crop growth status, current state of actuators, external environment and the local weather conditions by data fusion as the - global variables. Then, the greenhouses of the future state of the environment short-term predictive value are obtained by mathematical model of neural network control. The simulation results testify the validity and reputability of the global optimization prediction control strategy for the climate control in the greenhouse, and the achievement has certain reference value for the development in intelligent control of the greenhouse micro-climate.

## 1. Introduction

The greenhouse intelligent control system is to create a suitable environment for crop growth, high quality, high efficiency and low energy consumption of the industrial scale production. According to the change of greenhouse climate, Greenhouse control system has to control the actuator for the corresponding adjustment: the temperature is too low, adding temperature by the heating system, the temperature is too high, need to control the ventilation, shading system, exhaust fan or evaporation cooling device, and avoid overheating. Most of the greenhouse control system usually separate to control the actuators according to the actual measured value and set value. The conventional design scheme of this control system has the following disadvantages: (1) Actuator set value adjustment depends on the level of professional knowledge of the staff; (2) Control system work in a passive state, when the greenhouse climate environment changes then adjust. It cannot predict the state of greenhouse environment in the future; (3) each actuator set value and work-sites are independent, so each actuator easy to cause the overshoot and oscillation (Aaslyng et al., 2003; Bennis et al, 2008; Blasco, 2007; Eredics and Dobrowiecki, 2011; Fourati and Chtourou, 2007; Eredics et al., 2011).
In order to overcome the above disadvantages, this article approves the prediction model based on global environment control method, the environment information of the greenhouse internal and external, crop growth stage, and local weather conditions as a whole system to conduct a comprehensive analysis. (Blasco et al., 2007; Clerk et al., 2008; Fourati and Chtourou, 2007; Ghoumari et al., 2005).The global variables collected as input values, using the prediction model derived future temperature as indoor environment variables, according to the predicted value, can advance the greenhouse environment the imminent change to make the corresponding adjustment, effectively improve the control quality of greenhouse (Lafont and Balmat 2002; Mirinejad et al., 2008; Ozkan et al., 2007).

## 2. Characteristics and requirements of the greenhouse intelligent control system

### 2.1 Characteristics of intelligent greenhouse control system

The greenhouse intelligent control system is mainly based on the environmental temperature, humidity, illumination, wind speed, direction, precipitation and other climatic factors, setting the greenhouse expert system and user based parameters, through some control measures to regulate greenhouse temperature,

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humidity, ventilation, light and other environmental factors, create suitable environment for crop growth (the environment is overall optimized according to different crop growth requirements), it needs to formulate standards according to the different growing stages , through the real-time detection of the greenhouse environment measurement, the measured parameters were compared after adjustment for each of the control equipment of greenhouse automatic state, so that the environmental factors in accordance with established requirements .

**2.2 The requirements of greenhouse intelligent control system**

Greenhouse intelligent control system generates the control scheme by using AI (Artificial Intelligence) model, all actuators work together, to achieve the optimal control effect. The realization of intelligent control is based on the following necessary needs:

(1) Accuracy of control model. Greenhouse crop growth to a certain period, greenhouse environment regulation will affect the growth of crops on the one hand, on the other hand, because of crop photosynthesis, transpiration, the change of indoor environmental factors to produce new effects, resulting in a feedback mechanism, The various elements of the greenhouse environment also exists strong coupling, the change of an element will affect other elements.

(2) A large amount of data. Precise modelling requires large amounts of data (including time and space), the data sensor collected will provide support for the establishment of the model. It need consider the value of the internal parameters of greenhouse, such as temperature, humidity, illumination etc. And need to consider the outside environmental parameters, real-time local weather conditions, and short-term weather forecast.

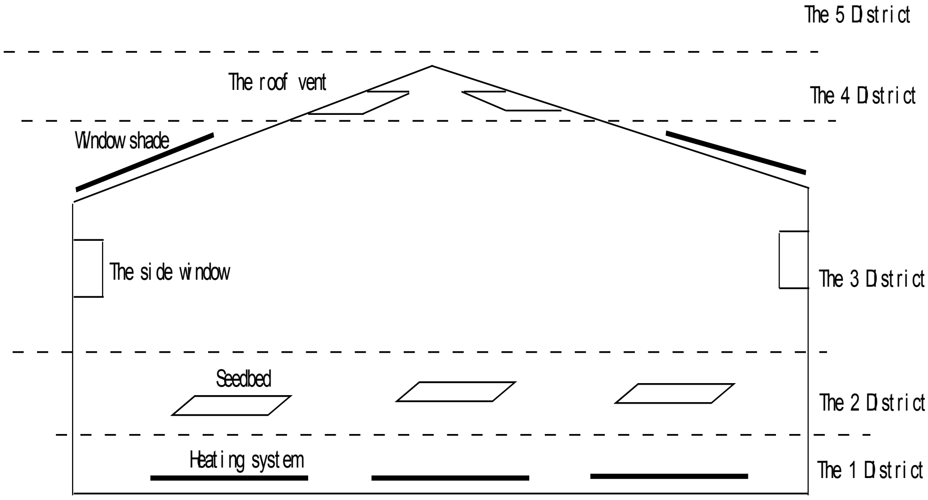


*Figure 1: The thermal zone structure of experiment greenhouse*

*Table 1: Data collection category and quantity of zones in greenhouse*

| District | Data acquisition category | The number of temperature sensor | The number of humidity sensor | The number of light sensor |
|---|---|---|---|---|
| | Heating system | | | |
| 1 | Seedbed data | 1 | 0 | 0 |
| 2 | Under the shade of air | 16 | 16 | 0 |
| 3 | data | 2 | 0 | 1 |
| 4 | On the shade of air data | 1 | 0 | 0 |
| 5 | Greenhouse external data | 1 | 0 | 1 |

## 3. The control scheme of greenhouse

In the greenhouse, the influence of the main parameters of crop growth status and the management cost is the internal temperature, humidity and light intensity. The control scheme is shown in Figure 2.

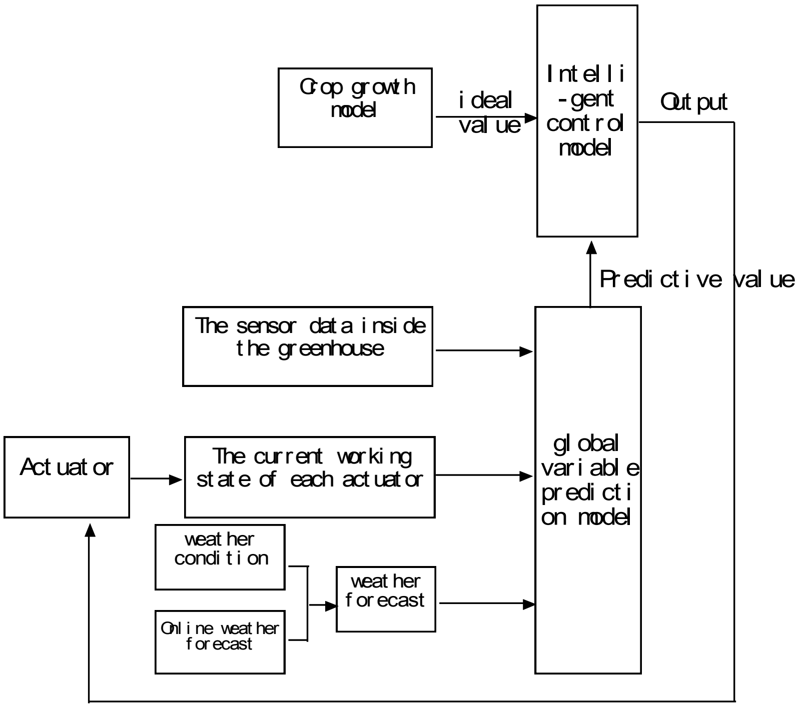


*Figure 2: Intelligent control structure of greenhouse*

### 3.1 Global variables prediction model

#### 3.1.1 Greenhouse external weather forecast module

The direct use of weather forecast to predict outside greenhouse climate models, the forecasting precision is low, so we need to set up outside greenhouse temperature sensor and light sensors, the specific data acquisition of external environment. According to the trend of future weather, by analogy method, use the data external sensors collected, combined with the weather forecast for the change trend of analogy, to do the judgment corresponding with the change of the greenhouse outside environment , in order to forecast short-term climate outside greenhouse (after a few hours).

#### 3.1.2 Online weather forecast module

From the perspective of control precision, the weather forecast online cannot meet the accuracy for modelling. But as an input value of the control model, trend prediction produces reliably ultimately. However, when the weather data network failure or acquired damage, must using an approximation of the data to replace the data. Surrogate data can be calculated using the following formula (empirical formula) to obtain approximate.

$$T_R = \alpha_0 + \alpha_1 T_L + \alpha_2 R_L + \alpha_3 R_L^2 \quad (1)$$

Formula (1), $T_R$ is the approximate local temperature, and $T_L$ is the actual local temperature values and $R_L$ is the light intensity value, $\alpha_i$ is the weighted coefficient value, using a linear regression to fit the data, conduct periodic adjustment according to the actual situation, its range is between 0-1.

#### 3.1.3 Global variable prediction model

Global variables, a total of 46, including 21 temperature values, 16 humidity values, 2 light intensity values, 6 actuator working state values, 1 online weather forecast future temperature value, the model is realized by neural network. The global variable prediction model input values is divided into 3 parts:(1) the regional temperature and humidity measurements, light intensity measurements, from each sensor acquisition, inside the greenhouse.(2)prediction weather value outside greenhouse by the online weather forecast, combined with greenhouse external environmental variables, provide predictive value.(3)the current device configuration (including shading, ventilation, heating, irrigation), namely each actuator working state, as global variables to predict reference.

### 3.2 Intelligent control model

Intelligent control model based on the input values, predicted the output state values, used to adjust the internal environment of greenhouse. The input of the model is divided into 2 parts: (1) the best environment for

the crop growth model phase value (temperature, humidity, light intensity), namely the ideal value. The model of crop growth including the best temperature, humidity, light and other conditions of crops different growth stages required ;(2)the global prediction value (temperature, humidity, light intensity);
The model has 6 inputs, respectively is the current crop growth stage optimal temperature, humidity, light intensity value prediction and global variables predicted by the model in future greenhouse temperature, humidity and light intensity value; the 6 output control signals, respectively is 6 actuator, the model function using PID control to achieve.

### 3.3 Neural network model and experimental results.

#### 3.3.1 BP neural network model

In this study, the neural network model is the role of reasoning that the predicted value, namely, the next stage in greenhouse temperature, humidity, light intensity value, control model for the realization of the internal environment variable greenhouse of advance control, in order to achieve early adjustment. In the structure of BP neural network in this research, adopt 3 layers of structure, and the 1 input layer, 1 hidden layers and 1 output layer, wherein the input layer neuron number is 46, corresponding to the 46 global variables; output layer neuron number is 3, corresponding to 3 predicted value (temperature, humidity, light intensity); hidden layer obtained by the following empirical formula, after four to five homes in rounding after a total of 25 neurons.

$$N_h = \frac{N_i + N_o}{2} \tag{2}$$

In formula 2, $N_h$— the number of hidden layer neurons, $N_i$— the number of neurons in the input layer, $N_o$— the number of output layer neurons.
In formula 3, with i, j, k respectively represent the number of input layer, hidden layer, output layer, $W_{ij}$ for the connection weights of the input layer and hidden layer, $T_{jk}$ is the connection weights of hidden layer to output layer. If the Xi is input mode, $Y_k$ is the output pattern vector. Then the node of hidden layer output:

$$O_j = f\left(\sum_{i=1}^{m} X_i \times W_{ij}\right) \tag{3}$$

The output layer output:

$$Y_k = f\left(\sum_{j=1}^{n} O_j \times T_{jk}\right) \tag{4}$$

The continuous value of activation Functions for (0, 1) Sigmoid function:

$$f(x) = \frac{1}{1+e^{-x}} \tag{5}$$

Error calculated formula:

$$E = \frac{1}{2}\sum (t_i - O_i)^2 \tag{6}$$

Among them, $t_i$ represents the expected output values of the first I sample; Oi represents the actual output value of I nodes. The initial weights generate by using random number, the range of [-0.5, +0.5], weight matrix correction using the formula:

$$W_{ij}(t+1) = W_{ij}(t) - \eta \frac{\partial E}{\partial W_{ij}(t)} \tag{7}$$

In the formula, $\eta$ represents the learning efficiency, this research takes 0.62; training sample selects in 2010 November -2011 year in April inside the greenhouse environment variables. Before using, BP neural network need to be train, the training procedure as follows: (1)selected the Group K samples ($X_k$, $Y_k$), k=1, 2, … , m, $X_k$ enters the network; (2)using a random number generator generates the initial weight;(3)using formula (6) calculates error, if error $E<\varepsilon(\varepsilon=0.001)$, exit; (4) calculation $\partial E_k/\partial W$; (5)calculation $\partial E_k/\partial W = \Sigma\partial E_k/\partial W$ (k=1,2,…,m); (6) using formula ; (7) correcting the weight, return (1).

After the training, the weights of neural network have been determined; we can predict the future environment temperature variable indoor using the network.

**3.3.2Analysis of the experimental results**

Experiments conduct according to the global variable prediction model (lack of the greenhouse supplemental lighting equipment, without illumination compensation, only control the temperature and humidity of the greenhouse), planting crop is tomato, the following experiment design:

(1) Chosen 7 January 16, 2012 morning to 6 January 17, morning, a total of 24 hours as a testing phase, using a predictive value as the basis, control of the greenhouse environment, obtained results;

(2)Chosen February 26, 2012 to in March 10, 2012, total of 2 weeks as a testing phase, use the same method to control greenhouse implementation, experimental results obtained;

(3) Simulated by using the prediction control mode model and the conventional PID control method, and then compared two methods.

This tomato is at the flowering stage, the optimal temperature range for 200℃-250℃ during the day, the optimal temperature range for 150℃- 200℃ at night, the best humidity range is 65%-85%, respectively, such as the green part is shown in the picture. Figure 3 shows the 2 weeks average temperature values during the day and night, Figure 4 for 2 weeks average humidity.

The value of greenhouse environment control model as the basis for the prediction model, can control the greenhouse environment is in the best state of crop growth environment, illustrate the effectiveness of the method.

Figure 5 for one day (March 5, 2011), comparison of the simulation by using the PID control and the prediction model control simulation. From the results we can see that, using predictive control model, change of indoor temperature and humidity gentle than conventional PID control changes, confirm that the method of prediction model can effectively avoid the large inertia and large delay caused by hysteresis and overshoot of the whole control system, the system stability is greatly improved.

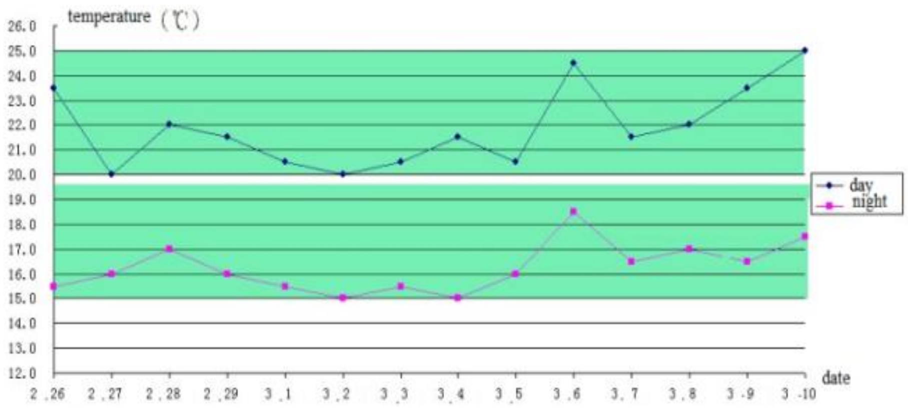


*Figure 3: Temperature of day or night in 2 weeks*

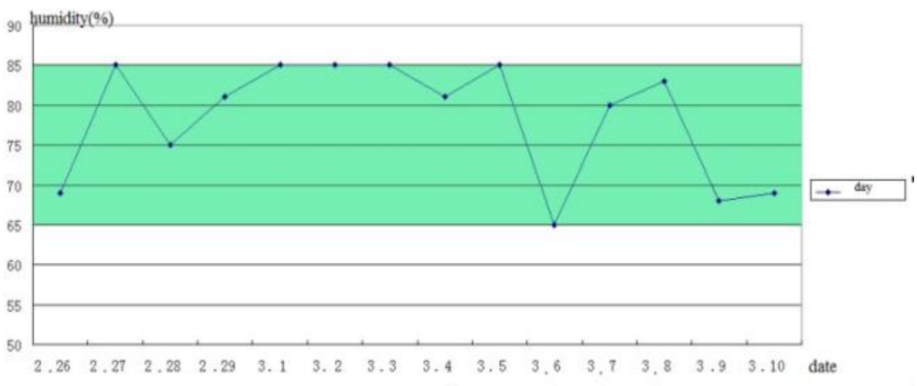


*Figure 4: Humidity of day in 2 weeks of blossom period of blossom period*

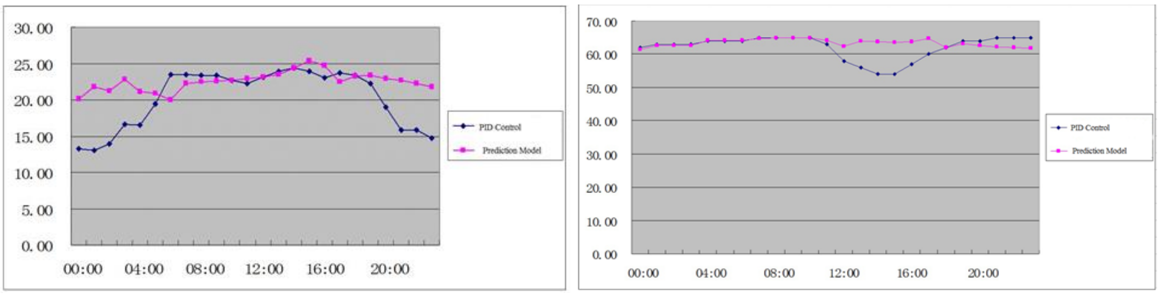


*Figure 5: Temperature and humidity change based on the different ways*

## 4. Conclusion

This paper presents control method of greenhouse based on global variable prediction model, and design a global variable neural network control system based on it, the model introduces the temperature outside greenhouse, humidity, light, the controller state, crop growth status as global variables, and short term prediction of the as one of the global weather variables discussed, ensure the prospective control model, overcome the hysteresis and oscillation control system in a certain extent. The property of the control model is proved by experimental data and comparative verification: greenhouse control method using the model, environment in the greenhouse can always basically guarantee is in the best state for crop growth, and the scheme is more stable compared with the conventional PID control, to avoid the lag and the overshoot, effectively control of the interior environment of the greenhouse.

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