ORIGINAL RESEARCH

A framework of fuzzy control-based intelligent control system for greenhouse

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ABSTRACT

The existing technology of carbon dioxide regulation methods are incomplete and time consuming. It is difficult to manage and not environmentally friendly. Carbon dioxide regulation systems in greenhouse can only set carbon density thresholds relying on human experience. They cannot meet the practical requirements of the carbon dioxide density accurately; hence result in negative effects on crop growth. Therefore, how to effectively control the carbon dioxide density is significant essential to the growth of crop. In this paper, we propose an intelligent control system about carbon dioxide in greenhouse which is based on fuzzy logic and integrated with photosynthesis mechanism. Through extensive experiences, we found that the proposed system can automatically adjust the carbon dioxide density to the suitable levels more accurate in terms of time and amount automatically.

Key Words: Greenhouse, Fuzzy logic, Intelligent control system, ZigBee

1. INTRODUCTION

As the rapid development of agriculture technology, carbon dioxide controlling in greenhouse is increasingly becoming an important approach to improve crop productivity recently. In this paper, we propose a Fuzzy Control-based Intelligent Control System (FC-ICS) for greenhouse cultivation environment. The overall system takes microcontroller as a core and adopts a variety of environmental factors sensors. The collected data firstly processed by carbon dioxide regulation algorithm based on light and temperature coupling to obtain the most suitable carbon dioxide value for plants' growth in environment. After that, the greenhouse carbon dioxide regulation system improves the level in greenhouse based on fuzzy logic algorithm to realize the intelligent control. Meanwhile, LabVIEW is used to present the real-time density changes of the different environmental factors. The practical test verified that the proposed system is inexpensive and highly-effective.

The remainder of this paper is organized as follows. Section 2 describes the structure of proposed system. Section 3 provides a high-level description of the proposed system. Followed by the simulation and analysis are presented in Section 4. Section 5 concludes this paper.

2. THE STRUCTURE OF PROPOSED SYSTEM

The architecture of the proposed FC-ICS is given in Figure 1. Data Collection Nodes (DCNs) are making use of sensors such as temperature sensors, luminous intensity sen-

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sors, humidity sensors and carbon dioxide sensors to detect environmental factors. The collected data is transmitted to wireless communication gateway (WCG) via ZigBee access interface.[1] WCG is mainly responsible for receiving information from ZigBee access interface and forwarding the data processed by microcontroller. Furthermore, it transmits the information to designated IP data server on the Internet via cellular network. The data server realizes the functions of storage, analysis, and displays the various environmental data timely. The core processor analyzes the data and makes decision based on fuzzy algorithm will be described in Section 3. Based on decision-making results, carbon dioxide generator/ventilation device makes corresponding actions to control the levels of carbon dioxide achieve the situation best for plants. Besides, while a system failure is detected, a timely message is sent to maintenance personnel via cellular networks.[2] The carbon dioxide density is eventually adjusted to the optimum value in a closed environment. By this intelligent system, the greenhouse can achieve the most suitable environment without human intervene, so as to save the manpower and material resources.

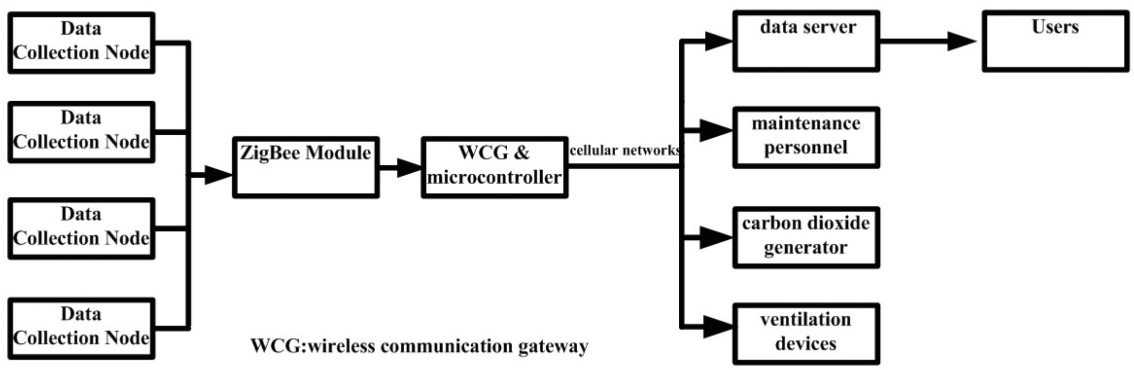

Figure 1. The architecture of the proposed system

3. The proposed fuzzy control-based intelligent control system

3.1 The framework of the proposed intelligent control system

It is difficult to control greenhouse environment in an exactly precise way. Therefore, fuzzy logic as an intelligent control method can be adopted in greenhouse control system. It is unnecessary to know the exact model of the controlled object. The operating time of carbon dioxide generator/ventilation is decided by the fuzzy logic. The framework of the proposed intelligent control system is depicted in Figure 2.

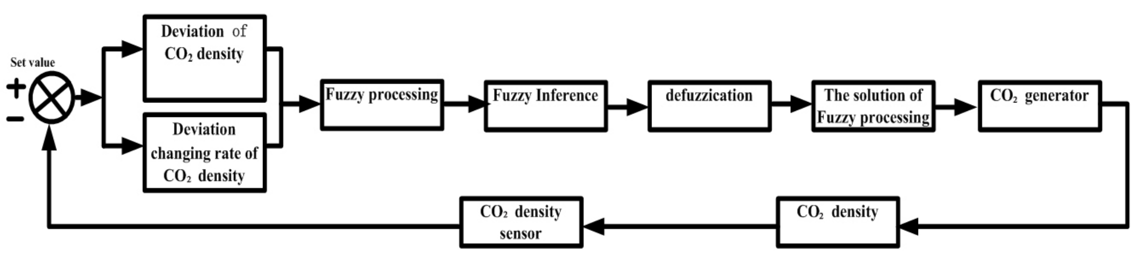

Figure 2. THE architecture of system controller

As shown in Figure 2, the deviation of carbon dioxide density (E) and the deviation changing rate of carbon dioxide density (Ec) are two input variables. These two variables are converted to two fuzzy variables by fuzzy processing. Fuzzy control rule R is used to decide the fuzzy control variable with the input variables E and Ec. The fuzzy variables are then transformed to accurate variable (T) to control carbon dioxide generator operation.

3.2 The designed fuzzy algorithm

According to the historical data about carbon dioxide density in Greenhouse, the deviation of the most suitable value for plants is ranging from -6% to 6%.[3] Setting the changing range of carbon dioxide density (E) is [-6,6], so the value of the fuzzy field is [-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6] and the quantification factors of deviation Q1 is set to 1. Meanwhile, the deviation changing rate of carbon dioxide density changes from -1 to 1. The quantification factors of changing rate of deviation Q2 is set to 6 as the value of the interval is [-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6]. The fuzzy language of carbon dioxide density are set to Positive Large (PL), Positive Middle (PM), Positive Small (PS), Zero (Z), Negative Small (NS), Negative Middle (NM), Negative Large(NL) respectively. Choose triangular function as the membership function. The membership functions of input variables are given in the Figure 3.

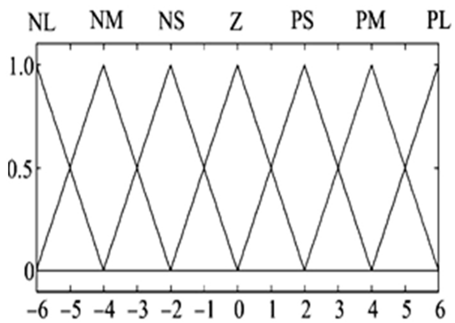

Figure 3. Input variables membership function

Because the output T is positive, the range of it is set to [0, 60]. The value of the fuzzy field is set to [0, 1, 2, 3], quantification factors Q3 is 20. The controlling time of opening ventilation is described as Zero (Z), Positive Short (PS). Positive Middle (PM). Positive Large (PL) respectively. The membership functions of output variables are shown in Figure 4.

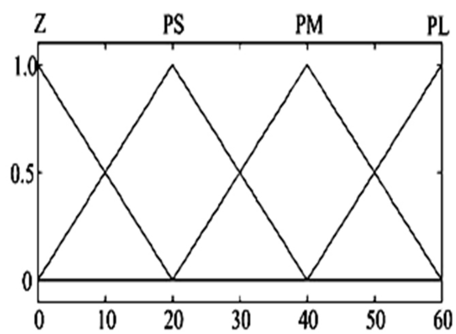

Figure 4. Output variables membership function

In order to control the density accuracy, the carbon dioxide generator or ventilation operation time is set to 0 min, 20 min, 40 min, and 60 min. For instance, controlling sentence can be described as if E = NL and Ec = PL, then T = PS. This means carbon dioxide density is negative large and changing rate of carbon dioxide density is positive large, then the output of controller is positive small, so the carbon dioxide generator operation will open for a short time. However, if E = PL and Ec = PL then T = Z, which means the carbon dioxide density is positive large and changing rate of carbon dioxide density is positive large, then the output of controller is Zero. Table 1 gives the control rule. The controller uses Mamdani reasoning algorithm and maximal subordination degree to solve ambiguity to gather the perform time of carbon dioxide generator/ventilation.

Table 1. The rules of fuzzy controller

Ec	E						
	PL	**PM**	**PS**	**Z**	**NS**	**NM**	**NL**
PL	Z	Z	Z	Z	PS	PS	PS
PM	Z	Z	Z	PS	PS	PS	PM
PS	Z	Z	PS	PS	PS	PM	PM
Z	Z	PS	PS	PS	PM	PM	PM
NS	PS	PS	PS	PM	PM	PM	PL
NM	PS	PS	PM	PM	PM	PL	PL
NL	PS	PM	PM	PM	PL	PL	PL

4. RESULTS AND ANALYSIS

4.1 Simulation setting

In this paper, simulation study was carried out by LabVIEW virtual instrument.[4] Figure 5 presents the interface of upper computer. Traffic data is transmitted to computer via cellular networks is shown on the curves. The curves show the temperature, humidity and light intensity are changing in the environment real-timely. According to light and temperature coupling-based carbon dioxide regulation algorithm, the most suitable carbon dioxide density of the growth of plants can be obtained. Figure 6 is a part of the programming of LabVIEW, by which we also developed an operation interface. Opposed to conventional measures controller which controls the environment factor individually, the proposed system improves the environment by an integrated system which coalesces different factors, and it shows a more intelligent performance as compared to conventional manual control.

4.2 Performance evaluation

The fuzzy rules can be changed according to the actual conditions. The surface plot of the output characteristics is shown in Figure 7. We use Matlab to realize the simulation of controller. The result is shown in Figure 8. Initially, we set the density of carbon dioxide is 28%, we found that the most suitable density is 32% by carbon dioxide regulation algorithm based on light and temperature coupling. It is worth noting another factor is that 1 second in simulation is set equal to 10 minutes in reality. The curve shows that the error ranges between the result of carbon dioxide density and target value is within 1%, and the response time is 3 seconds.

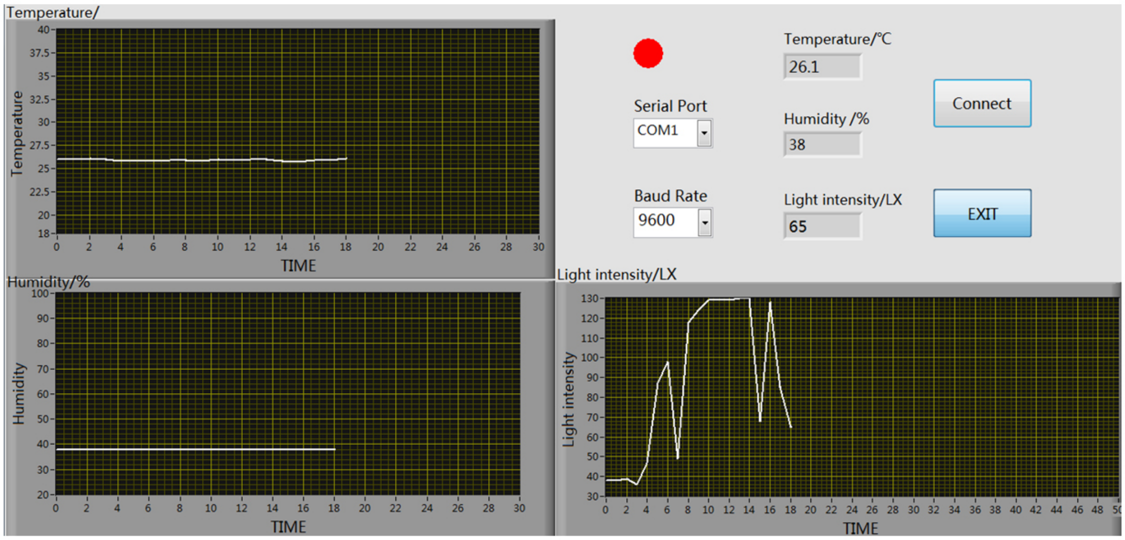

Figure 5. Front panel of PC

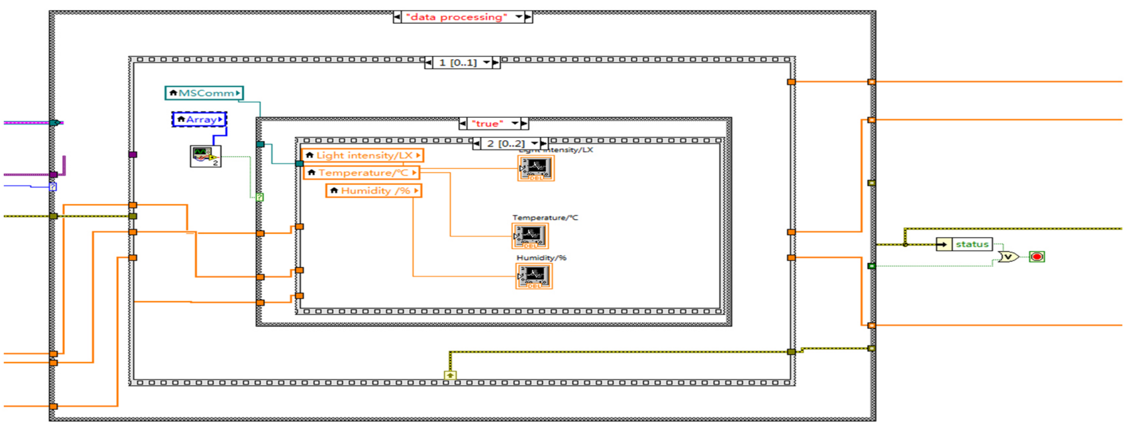

Figure 6. Program panel of PC

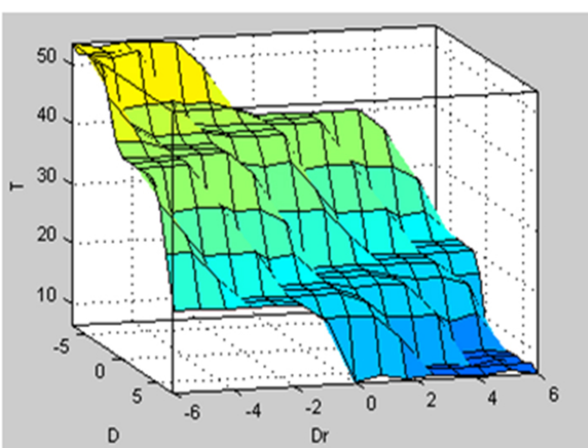

Figure 7. Output feature response surface plot

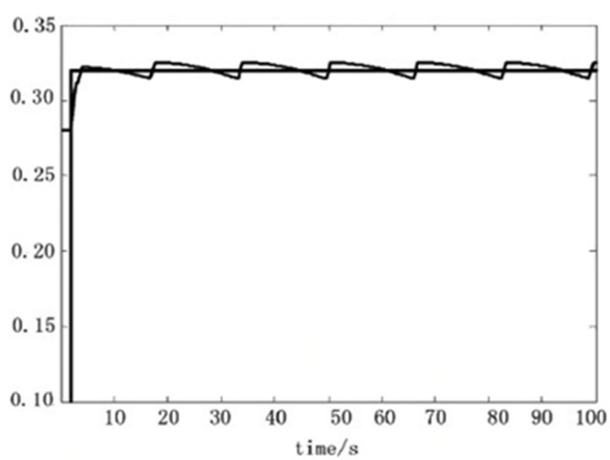

Figure 8. Carbon dioxide step response

5. CONCLUSION

Intelligent agriculture is developing rapidly in recent years and it raises more attentions in both industrial and academic societies. In this article, a fuzzy control-based intelligent control system has been proposed and implemented in a certain greenhouse cultivation environment. Moreover, a carbon dioxide regulation algorithm based on light and temperature coupling is developed. Through extensive experiences, we found that as compared to manual control mechanism, the proposed system enables to make measurements timely, appropriately and automatically meanwhile the proposed system also enables to adjust the carbon dioxide density more accurate in terms of time and amount automatically.

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