Research on Greenhouse Intelligent Control System Based on Genetic Optimization Fuzzy PID Algorithm

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Abstract

With the rapid development of intelligent information and agricultural modernization, the significant progress has been made in greenhouse cultivation in our country, which forming the concept of scientific management and control of the greenhouse environment in greenhouses. However, due to the lack of factory management methods, greenhouse intelligent control technologies are widely used in facilities and industries, which are still some shortcomings in automation. Therefore, it is very important to design a modern greenhouse control system that is suitable for our country's agricultural conditions. It has far-reaching significance for real-time monitoring and precise control of greenhouse environmental parameters and improvement of crop yield and quality. Based on the characteristics of greenhouse cultivation, a set of unique greenhouse intelligent control system is designed and researched based on genetic algorithm and fuzzy PID algorithm. The system performance simulation experiment is carried out. The results showed that: the greenhouse intelligent control system with good performance, high degree of automation, energy saving significantly, the greenhouse vegetable cultivation has an important role in promoting.

Keywords: Intelligent Control System, Genetic Optimization, PID Algorithm.

1. INTRODUCTION

Since ancient times, our country is an agricultural power with an area of cultivated land of 12.1 billion (Meza et al., 2009). With the continuous development of rural economy in our country, agricultural production gradually shifted from the traditional extensive management to modern intensive management (Zhang et al., 2004, Chen et al., 2014). Greenhouse cultivation in greenhouses has emerged as a model window for intensive agricultural application. With the rapid development of agricultural science technology and automated production, the structural grade of greenhouses is gradually increasing. Therefore, building an intelligent greenhouse control system which can improve crop quality and output and reduce farmers' labor has become an urgent need of agricultural growers (Dai et al., 2017). Thus, in order to further improve the accuracy of intelligent greenhouse control and improve crop production efficiency, a set of greenhouse intelligent control system is designed based on genetic optimization fuzzy PID algorithm (Hu and Wang, 2003). The system will play a significant role in regulating the environmental parameters in the greenhouse and improving the crop growth environment.

2. THE PRINCIPLE OF GENETIC OPTIMIZATION FUZZY PID FUSION ALGORITHM

2.1 The principle of genetic algorithm

Genetic algorithm is a global optimal search method proposed by Holland researcher Holland to simulate natural genetic mechanism and biological evolution theory. It develops gradually based on Darwin's natural selection theory (Najita et al., 2003). It combines the biological evolutionary theory of survival of the fittest with an optimized form of coding tandem population, selecting individuals according to an efficient fitness function through genetic duplication, and it retains a highly competitive and highly adaptive individual; And then it is reorganized into new groups so that the new group retains the genetic information of the previous generation but outperforms the previous generation in terms of survival (Spyrou and Thompson, 2000). Under the long-term
Effect of genetic algorithm, the population fitness gradually increases and reaches the researchers’ design standards as the same as the laws of nature evolution. Genetic algorithm is simple and practical, and can be multi-conditions, then passed down from generation to generation, which is easy to find the global optimal solution. Genetic algorithms generally do not simply manipulate parameters, but rather operate on the encoding of parameters (Ladjavardi and Masoum, 2008). In general, the searching process simultaneously uses multiple search point information and directly processes the objective function as search information. The operation of genetic algorithm was shown in Figure 1.

![Figure 1. Principle of genetic algorithm](image)

2.2 PID fusion controller principle

In the greenhouse intelligent control process, it often needs the temperature, humidity and other variables for real-time monitoring to meet the needs of the growth of fruits and vegetables. For the PID fusion control, the control of the controlled parameters are mainly carried out according to the proportion, integration, and differentiation. Generally, the Kth generation sampling value is compared with the given value.

\[ e(k) = y_d(k) - y(k) \]  

Where, \( y(k) \) is the system given value, \( y_d(k) \) is the actual sampling value of the system (Chen and Liu, 2016), and the actual feedback control quantity can be obtained after comparing them. PID control system principle shown in Figure 2.

\[ u(t) = K_c \left( e(t) + \frac{1}{T} \int e(t) dt + T_D \frac{de(t)}{dt} \right) \]  

\[ (2) \]
Among them, $K_c$ is a scale factor, $T$ is the integral time constant, $T_D$ is the differential time constant.

![Figure 2. PID control system schematic](image)

3. DESIGN OF GREENHOUSE INTELLIGENT CONTROL SYSTEM

Large temperature changes with large summer light intensity, high temperature and winter cold, thus the use of genetic optimization fuzzy PID control of greenhouse control system for real-time monitoring is in essence. Greenhouse intelligent control of the main measures is to heat cool, moisturize and control the light and so on. The system detects the indoor environment parameters through various sensors, and then automatically controls each implementing agency to realize the regulation and control of the parameters.

3.1 Temperature control

Appropriate temperature is very important for the growth of crops. Photosynthesis of crops must be carried out in a proper temperature environment. The temperature in greenhouse is mainly controlled by heating and cooling.

1) Heating control. When the weather is cold, heating control will be performed when the indoor temperature is lower than the most suitable temperature for crop growth. First close the ventilation window, then turn on heating or air conditioning to heat up. As the heating is difficult to achieve constant temperature control, the higher the temperature requirements of the greenhouse air-conditioning heating method. Through the air conditioning thermostat set automatically adjust the control room temperature.

2) Cooling control. Summer high temperature and indoor temperature are higher than the set value, the system will be cooling control, which generally take to open the window or open the wet curtain fan equipment and other measures.

3.2 Humidity control, lighting control and CO$_2$ concentration control

Greenhouse intelligent control system detected greenhouse greenhouse humidity is high or below the set value, the system automatically open the sprinkler or ventilation equipment to achieve the purpose of regulating the control room humidity.

When the weather in summer is sunny, the light intensity is high, which may easily result in high temperature and low humidity in the greenhouse, and then increase the transpiration of fruits and vegetables and reduce the efficiency of photosynthesis. Therefore, you need to open shade net for reducing the impact of glare on the greenhouse. Rainy weather or winter care intensity is low, in order to meet photosynthesis needed for crop growth, the system should automatically turn on the indoor fluorescent light.

CO2 concentration is an important indicator of crop growth, the system detects the sensor to determine indoor CO2 concentration values, and according to the set value to automatically adjust the control.
4. GREENHOUSE INTELLIGENT CONTROL SYSTEM HARDWARE AND SOFTWARE DESIGN

Crops need to be able to grow normally under the right conditions, while the environment required for different growth periods is different. The greenhouse intelligent control system can set suitable environmental parameters according to the growth of crops at each stage. The intelligent control part of the system uses MSP430F149 single-chip processor as the core processing unit, which uses the temperature, humidity and light intensity sensors to collect environmental parameters, and adopts the fuzzy PID fusion algorithm to control each executing device.

Complex and changeable greenhouse environment, there are a lot of interference factors, so microcontroller as a greenhouse intelligent control system core components, must be stable, high reliability and low power consumption. Greenhouse intelligent control system hardware framework was shown in Figure 3. Greenhouse intelligent control system is the core of TI's MSP430F149 low-power processor, peripheral LCD display, temperature and humidity, light intensity, CO2 concentration, power, alarm and implementing agencies such as test control circuit. Among them, the implementing agencies mainly include ventilation windows, wet curtains, sun shades, ventilating fans, fluorescent lamps, CO2 generating equipment and thermostatic air conditioners. The system real-time monitors and automatically controls various greenhouse factor parameters through solenoid valves. The controlled environmental parameters mainly include temperature and humidity, light intensity and CO2 concentration.

(1) Temperature detection circuit. Many types of temperature sensors are on the market. In order to ensure accuracy, the system uses DS1820 temperature sensor. It is a digital sensor with an accuracy of ± 0.5 °C over a range of -10 to +85 °C. With a single line, only one A / D port is required to measure the greenhouse temperature directly. The device's composition is not required external components, smaller interference factor, suitable for harsh environments on-site temperature measurement.

![Diagram of greenhouse control system](image)

Figure 3. Temperature intelligent control system hardware frame diagram

(2) Humidity detection circuit. The system humidity detection circuit uses HS1101 capacitive sensor, and the working temperature is in range of -40 ~ 100 °C. The detection circuit NE555 devices and HS1101 combined use of humidity sensor capacitance changes after the change of moisture, the higher the value of humidity in the greenhouse, the greater the value of the sensor capacitance. Humidity detection circuit shown in Figure 4.
5. EXPERIMENT ANALYSIS

In order to verify the reliability and practicability of the intelligent control system, this paper applies the system to a cucumber greenhouse and realizes the real-time monitoring of the environmental parameters of the cucumber greenhouse. The greenhouse is double-sided, 32m long and 18m wide and is designed to be north-south. Taking the control on January 25, 2017 as an example, the weather was fine on that day with the data selected from 9:00 am to 15:00 am and collected every 30 minutes. During the data collection, the intelligent greenhouse control system was operating normally. The collected specific data is as shown in Table 1.

<table>
<thead>
<tr>
<th>Time</th>
<th>Humidity /RH</th>
<th>CO2 concentration /%</th>
<th>Light intensity</th>
<th>Room temperature / °C</th>
<th>Outdoor temperature / °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>71.3</td>
<td>597</td>
<td>52 230</td>
<td>23.6</td>
<td>5.8</td>
</tr>
<tr>
<td>9:30</td>
<td>72.1</td>
<td>603</td>
<td>51 228</td>
<td>22.7</td>
<td>5.6</td>
</tr>
<tr>
<td>10:00</td>
<td>70.5</td>
<td>602</td>
<td>52 756</td>
<td>21.5</td>
<td>5.4</td>
</tr>
<tr>
<td>10:30</td>
<td>71.5</td>
<td>589</td>
<td>53 118</td>
<td>22.4</td>
<td>5.3</td>
</tr>
<tr>
<td>11:00</td>
<td>73.0</td>
<td>612</td>
<td>53 524</td>
<td>22.8</td>
<td>5.5</td>
</tr>
<tr>
<td>11:30</td>
<td>75.2</td>
<td>588</td>
<td>52 663</td>
<td>23.1</td>
<td>6.9</td>
</tr>
<tr>
<td>12:00</td>
<td>74.5</td>
<td>602</td>
<td>51 211</td>
<td>23.0</td>
<td>7.1</td>
</tr>
<tr>
<td>12:30</td>
<td>73.8</td>
<td>607</td>
<td>50 889</td>
<td>23.2</td>
<td>7.9</td>
</tr>
<tr>
<td>13:00</td>
<td>74.2</td>
<td>601</td>
<td>50 226</td>
<td>24.1</td>
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</tr>
<tr>
<td>13:30</td>
<td>73.9</td>
<td>577</td>
<td>49 880</td>
<td>24.6</td>
<td>4.9</td>
</tr>
<tr>
<td>14:00</td>
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<td>573</td>
<td>51 335</td>
<td>23.8</td>
<td>4.5</td>
</tr>
<tr>
<td>14:30</td>
<td>72.8</td>
<td>580</td>
<td>52 289</td>
<td>23.8</td>
<td>5.2</td>
</tr>
<tr>
<td>15:00</td>
<td>72.6</td>
<td>583</td>
<td>52 470</td>
<td>23.2</td>
<td>5.0</td>
</tr>
</tbody>
</table>
The temperature and humidity data analysis, data trends are shown in Figure 5.

![Figure 5. The trend of greenhouse temperature and humidity](image)

It can be seen from Figure 5 that during the data acquisition, the temperature in the greenhouse is kept within the set temperature range (21 °C ~ 24 °C) during the adjustment process and the overall fluctuation of the humidity is small, and humidity values tend to be stable. Experiments show that the control effect of the system reaches the expected value, which can realize the control of the environmental parameters in the greenhouse, and has strong stability. Finally it can meet the needs of greenhouse cultivation.

6. CONCLUSIONS

The establishment of environmental parameters control model is more difficult with environmental greenhouse control with many parameters. In this paper, a set of intelligent control system for greenhouse environmental parameters that is suitable for agriculture in our country is designed by genetic algorithm, fuzzy PID fusion algorithm and advanced computer control system. The experiment shows that the system has good performance, high degree of automation, strong regulation ability and cost-effective characteristics, which has a positive effect on agricultural modernization in our country.

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