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Research on multi-agent control system for concrete distribution

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Abstract. A concrete distributor is the key equipment in the production of precast concrete, abbreviated PC, components. Due to the lack of the automatic and intelligent distribution control system for the most domestic concrete distributor, the quality index is poor and the efficiency is low in the concrete distributing process. In order to solve the above problem, the method of constructing a control system is proposed in this paper. This method is based on the theory of multi-agent and the production technology of PC components. The model structure of complex control systems of multi-agent is studied, and the partition mechanism and coordination mechanism of multi-agent for concrete distribution are analysed. Then, the new model of a multi-agent control system for concrete distribution is designed, and the simulation platform of the system is built. The model of the multi-agent control system for concrete distribution designed is beneficial to theory research in the process control of concrete distribution and its application in the field bus control system. Therefore, the foundation for realizing the automation and intelligence of production in concrete distributing is established.

1. Introduction

In the concrete distributing production link, precast concrete (abbreviated PC) components are mainly produced with specialized and industrialized production methods by using the concrete distributor. Abroad, the control system of the concrete distributor is usually designed with the field bus control system [1]. For the control system, it is not enough to realize the digitization in the form, but also to pursue the deeper automation and intelligence in the structure of the control system, integration strategies and control methods. However, in our country, manual control of the concrete distributor is widely used and the distributing process is too dependent on artificial auxiliary distribution. These artificial factors lead to poor quality index and low efficiency in the concrete distributing production. Therefore, a control system with a digital, automatic and intelligent function for the concrete distributor is urgently needed to meet the quality stability and production demand in the production of PC components.

Multi-agent theory is one of the frontier directions in the field of artificial intelligence. With this theory, a complex system, such as a software system, a hardware system, or a hybrid system of the above two systems, can be divided into agents of small, interconnected, coordinated and easy-to-manage [2, 3]. These agents constitute a multi-agent system, which is well compatible with the control system, and can significantly improve the intelligence level of the latter. So, multi-agent theory is



applied to various fields gradually, for example the rolling process automation, robotics, distribution networks, and so on [4-8]. These application cases provide a solid theoretical support and practical basis for the optimization design and advanced control of complex systems. Therefore, the direction for the intelligent development of the complex industrial process of concrete distribution production is pointed out by the multi-agent theory.

In the production of PC components, in order to realize the automatic and intelligent distribution of concrete distributor, and to ensure the accuracy of PC components in size and weight, it is not only necessary to adopt a variety of setting functions, such as pass schedule planning, discharge quantity prediction, landing point model, screw speed setting and self-learning model, etc., but also to employ multiple control functions at the same time, for example the speed control of the small cart of concrete distributor, the pre-calibration position of the concrete distributor, weight control, thickness control and so on. From the point of view of concrete distribution control, all the above setting functions and the control functions can be regarded as agents of the multi-agent system. With the help of multi-agent technology, the mathematical model, expert system, neural network and so on can be integrated into the corresponding setting functions the control functions. Then, the platform of the multi-agent control system for concrete distribution is formed and the automatic and intelligent control for the whole process of concrete distributing is achieved.

In this paper, the control system model for the production of concrete distribution is established with the multi-agent theory. The model structure, partition and coordination mechanism of the multi-agent system are studied, and the intelligent control system for concrete distribution production based on multi-agent is designed. After that, a multi-agent simulation platform of concrete distribution is built. Then, the partition of the functions, tasks, knowledge and data sources of the control system based on the multi-agent theory is completed. A theoretical and practical foundation for the automatic and intelligent development of concrete distributor is laid.

2. Model structure of control system based on multi-agent

For a complex control system, it is easier to handle, debug, and maintain by breaking it down into multiple subsystems which are relative and independent. After that, the fault tolerance of the control system can be also improved [9, 10]. The multi-agent system is composed of several single agents coordinating with each other, and it is easy to form a corresponding relationship with a complex control system. Therefore, the system design method in the multi-agent system can provide ideas for the decomposition and design of complex control systems [11, 12]. Based on the hierarchical design attributes of the multi-agent, the model structure of a complex control system based on the multi-agent is constructed, as shown in figure 1.

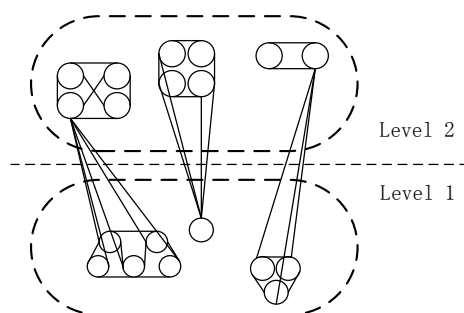


Figure 1. Model structure of a complex control system based on multi-agent

As we can see from figure 1, the multi-agent control system can be composed not only of multiple agents with low capability or single capability, but also of several complex agents, as well as of the two kinds of agents mentioned above. In the two adjacent layers of the multi-agent control system, a unit consisted of multiple agents in Level 2 can be considered as a single entity in Level 1 and a single entity in Level 1 can be regarded as a unit consisting of multiple agents in Level 2.

Based on the model structure shown in figure 1, the multi-agent control system of the concrete distributor is planned according to the control function of the concrete distribution. Level 2 is the

control function of the distribution process, including the positioning function, the speed setting function, the weight control function and so on. On the basis of Level 2, partial control functions are refined to get sub-functional agents represented by Level 1. For example, the weight control function can be divided into the sub-functions about calculation, control and setting, including the prediction calculation of the discharge quantity, the calculation of the number of opening doors, the real-time weight control, and the screw speed setting and so on. The positioning function can be divided into the sub-functions about the landing point calculation, the position pre-calibration, etc. In addition, it is necessary to consider the relatively independent control function when the model structure of the multi-agent control system for concrete distributor is established, such as thickness control, model self-learning, pass schedule planning, coordinated control, etc.

3. Multi-agent partition mechanism of concrete distribution

The cooperation of each agent is required in order to realize the control of complex systems in multi-agent control systems. When a multi-agent system is partitioned, each agent can be matched to an actual physical unit. For instance, in accordance with the physical structure of a concrete distributor, the small cart, the big cart, or each screw can be defined as an agent separately. Alternatively, each agent can also be matched to an abstract unit. For example, according to the function needed in automatic concrete distributing, the speed setting, weight control and thickness control can be designed as an agent respectively. The divided agents can respond reason and make decisions about the environment, solve the given problem and achieve the goal by cooperating with each other.

When a complex system is divided into multi-agent systems, the divided agents can neither be too coarse nor too fine. If the agents are divided too coarsely, the complexity of a single agent increases; If the agents are divided too finely, the single agent will be simplified, but the number of agents will be increased, the system will be complex, and the workload of collaboration will be increased [13]. So it is necessary to consider the complexity of single agent and multi-agent systems in a comprehensive way when a multi-agent control system is divided.

In the control system of a concrete distributor, each function for weight control can be used as an agent and the agents, such as the pass schedule planning agent and self-learning agent, should also be considered. Then, the multi-agent system of weight control is built for automatically and intelligently controlling the distributing weight. The model of the weight control system of multi-agent is shown in figure 2.

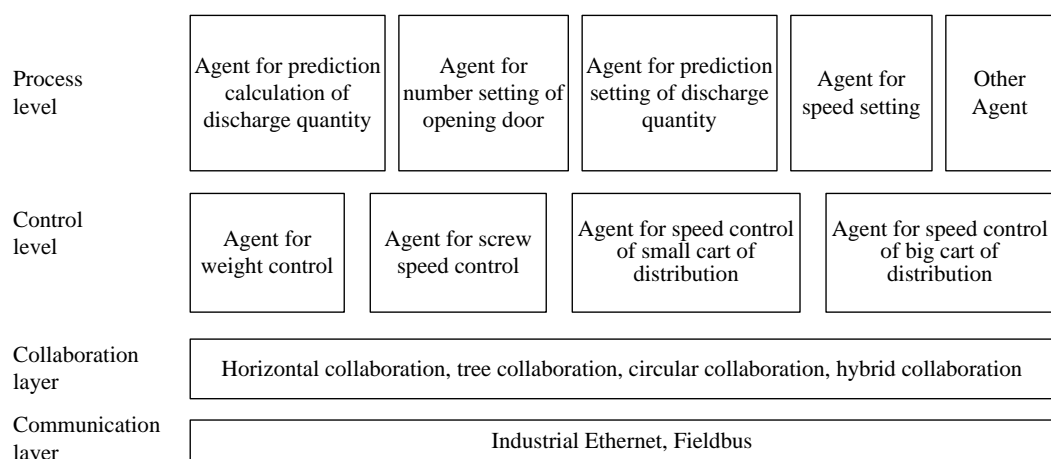


Figure 2. Model of weight control system of concrete distributor based on multi-agent.

4. Multi-agent control coordination of concrete distribution

The process of concrete distribution is characterized by a fast, time variation and high reliability demand. The multi-agent control system for concrete distribution needs to use finite time and

conditions to solve the problems about the coordination and cooperation, such as task assignment and action coordination, under this production process.

Based on the current production characteristics of PC components, according to the degree of mutual influence and restriction of each mechanical device, the system should have a cooperation and coordination mechanism of self-adaption, self-learning and fault-tolerant ability in the design of multi-agent control system for concrete distribution. The self-adaptive capabilities are mainly reflected in that the system can coordinate and control each mechanical device independently according to the latest state of concrete distributing. The self-learning ability is mainly reflected in: the system's ability to improve the accuracy of the model according to the real-time feedback information of the production link, such as screw speed, distribution weight, etc. Fault tolerance is mainly reflected in: the remaining agents' ability to work normally to avoid "paralysis" of the equipment when agents of relatively low importance are in trouble.

5. Model of the multi-agent control system for concrete distribution

In the multi-agent control system for concrete distribution production, each agent has its own task. The model of multi-agent control system, which can deal with the problem of distributing process, is constructed reasonably through the division of work and cooperation, mutual exchange and sharing of resource information, as shown in figure 3.

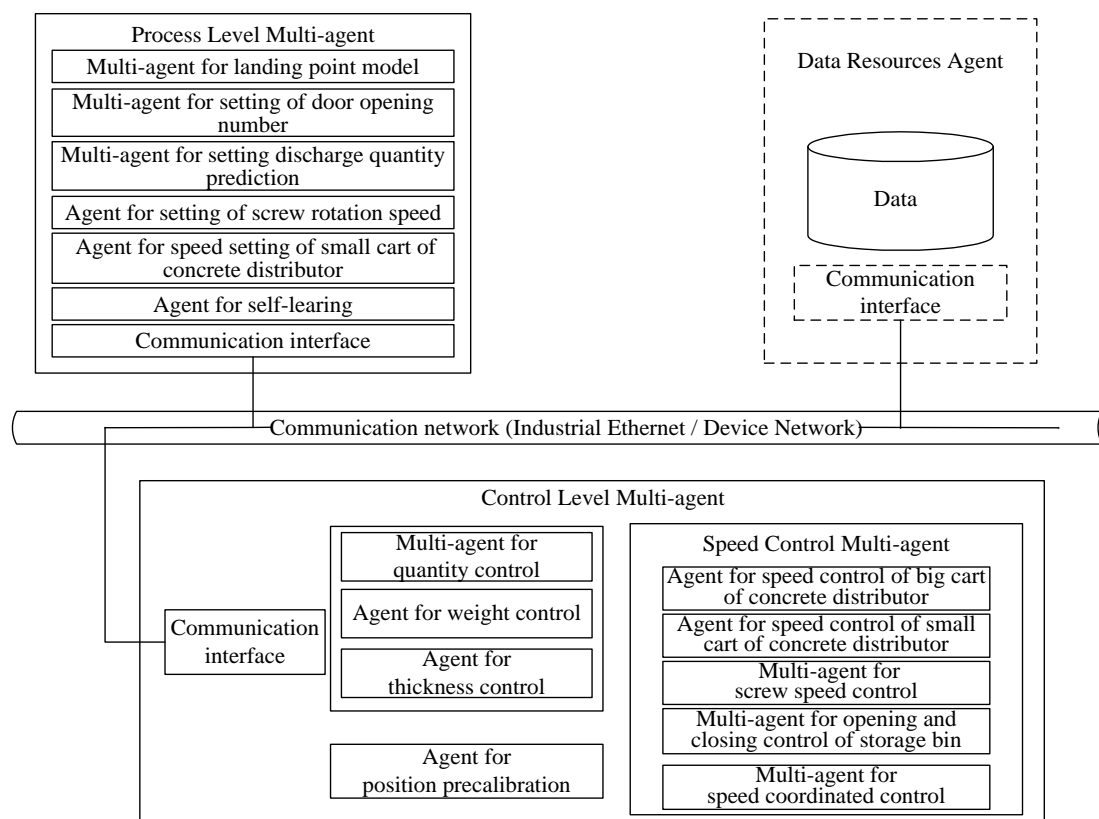


Figure 3. Model of the multi-agent control system for concrete distribution.

The theoretical and practical basis for the design of the control system model shown in figure 3 is provided by both the process engineering of concrete distributing production and the guidance method for designing the multi-agent control system in literature [14-16]. With the help of this model, agents at different network levels can easily communicate and cooperate with each other and successfully complete the corresponding tasks in the distributing process. At the same time, the model also lays a foundation for the realization of the multi-agent control system of concrete distribution.

6. Establishment of the simulation platform for the multi-agent control system

Based on the model of the multi-agent control system shown in figure 3, the simulation platform of the multi-agent control system for concrete distribution is designed, as shown in figure 4.

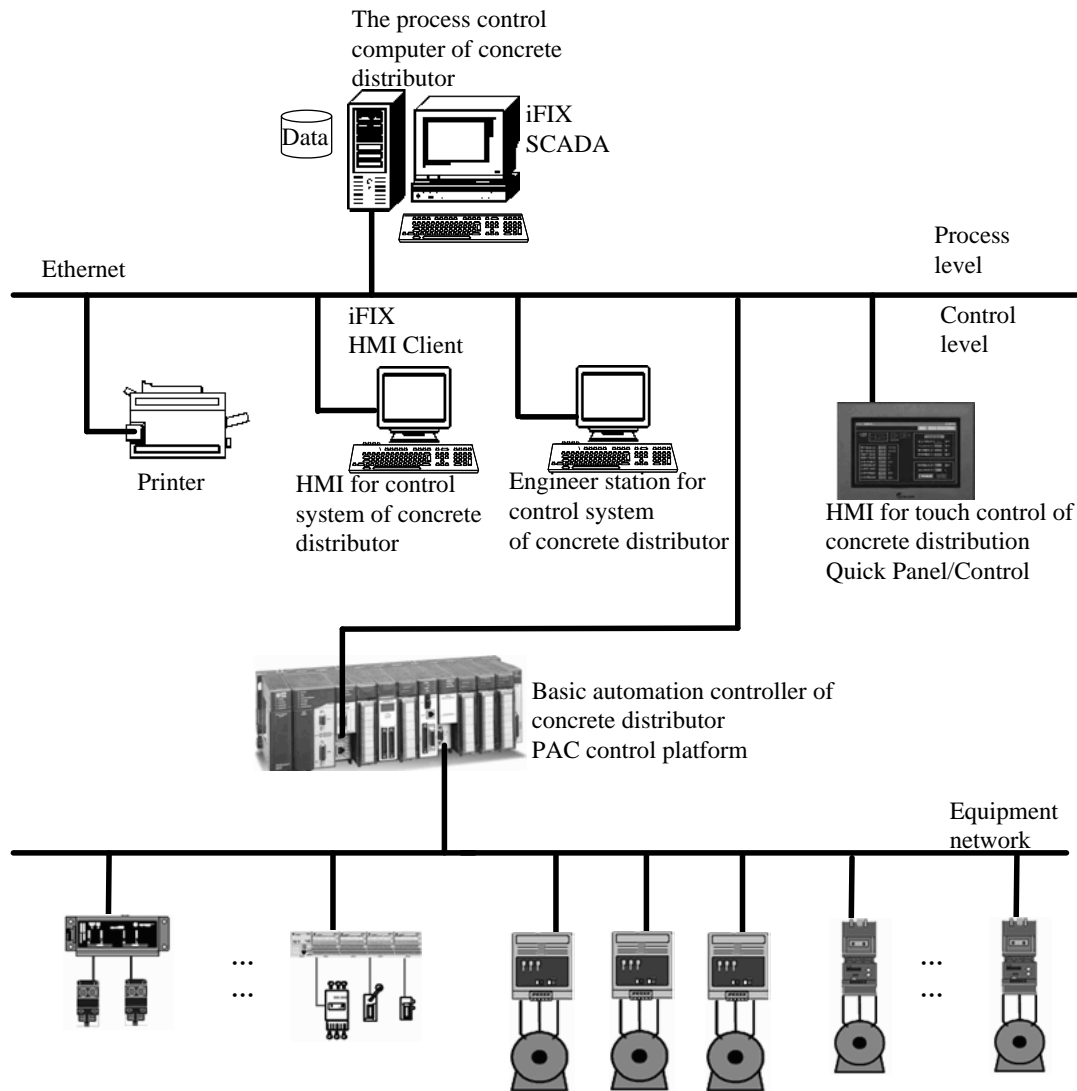


Figure 4. Simulation platform of the multi-agent control system for concrete distribution.

Figure 4 shows that the simulation platform is mainly composed of the process control computer, the human-machine interface, the programmable-automation-controller (abbreviated as PAC) the control platform and the communication network, and it is easily realized with the field bus control system. The process control computer is the realization foundation of the agents with the function of calculation, setting and self-learning. The PAC control platform is the running platform of the agents with autonomous control functions and adaptive functions. The human-machine interface is mainly used to provide the interface between human, machine and platform for monitoring and controlling for the whole system. The Ethernet network is used to establish communication between the process level and the control level. The equipment network is mainly used to connect the controller and the actuator for realizing the control of the controller to the actuator. The simulation platform of the multi-agent control system for concrete distribution is built to lay the foundation not only for further theoretical research and practical application of the process control of the concrete distribution, but also for the intelligent development in the future.

7. Conclusions

With the improvement of customers' requirements for the quality and output of PC components, the automation and intelligence level of the control system for the domestic concrete distributor is difficult to meet the production demand of components. Therefore, the method of constructing control system based on the multi-agent theory is presented, the new model for the multi-agent control system of the concrete distributor is designed, and the simulation platform of the system is built in this paper. The multi-agent control system for the concrete distributor designed in this paper is clear in structure and reasonable in function division. It is beneficial to the theoretical research and application integration of the control function of the concrete distributor, and also to the realization of the automation and intelligence in the process control of concrete distribution production.

Acknowledgments

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