The Enhancement of the Interaction Ability of Robot Perception and Decision-making through Artificial Intelligence from the Perspective of Nonlinear Control Systems

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ABSTRACT

Based on the theory of nonlinear control systems, this paper explores how artificial intelligence can enhance the perception, decision-making and interaction ability of robots. Under the framework of nonlinear control systems, robots will encounter many challenges brought by complex environment, and joining artificial intelligence can help us solve these problems. By analyzing the specific applications of artificial intelligence in perception, decision-making and interaction, we find that it can make robots better adapt to complex environment, improve the accuracy and speed of decision-making, and make people interact with robots more natural and efficient. This provides theoretical support and application reference for the development of robot technology.

Keywords: Nonlinear control system; Artificial intelligence; Robot perception; Robot decision-making; Robot interaction.

1. INTRODUCTION

As an important branch of modern science and technology, robot technology is profoundly changing human production and lifestyle. From automated assembly in industrial production, to precise surgical assistance in medical field, and then to intelligent companionship service industry, the application scenarios of robots are constantly expanding [1]. The theory of nonlinear control system provides an important theoretical basis for the development of robot technology. It takes into account the nonlinear factors such as friction and inertia changes that are common in robot systems, and can describe the dynamic behavior of robots more accurately [2]. However, with the increasingly complex application scenarios, traditional nonlinear control systems face many limitations in perception, decision-making and interaction [3].

The rise of artificial intelligence has brought new development opportunities to robotics. Artificial intelligence has powerful data processing, pattern recognition and self-learning capabilities, which can make up for the shortcomings of traditional nonlinear control systems [4]. By adding artificial intelligence technology to nonlinear control system, robots can better perceive complex environmental information, make more accurate judgments, and interact with us in a more natural and efficient way [5]. Therefore, from the perspective of nonlinear control system, it is of great theoretical significance and practical application value to study how artificial intelligence can enhance the robot’s perception, decision-making and interaction ability.

2. NONLINEAR CONTROL SYSTEMS AND CHALLENGES FACED BY ROBOTS

2.1 Basic Concepts of Nonlinear Control Systems

Nonlinear control system is different from linear control system. The output and input of linear control system are linear, but nonlinear system is not. In the robot system, the dynamic model of the robot is usually nonlinear because of the nonlinear factors such as friction, elastic deformation and joint coupling [6]. The theoretical study of nonlinear control system is how to design a suitable controller so that the robot can follow the desired trajectory stably and accurately under the influence of these nonlinear factors and complete various tasks. Common nonlinear control methods include feedback linearization control, adaptive control, sliding mode control and so on. These methods improve the control performance of the robot to a certain extent, but they still have limitations in the face of complex and changeable environment [7].

2.2 Complex Environmental Challenges Faced by Robots

In practical use, the working environment of robots is often complicated and will change. For example, in a factory, robots have to work in places with noise, vibration and clutter; In the service industry, robots have to cope with changes in user behavior and needs; Outdoor, robots are also affected by weather and terrain [8]. These complex environments bring great challenges to the robot's perception, decision-making and interaction. In terms of perception, robots need to accurately recognize various things and environmental characteristics, but the interference in complex environment may make the sensor data inaccurate and affect the perception effect [9]; In terms of decision-making, robots should quickly make reasonable decisions based on perceived information, but the uncertainty of the environment makes decision-making more difficult; In terms of interaction, robots need to communicate and cooperate effectively with people, but the differences in needs and expressions of different users increase the difficulty of interaction [10].

3. ENHANCEMENT OF ROBOT PERCEPTION CAPABILITIES BY ARTIFICIAL INTELLIGENCE

3.1 Multimodal Perception Fusion

In a complex environment, only one way of perception is often not enough. For example, visual perception is ineffective when the light is dark or blocked, and auditory perception is difficult to accurately distinguish sound information in noisy environment. AI technology promotes the development of multi-modal perception fusion of robots. By combining the data of vision, hearing, touch and other sensors, robots can perceive environmental information more comprehensively and accurately. For example, in the task of item classification, the robot can identify the shape characteristics of items with visual sensors at the same time, and then feel the material and weight of items with tactile sensors, so that items can be classified and grabbed more accurately. Multi-modal sensing fusion can also enhance the stability of the robot in the environment. When a sensor fails or is disturbed, other sensors can provide supplementary information to ensure the normal work of the robot's sensing system.

3.2 Application of Deep Learning in Perception

Deep learning is an important branch of AI, which has made great achievements in the field of robot perception. The deep learning model can efficiently extract features and recognition patterns, and can quickly process the massive data collected by sensors. In terms of visual perception, Convolutional Neural Networks (CNNs) can be used for image recognition, object detection and semantic segmentation. For example, in the field of autonomous driving, robots can use CNNs to recognize vehicles, pedestrians and traffic signs on the road, so that they can open their own roads safely. In tactile perception, the force feedback system based on capsule network can sense the subtle changes of organizational resistance and provide more accurate operational feedback for medical robots. The application of Deep learning enables robots to extract useful information from complex environmental data, which greatly improves the accuracy and efficiency of perception.

3.3 Real-time Processing of Perception Data

In a complex environment, robots need to quickly process the data they sense in order to respond in time. AI technology can help them realize the ability of real-time data processing. On the one hand, through the optimization algorithm and hardware acceleration technology, such as using high-performance computing units (like GPU and FPGA), the reasoning speed of deep learning model can be accelerated, and the robot can perceive the surrounding situation in real time. On the other hand, the rise of edge computing technology allows the robot to preliminarily process and analyze the sensed data locally, which reduces the delay of data transmission and improves the real-time performance of the system. For example, in the application of industrial robots, edge computing equipment can process the images captured by the camera in real time, so that the robot can quickly find the defective products on the production line and adjust and deal with them in time.

4. THE ENHANCEMENT OF ROBOT DECISION-MAKING ABILITY BY ARTIFICIAL INTELLIGENCE

4.1 Application of Reinforcement Learning in Decision-making

Reinforcement learning is a technology that enables robots to learn to make the best decisions by interacting with the environment. In reinforcement learning, robots will try different behaviors by trial and error, and then adjust their behavior strategies according to the reward signals given by the environment, so that they can get the most long-term rewards. In a complex environment, reinforcement learning allows robots to explore and learn by themselves and adapt to uncertain environmental changes. For example, in the field of warehouse logistics, mobile robots can learn the optimal path planning strategy through reinforcement learning, avoid obstacles and congested areas, and improve the efficiency of carrying goods. Reinforcement learning can also be used in robot task allocation and cooperative decision-making, so that multiple robots can cooperate efficiently to complete complex tasks.

4.2 Knowledge-based Decision-making System

Artificial intelligence technology can turn our human knowledge and experience into the basis for robots to make decisions and help them establish a knowledge-based decision-making system. By establishing knowledge base and reasoning mechanism, robots can match and think in the knowledge base according to the information they perceive, and then make reasonable decisions. For example, in the field of medical robots, we put medical knowledge and clinical experience into the knowledge base, so that the robot can diagnose the disease and recommend the treatment plan according to the patient's symptoms, examination results and the rules in the knowledge base. This knowledge-based decision-making system can constantly learn and update knowledge, adapt to new situations and needs, and make its decisions more and more accurate and reliable.

4.3 Optimization of Real-time and Accuracy of Decision-making

In a very complex environment, robots need to make the right decision at once. Nowadays, artificial intelligence technology can help robots make decisions quickly and accurately by improving algorithms and speeding up calculation. On the one hand, using some intelligent search and optimization methods, such as genetic algorithms and particle swarm optimization algorithms, can make the decision-making process faster and take less time. On the other hand, the decision-making system is divided into different levels to manage which is more important, so that the robot can allocate resources reasonably according to the urgency of the task and ensure that the most important things can be dealt with immediately. For example, in the field of autonomous driving, robots must judge road conditions and decide how to drive in a very short time. By optimizing decision algorithm and processing data in real time, the robot can drive safely and efficiently.

5. ENHANCEMENT OF ROBOT INTERACTION CAPABILITIES BY ARTIFICIAL INTELLIGENCE

5.1 Natural Language Processing and Voice Interaction

Natural language processing is the core technology of AI. It allows robots to understand and speak our words and realize voice chat with us. Through speech recognition technology, robots can turn what people say into words and understand what we want to do; Through speech synthesis technology, it can turn words into fluent sounds, which is convenient for communication with us. In the field of service robots, natural language processing technology allows robots to talk to us continuously, answer questions and provide intimate services. For example, hotel service robots can provide room service and query information through voice interaction, so as to make guests' accommodation experience better.

5.2 Emotional Recognition and Response

Emotion recognition is an important application direction of artificial intelligence in robot interaction. Robots can identify users' emotional states, such as happy, angry, sad and so on, by analyzing people's multi-modal information, such as facial expressions, tone of voice and body movements, and make corresponding responses. Emotional recognition and response can make the interaction between robots and people more natural and human, and enhance the emotional experience of users. For example, in the old-age robot, through emotion recognition technology, the robot can detect the emotional changes of the elderly in time, give comfort and companionship, and improve the quality of life of the elderly.

5.3 Multi-Robot Collaborative Interaction

In some complex tasks, a single robot often can't do it alone, and multiple robots need to work together. Artificial intelligence technology provides support robot this multi-robot collaboration. By establishing communication protocol and cooperative decision-making mechanism, multiple robot can share information, coordinate actions and complete tasks together. For example, in disaster relief, multiple drone can cooperate to search the affected areas, and through information sharing and task allocation, the efficiency and accuracy of search can be improved. Multi-robot cooperation can also realize the optimal allocation of resources and improve the performance of the whole system.

6. CONCLUSION

From the perspective of nonlinear control system, this paper discusses how to improve the robot's perception, decision-making and interaction ability with artificial intelligence. In terms of perception, artificial intelligence enables robots to perceive complex environments more accurately and quickly through multi-modal perception fusion, deep learning application and real-time data processing; In decision-making, reinforcement learning, knowledge-based decision-making system and decision-making optimization algorithm enable robots to make more accurate and real-time judgments; In terms of interaction, natural language processing, emotion recognition and multi-robot cooperative interaction technology make the interaction between robots and people more natural and efficient. The integration of artificial intelligence provides strong support for the application of robot technology in complex environment, and promotes the continuous development of robot technology.

In the future, with the continuous advancement of AI technology, the robot's perception, decision-making and interaction capabilities will become stronger. On the one hand, AI will be more deeply integrated with other disciplines, such as cooperation with neuroscience and cognitive science, so that robots have more human-like perception and thinking ability; On the other hand, the interpretability and safety of AI technology will become the focus of research, ensuring that the decisions and behaviors of robots conform to human values and ethics. Moreover, with the development of technologies such as 5G and Internet of Things, robots can be more widely interconnected to form an intelligent robot ecosystem, which will bring greater changes to human society.

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