Overview of Intelligent Control

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Abstract

This paper briefly introduces the basic concept, development status and basic characteristics of intelligent control, introduces and analyzes several typical intelligent control forms, and finally looks forward to the development trend of intelligent control.

Keywords

Intelligent control, Fuzzy control , Neural networks.

1. Introduction

With the rapid development of modern science and technology, the scale of production system is gradually expanding, which makes the control objects, controllers, control tasks and effects increasingly complicated. These large complex systems have many forms of complexity. In the whole structure, it is nonlinear, uncertain, infinite dimension, distributed and multi-level. The processed information is represented by the uncertainty, randomness and incompleteness of the signal, as well as the mixture of qualitative knowledge and quantitative calculation. The traditional control theory based on pure mathematical analytical structure has obvious limitations and is no longer suitable for the control of complex systems. To establish a new generation of control theory and method, the control object is not completely taken as the research subject, but the controller is taken as the research subject, and the control problem of complex systems is solved by using the logic reasoning, heuristic knowledge, self-learning and other advantages of artificial intelligence. Intelligent control is proposed and formed in this context.

Intelligent control technology is an advanced stage of the development of automatic control theory. It is a very active and challenging research field in the field of automation at home and abroad. It is closely related to artificial intelligence, automatic control, operations research, computer science, evolution, information theory, bionics and cognitive psychology. It is the product of the combination and penetration of related disciplines and has a broad application background. At present, intelligent control technology has been used in industry, agriculture, national defense, aerospace, communications, services and other fields.

2. Overview of intelligent control

2.1 The development of intelligent control

With the rapid development of aerospace technology, information technology and manufacturing technology, control theory is required to deal with more complex system control problems, so as to provide more effective control strategies. At the same time, it was found that in many systems, complexity, not just on the high dimensional sex, more is reflected in the system of information ambiguity and uncertainty and random and incomplete, which makes people thinking about whether the control object as the research subject into a controller as the research subject, with logic reasoning of artificial intelligence, the way such as heuristic knowledge to solve the control problem of complex objects? Intelligent control is thus born.

The concept of intelligent control was first proposed by professor fu jingsun, a Chinese American from purdue university. In his paper published in 1965, he first proposed to apply heuristic reasoning rules of artificial intelligence to the learning system, which opened a new page for the development

of intelligent control technology. Then, Mendel proposed the new concept of "artificial intelligence control" in 1966. In 1967, Leondes and Mendel first used the term "intelligent control" and applied techniques such as memory and object decomposition to learning control systems. In 1974, British professor Mamdani applied fuzzy language to the theory of fuzzy control, and successfully applied his proposed fuzzy control method to the control of steam engine and boiler. This is the widely used Mamdani fuzzy model. In 1977, Saridis comprehensively discussed the process from feedback control to optimal control, random control to adaptive control, self-organizing control, learning control and finally to intelligent control. In 1979, Mandani successfully developed an organizational fuzzy controller, which made the fuzzy controller more intelligent. In the 1980s, the research on intelligent control entered a period of rapid development. In 1983, Saridis applied intelligent control to the control of robots. In 1984, Astrom directly introduced the expert system technology of artificial intelligence into the control system, and explicitly proposed the new concept of establishing expert control. In the same year, the Hopfield network proposed by Hopfield and the BP algorithm proposed by Rumelhart injected new vitality into the research of artificial neural network, and were quickly applied widely. In August 1985, IEEE held the first academic symposium on intelligent control in New York, marking the birth of intelligent control as an emerging discipline and its establishment internationally as an independent discipline. Since the 1990s, the research momentum of intelligent control has been extremely rapid. Intelligent control has entered the application stage, and its application research field has expanded from the industrial process control to the military, aerospace and other high-tech fields or the field of household appliances. In 1995, the establishment conference of intelligent automation committee and the first China intelligent automation academic conference were held in tianjin. Although China's intelligent control research started late, but the development is very fast, the level of intelligent control research has been recognized by the international academic community.

2.2 Definition of intelligent control

From the perspective of information, intelligence can be specifically defined as the ability to acquire, transmit, process, reproduce and utilize information effectively, so as to successfully achieve a predetermined purpose in any given environment. As for intelligent control, there is no unified definition. According to the definition of general behavioral characteristics, Albus believes that intelligent control is a knowledgeable "behavioral helmsman", which combines knowledge with feedback to form a perception-interactive, goal-oriented control system. The system can carry out planning and decision-making, produce effective and purposeful behaviors, and achieve established goals in an uncertain environment. According to the process definition of human cognition, a.m. stel believes that intelligent control is a computationally effective process, which leads the uncertain complexity to the specified target through the most basic operations, namely induction (G), concentration (CS), and combination operation (CS), under the non-complete indicators. According to the definition of machine intelligence, Saridis points out that intelligent control is a combination of cognitive science, a variety of mathematical programming and control technologies, which integrates various algorithms and mathematical and linguistic methods applied to the system.

Saridis et al. extended fu jingsun's dualistic intersection theory and put forward the ternary theory, which regarded intelligent control as the product of the combination of artificial intelligence, automatic control and operational research. Among them, artificial intelligence is a knowledge processing system, with memory, learning, information processing, language formation, heuristic reasoning and other functions. Automatic control describes the dynamic characteristics of the system and is a kind of dynamic feedback. Operations research is a quantitative optimization method, such as linear programming, network planning and scheduling management, optimization decision-making and multi-objective optimization methods. The IEEE control systems association concludes that intelligent control must have the ability to mimic human learning and adaptation. In short, an intelligent control system has the ability to perform appropriate behavior in an uncertain environment, increasing the probability that the system will complete the task.

2.3 Features of intelligent control

Different from the traditional control theory, the controller is no longer a single mathematical analytical model, but a generalized model combining mathematical analytical model and knowledge system. Generally speaking, intelligent control has the following basic characteristics: 1) have sufficient knowledge of human control strategies, controlled objects and environment and the ability to use such knowledge, and have the ability of compensation and self-repair and judgment and decision-making. 2) in the face of complex systems (such as nonlinear, fast time-varying, multivariate, strongly coupled, uncertain, etc.), it should be able to carry out effective global control to solve generalized problems and have strong fault tolerance. 3) adopt open closed loop control and multi-mode combination control combining qualitative decision and quantitative control. 4) with variable structure. From the perspective of system function and overall optimization to analyze and integrate the system, can be overall self-optimization, in order to achieve predetermined goals, should have adaptive, self-organization, self-learning and self-coordination capabilities. 5) a hybrid control process with a non-mathematical generalized model represented by knowledge and a mathematical model represented by mathematics. In terms of information processing, the system has both mathematical operation and logic and knowledge reasoning.

3. Basic contents of intelligent control theory

Conventional intelligent control methods include fuzzy logic control (LC), hierarchical intelligent control (HIC), neural network control (NNC), expert control (EC) and artificial intelligence control (AHC). Austrom, a famous authority of control theory, pointed out in his article "direction of intelligent control" that fuzzy logic control, neural network and expert control are typical intelligent control methods.

3.1 Fuzzy control

Professor l. a. zadeh, an expert in automation theory at the university of California, first proposed the concept of fuzzy set in 1965, which marked the formal birth of fuzzy mathematics. The basic idea of fuzzy control is to summarize the control strategy of human experts on a specific controlled object or process into a series of control rules expressed in the form of "IF(condition)THEN(action)", and obtain the control action set through fuzzy reasoning and act on the controlled object or process.

Fuzzy control system can realize the automatic control of the system, which integrates fuzzy mathematics, fuzzy language and fuzzy logic. It is a closed-loop numerical control system built by computer. The key of fuzzy control system is the fuzzy controller that can realize fuzzy control. Fuzzy logic is realized by a free way control algorithm, which is applied in the system with high complexity, strong qualitative information, inaccurate information and uncertain information. There is a high similarity between fuzzy control system and negative feedback closed-loop control system. The difference between the two is that the control of fuzzy control system is realized by fuzzy controller, as shown in FIG. 1.

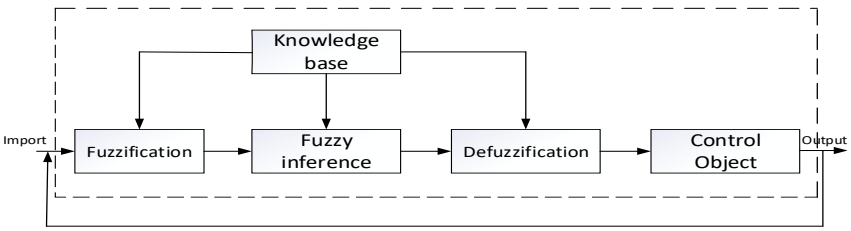

FIG. 1 fuzzy control system

At the beginning of human beings' understanding of things is qualitative, fuzzy and imprecise, so it is of realistic significance to introduce fuzzy information into intelligent control. Compared with conventional control, it has the following characteristics:

Advantages of fuzzy control:

1) the design does not need to establish the mathematical model of the controlled object, but only requires the mastery of human control experience.

2) the system has strong robustness, and the change of controlled object parameters has no obvious influence on the fuzzy control, which can be used for the control of nonlinear, time-varying and time-delay systems.

3) the control query table is obtained by off-line calculation, which improves the real-time performance of the control system.

4) the control mechanism conforms to people's intuitive description and thinking logic of the process control function.

Disadvantages of fuzzy control:

1) when establishing the methods of fuzzification and inverse fuzzification, there is no systematic method, mainly relying on experience and trial and error.

2) once the control rules are determined, they cannot be adjusted online and cannot be well adapted to the changes of the situation.

3) the steady-state accuracy of the fuzzy controller is not high because it does not have an integral link.

From the above characteristics, it can be seen that fuzzy control technology can be used in all cases where mathematical model cannot be established or it is difficult to establish mathematical model. On the one hand, fuzzy control provides a new mechanism to realize the control rules based on natural language description rules. On the other hand, it provides an alternative method to improve the nonlinear controllers, which are generally used to control devices with uncertainty and difficult to deal with by traditional nonlinear theory.

3.2 Neural network control

Artificial neural network (Ann) USES bionics to study advanced information processing in human brain and intelligent system. The controller based on neural network can be regarded as a pattern recognition problem. The pattern to be identified is some signal of a change in a controlled state, output, or a performance evaluation function. These signals are mapped into control signals by neural network. Even if the input information of neural network is insufficient, the pattern can be recognized quickly and the appropriate control signals can be generated. The control effect is reflected by the evaluation function of the system, which is input into the neural network as a kind of change signal to be the learning algorithm or learning criterion of the neural network. The structure of neural network is shown in figure 1-2.

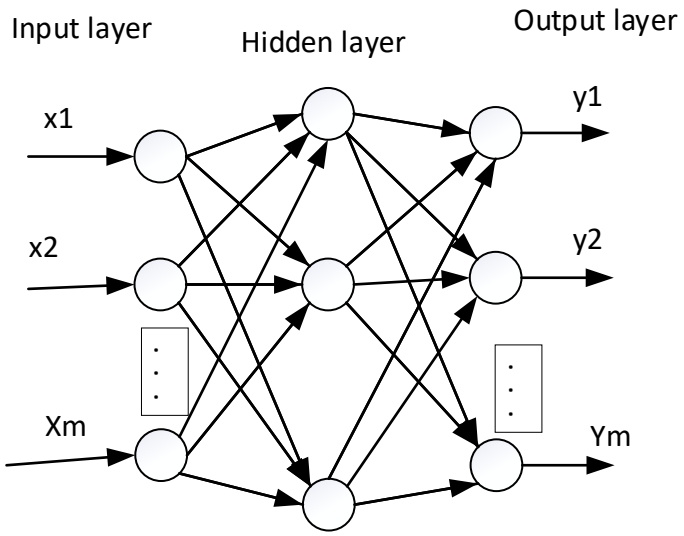

FIG. 2 neural network structure

At present, the research on neural network control is very active, and neural network control is a new research direction of intelligent control. Neural network has the following characteristics:

Advantages of neural network control:

1) can fully approximate any complex nonlinear relationship.

2) all quantitative or qualitative information is equipotential distributed in each neuron in the network, so it has strong robustness and fault tolerance.

3) the parallel distribution processing method is adopted to make it possible to conduct a large number of fast computation.

4) can learn and adapt to unknown or uncertain systems.

5) data fusion ability.

Disadvantages of neural network control:

1) slow learning speed, easy to converge to the local minimum point.

2) the stability of the control is poor.

3) it is difficult to express and deal with a large number of uncertain information in the production process.

From the above characteristics, it can be seen that neural network has a strong ability of information synthesis. It can handle a large number of different types of input at the same time, and can solve the problem of complementarity and redundancy between input information. As an essentially parallel structure, neural network has shown great advantages in the field of automatic control which requires high real-time performance.

3.3 Expert control system

Expert Control System (ECs), one of the most successful branches in the field of artificial intelligence, has been widely used in fault diagnosis, various industrial process Control and industrial design of intelligent Control systems. The emergence of expert control system has changed the situation that traditional control system design only relies on mathematical model, which combines knowledge model with mathematical model, knowledge information processing technology with control technology. Most expert systems are mainly composed of knowledge base, database, reasoning machine, interpreter and knowledge acquirer, as shown in figure 3.

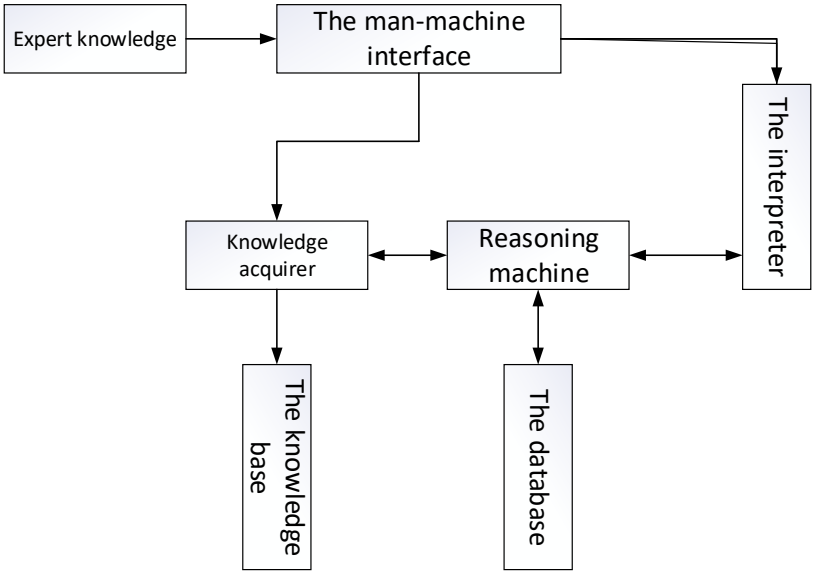

Figure 3 expert control system

Advantages of expert control system:

1) to a certain extent, it can simulate people's thinking and activity rules, carry out automatic reasoning, be good at coping with various changes, and have transparency and flexibility.

2) it can continuously supervise the production process, realize the optimal control under specific performance indexes, handle a large amount of low-level information, and provide operational guidance.

3) compared with traditional control, it has extended many functions, such as high-quality control of complex systems, fault diagnosis and fault-tolerant control, automatic modification of parameters and algorithms, and combination of different algorithms.

4) the introduction of deep knowledge can make up for the lack of experts' experience, and can naturally eliminate decision-making conflicts.

There are still many problems of expert control that need to be solved further:

1) how to solve the problem of knowledge acquisition and how to conduct real-time search to solve the problem of real-time control.

2) how to reasonably combine the deep and shallow knowledge of the process to construct the knowledge base and effectively automatically modify the knowledge base.

3) how to analyze the stability and controllability of the expert control system.

4) how to build generic expert development tools that satisfy process control.

Based on the above characteristics, expert control technology is a knowledge-based control method, which USES the reasoning mechanism of expert system to determine the flexible selection of control method, and realizes the combination of analytic law and heuristic logic, and the combination of knowledge model and control model. It imitates the intelligent behavior of human beings and adopts effective control strategies, thus making it possible to achieve satisfactory control performance. The key to the design and implementation of expert control lies in the complex and diverse control knowledge acquisition and organization methods and the techniques of real-time reasoning. On the one hand, the progress of expert control should introduce the method of knowledge engineering; On the other hand, the development and application of expert control system depends on the help of expert system to develop software and fast computer hardware.

4. Conclusion

This paper systematically discusses the definition and characteristics of intelligent control system, discusses the current situation and development trend of intelligent control system, briefly introduces several basic forms of intelligent control, and expounds their advantages and disadvantages respectively. Intelligent control is a hot topic in the fields of artificial intelligence, automation and computer technology at home and abroad. However, intelligent control is still in the pioneering research stage, and we still need to further study the theory and application problems. The development of intelligent control system will promote the development of automation and the progress of social science and technology.

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