Research on Coordination Control Theory of Greenhouse Cluster Based on Cloud Computing

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Abstract. With the development of modern agriculture, the clustering phenomenon of greenhouses is prominent. The traditional single greenhouse management is oriented to farmers. It is difficult for upper management to obtain the information of greenhouses conveniently. The real-time transmission of monitoring results and the real-time regulation of the internal environment of greenhouse clusters are difficult. And the scope of management of large-scale agricultural companies is also growing, and an integrated management platform is urgently needed. The emergence of cloud computing technology has made this management model possible. On the other hand, the greenhouse cluster is a non-linear complex large system, which not only needs to improve the capacity of the greenhouse cluster, but also take into account the utilization of regional resources. The traditional control methods are insufficient in the efficient use of regional resources, and the existing control theory can't meet the above requirements. Target requirements. The computing power of local equipment can't meet the needs of massive data processing. Therefore, based on the cloud computing platform, this paper draws on the theory of complex systems to carry out coordinated control theory research on greenhouse clusters, establishes a cloud computing-based greenhouse cluster management system, and designs greenhouse clusters. The control system description model is coordinated; on this basis, the greenhouse cluster coordination control structure model is designed. This study provides a reference for the control of modern greenhouse clusters, and has certain theoretical significance and application value for the development of greenhouse cluster coordinated control theory.

Keywords: Cloud computing · Greenhouse cluster · Coordinated control

1 Introduction

Greenhouses are facilities that provide a production environment and increase production for off-season cash crops. The regulation of the greenhouse environment is one of the important factors affecting crop yields in the greenhouse [1]. Control in the greenhouse (the influence of the two control methods) greenhouse atmospheric environment,

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greenhouse plant growth environment, is two common single greenhouse environmental control methods. However, under the large-scale greenhouse planting mode, the construction of a control system for greenhouse clusters can greatly enhance the core competitiveness of the regional economy [2].

The coordinated control of greenhouse clusters is significantly different from the previous single greenhouse control, and it also faces more problems: 1. Effectively use and manage resources under the constraints of regional resources [3, 4]; 2. Effectively control the fruiting period [5, 6], linkage Regulate the parameters in each greenhouse; 3. Monitor the growth of crops in each greenhouse and make regional-level warnings and forecasts [7]. Therefore, research on the regulation of such large-scale greenhouse cluster systems is not only very important, but also challenges existing greenhouse research methods and greenhouse control theories.

At present, the research on smart agriculture has seen the issue of intelligent regulation of agricultural systems from a more macro perspective. Mainly manifested in: the agricultural system is a complex large system with many specialities, such as: the ambiguity of the system dynamics characteristics and the uncertainty and uncertainty of the object feature model with different objects and environments [8] etc. Therefore, it is difficult to control by traditional control methods, so there are still many difficulties in the study of the overall intelligent control of agricultural systems.

Based on the cloud computing architecture, this paper studies the coordinated control theory model for greenhouse clusters based on the theory of large-scale agricultural systems. With the help of complex large-system theory, this paper studies the construction of greenhouse system hierarchical control system and establishes greenhouse from the perspective of large-scale system control. The cluster coordination control system description model and the control structure model have theoretical significance and application value for improving the accuracy of greenhouse cluster control. In addition, the analysis of the greenhouse cluster coordination control process from the perspective of large-scale hierarchical control has undoubtedly expanded a new research field and enriched the theoretical research in the field of greenhouse control.

2 Related Work

For greenhouse cluster systems, the direct target is a single greenhouse. The greenhouse cluster system based on tens of thousands of greenhouses is a typical MIMO nonlinear system. If the controlled parameters of each greenhouse are 5 typical parameters of temperature, light, ventilation, irrigation and fertilization, the control parameters of the greenhouse will reach 50,000. Based on the foregoing analysis, if the specific parameters of each greenhouse are directly controlled by this large system, it is obvious that the system is a high-dimensional complex system. In order to reduce the dimension and reduce the complexity of the control system, according to the control architecture of the complex system, the design is a hierarchical control mode, and the micro-, medium-, and macro-architecture is adopted from the bottom to construct the greenhouse cluster system [9].

In the description model of the greenhouse cluster coordinated control system, the traditional modeling method is to treat the greenhouse system as a simple and independent environmental system for analysis and modeling, which has some drawbacks. Considering the greenhouse system as a greenhouse-crop system, that is, dividing the greenhouse system into an environmental system and a crop growth system is currently the accepted greenhouse system analysis and modeling method in Europe [10]. Figure 1 shows a general description of the greenhouse system.

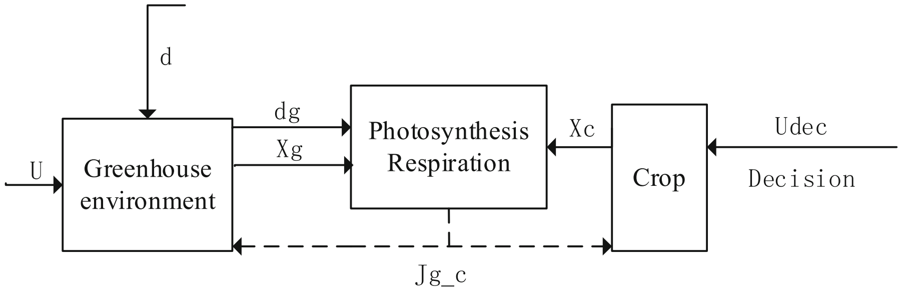

Fig. 1. Greenhouse cluster coordinated control system description model diagram

In Fig. 2: j_{g_c} represents the exchange of greenhouse environmental systems with crop systems, such as reduction of CO2 by photosynthesis, increase of CO2 caused by various exhalation of crops, and transpiration of water and gas [11].

In terms of the control structure model of the greenhouse system, the state space model of the traditional single-unit greenhouse system can be expressed by the following formula:

$$\dot{x}(t) = f(x(t), u(t), d(t), t)$$
$$y(t) = g(x(t), u(t), d(t), t)$$
$$x \in \Re^{n_x}, u \in \Re^{n_u}, d \in \Re^{n_d}, y \in \Re^{n_y}$$

Where: $x(t)$ is the n_x dimensional system state vector, such as greenhouse air temperature, air humidity, air CO2 concentration, crop physiological carbon content, fruit weight, etc.; $u(t)$ is the n_u dimensional control input vector, such as: heat input or mixing valve position, window opening, CO2 application Quantity, shading net position, etc.; $d(t)$ is the n_d external disturbance vector, such as solar radiation, outside air temperature, external light, wind speed, etc.; but $y(t)$ is the n_y dimensional output vector, such as: air temperature, relative humidity, crop dry matter [12]. The greenhouse system control structure is shown in Fig. 3.

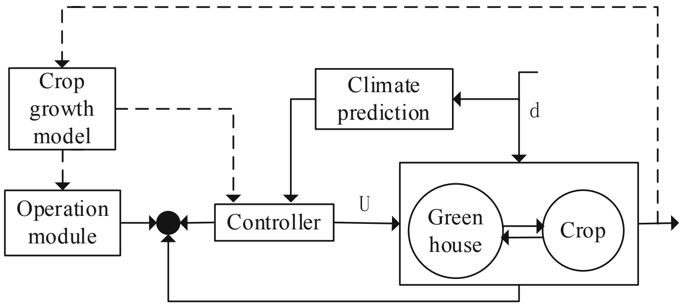

Fig. 2. Structure diagram of greenhouse cluster coordination control system

Monolithic greenhouse systems are often regulated by single crop cultivation. The above system is currently recognized as a greenhouse control system structure in which crop models are introduced into the system as a given reference for the system. Such a control system can indirectly control the greenhouse according to the needs of the crop at different stages of growth [13]. Planting in greenhouse clusters is a variety of crops with different growth cycles, which poses great difficulties for coordinated control of greenhouse clusters.

3 Greenhouse Cluster Theory Model

According to the characteristics of the nonlinearity of greenhouse clusters and the basic requirements for the regulation of plant growth environment, based on the theoretical basis of complex large-scale systems, the application of multi-level hierarchical nonlinear decoupling adaptive control is practical, efficient and robust. The theory of greenhouse cluster control solves the bottleneck problem that plagues greenhouse cluster control to wide-area intelligent expansion from a theoretical level, and makes breakthroughs in the theory of nonlinear control such as greenhouse cluster.

The research scheme of the greenhouse system hierarchical large-scale system architecture control theory is as follows: Based on the actual application status, the conditions can be assumed here: according to the coordinators A, B, C, D, and ···, each greenhouse under the control of the coordinated controller is to be planted. The same crop, including the same plant and the same variety. For example, the greenhouse $A_i\ |_{i=1,2...,n}$ is planted with the same crop (others). The level of the coordinator A, B, C, D, ··· is the micro level of the large system, the z coordinate level of the regional coordinator is the middle level of the large system, and the level above the Ethernet is the macro level coordinator H. The crop model W acts on the microlevel coordinator. Figure 3 shows the block diagram of the system control.

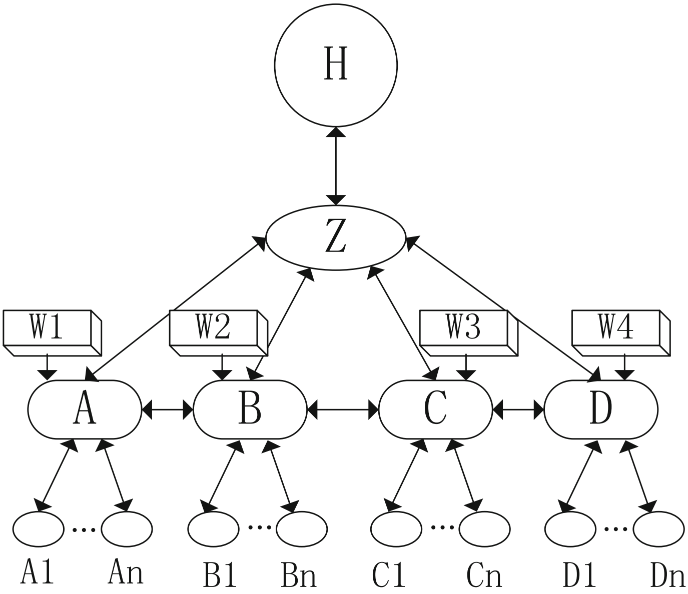

Fig. 3. Greenhouse cluster large system control structure diagram (taking 4 micro-coordinators as an example)

The characteristics of the control structure are:

(1) the crop model expert description acts as a constraint on each micro-coordination controller;
(2) each bottom-level greenhouse system within the micro-level: $(A_1 - A_n)$, $(B_1 - B_n)$, $(C_1 - C_n)$, $(D_1 - D_n)$, D Control recommendations are ON. OFF feedback control mode;
(3) micro-level coordination controllers A, B, C and D can establish a coordination relationship with each other;
(4) from macro coordinator H to meso-level coordinator Z, then to micro-level coordinator A, B, C and D both optimize and design three optimal indicators as constraints, while the underlying control of each greenhouse system is set according to actual needs;
(5) the coordinator not only has network communication and router capabilities, It also features advanced control computing capabilities and a common standard I/O interface.

In this large system control structure, how to design a greenhouse description model based on three constraint parameters is the basis of the control system. Here, the micro-level coordination controller takes the humidity, temperature, and illuminance as the necessary binding amount for the three crops, and the three constraints of the middle-level coordination controller are: water consumption, electricity consumption, output, and macro-level coordination. The three constraints of the device are: output, electricity consumption, and labor. And the generalized space modeling method of large system cybernetics is used to construct the mapping relationship of models in three-dimensional space of granularity, format and intelligent form. There is also a space vector matrix: $\overline{A} = \left[\overline{A}_1, \overline{A}_2, \overline{A}_3\right]$, to establish the following greenhouse cluster object description model:

$$Z_1 = \begin{bmatrix} \overline{A}_1 & 0 & 0 \\ 0 & \overline{A}_2 & 0 \\ 0 & 0 & \overline{A}_3 \end{bmatrix} \cdot \begin{bmatrix} S(x,y)_{z_1} & 0 & 0 \\ 0 & S(x,z)_{z_1} & 0 \\ 0 & 0 & S(y,z)_{z_1} \end{bmatrix}$$

$$Z_2 = \begin{bmatrix} \overline{A}_1 & 0 & 0 \\ 0 & \overline{A}_2 & 0 \\ 0 & 0 & \overline{A}_3 \end{bmatrix} \cdot \begin{bmatrix} S(x,y)_{z_2} & 0 & 0 \\ 0 & S(x,z)_{z_2} & 0 \\ 0 & 0 & S(y,z)_{z_2} \end{bmatrix}$$

$$Z_3 = \begin{bmatrix} \overline{A}_1 & 0 & 0 \\ 0 & \overline{A}_2 & 0 \\ 0 & 0 & \overline{A}_3 \end{bmatrix} \cdot \begin{bmatrix} S(x,y)_{z_3} & 0 & 0 \\ 0 & S(x,z)_{z_3} & 0 \\ 0 & 0 & S(y,z)_{z_3} \end{bmatrix}$$

In the formula: three spatial vectors $\overline{A}_1, \overline{A}_2, \overline{A}_3$, respectively, can represent the spatial hierarchy in the generalized model, that is, the microscopic level, the intermediate level and the macro level, and can also represent the mapping level of a single complex model in different spatial coordinates: Z the granularity direction Fine-grained Z_1, medium-grained Z_2, and coarse-grained Z_3, Math X_1, knowledge X_2, and relationship X_3 in the format X direction, Form self-learning Y_1 in the direction Y, adaptive Y_2, and self-organizing Y_3. And $S(x, y)$, $S(x, z)$, $S(y, z)$ is the object description of a certain layer in the hierarchical structure of the system after dimension reduction. For example, the three most concerned indicators *x, y,* and *z* in the greenhouse cluster system represent water consumption, electricity consumption, and output, then: $\overline{A} \cdot S(x, y) \mid z_1$ represents the microscopic level, that is, the fine-grained relationship between water consumption and electricity consumption in the bottom greenhouse group. However, $\overline{A} \cdot S(x, y) \mid z_2$ indicates the medium-grain relationship between the water consumption and the output of the greenhouse cluster at the meso level. These descriptions relate to the particularity of the agricultural system, boundary fuzzy, coupled associations, non-zero starting points, etc., which can be obtained by fuzzy cluster analysis. Based on this description model, a cloud computing-based greenhouse cluster management system can be built.

4 Greenhouse Cluster Coordinated Control System Model Algorithm

In the hierarchical intelligent control architecture of the greenhouse cluster, the adaptive layer is added to introduce the feedback information of the controlled object, so as to study the robust problem of the objective slow disturbance in the greenhouse, and derive the effective and convergent based on the Lyapunov function. Control rate and adaptive rate; 2. According to the coupling phenomenon of greenhouse cluster control parameters, solve the problem of primitive event sequence organic conversion between the dispatcher and each coordinator in the coordination layer, and use Petri net to solve the conversion operation language combination problem; 3. In the execution layer, according to the objective requirement that the intelligence of the hierarchical system is higher and higher and the control precision is lower and lower, an effective entropy function is designed to find the optimal control instruction sent by the coordinator. (Language), and use this to assess the performance of the greenhouse multi-level hierarchical intelligent control system. The specific design is as follows:

The coordinator designed in this paper consists of four functional modules, which are attached to the cloud server to implement the operation of the four internal modules. Its architecture is shown in Fig. 4. The information is processed, delivered to the task processor and the learning processor, the output of the learning processor is then constrained to the processing of the task, and finally the result is output through the distributor. The key research here is: for the data processor, for determining information, such as: feedback information of on-site detection, processing of sub-controller state feedback information, and given information for uncertain information such as crop yield target and energy consumption target processing method.

For the task processor, the cognitive model should be studied, that is, the cognitive modeling method should be used to establish a knowledge representation; for the learning processor: the cognitive reasoning and optimization algorithm should be studied, and the comprehensively calculated information should be constrained to the task processor. Work so that the task assignments made during each time period are optimal; For the allocator: To study a membership function assignment method, and the algorithm that the distributor generates the output according to the requirements of the task processor output. After four modules, the control output of the greenhouse environmental controller and the crop growth controller is extracted at the output of the coordinator through the distributor. The calculation of the entire module is run on the cloud server. After the control parameters are calculated, they are sent to the controller in the specified greenhouse. The controller controls the actions of the actuator according to the command parameters to realize coordinated control of the greenhouse cluster.

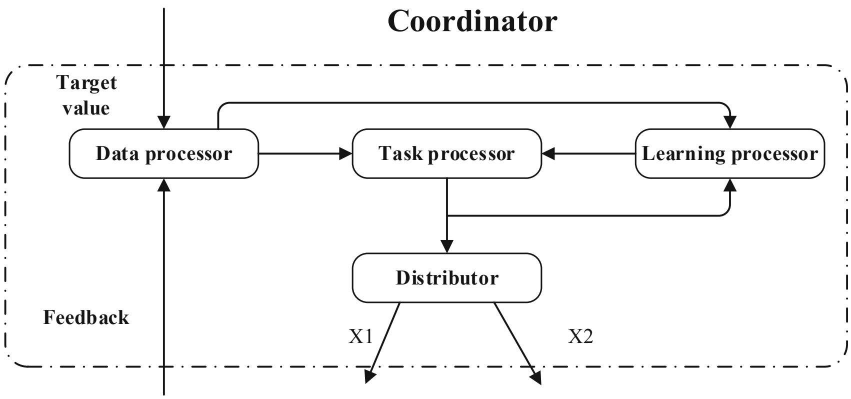

Fig. 4. Coordinator architecture

5 Conclusion

Aiming at the problems in the current greenhouse cluster control system, an information management platform was built based on cloud computing, which realized the distributed collection and unified management of greenhouse cluster information. On this basis, the theoretical research on coordinated control of greenhouse clusters was carried out. On the one hand, the research scheme of the greenhouse system hierarchical large-scale system architecture control theory is proposed. Based on this description model, the cloud computing-based greenhouse cluster management and control system can be built. On the other hand, the greenhouse cluster coordinated control system model algorithm research scheme is designed. A reasonable code framework. In order to study the theoretical model of greenhouse cluster coordinated control, construct a large-scale system of greenhouse cluster hierarchical control, and provide a reference for establishing a greenhouse cluster coordinated control system, it lays a foundation for solving the key model construction and control theory innovation in the greenhouse cluster coordinated control system. It is of theoretical significance and application value to reveal the essential characteristics of hierarchical control in greenhouse clusters, to establish a greenhouse cluster coordination description model, and to establish a greenhouse system control structure model based on large system theory.

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