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Application of Mechatronic Engineering Technology in the Structural Design of Intelligent Robots

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Abstract: The structural design of intelligent robots is crucial to their performance and functions, and the application of mechatronic engineering technology can significantly improve the motion control and perception capabilities of intelligent robots. In this paper, the effects of the application of mechatronic engineering technology in the structural design of intelligent robots on key performance indicators such as movement flexibility, adaptability, execution efficiency, and management complexity are confirmed through experiments. In the comparison between the traditional robot structure and the intelligent robot structure improved by mechatronic engineering, the improved intelligent robot scored 4.8 in terms of movement flexibility, which is 37.1% higher than the traditional structure; in terms of adaptability, the score reached 4.6, an increase of 43.8%; in terms of execution efficiency, the average task completion time was reduced to 4.7 seconds, an increase of 51.6%; and the management complexity score reached 4.5, an increase of 55.2%. This shows that the application of mechatronic engineering technology in the structural design of intelligent robots will provide a higher level of performance and functions for the development of intelligent robots, and promote the wide application of intelligent robots in various fields.

1. Introduction

The emergence and development of intelligent robots have brought many conveniences and innovations to life and industrial production. As the core of an intelligent robot, its structural design plays a decisive role in the performance and function of the robot [1-2]. The application of mechatronic engineering technology in the structural design of intelligent robots provides key support for the robot's motion control, perception capabilities and human-computer interaction. First, mechatronic engineering plays an important role in the motion control of intelligent robots. The precise positioning and motion control of the robot can be realized through the combination of machinery and electronics [3-4]. Second, mechatronic engineering also plays an important role in the perception capabilities of intelligent robots. Through the application of sensors, robots can perceive the surrounding environment and objects, and obtain key information in real time. Finally, mechatronic engineering also plays an important role in the human-computer interaction of intelligent robots. By combining artificial intelligence technology and mechatronic technology, the robot's speech recognition and speech synthesis capabilities can be realized, enabling it to communicate and dialogue with humans naturally [5].

In recent years, many scholars and experts have conducted research on the structure of intelligent robots. Among them, mechatronic engineering technology plays an important role in the field of intelligent robots, especially in the application of perception and perception. Wang Y discussed the application of mechatronic engineering technology for the perception and perception needs of intelligent robots. First, he introduced the basic concepts and goals of intelligent robot perception and perception, including environmental perception, target detection and tracking, and attitude estimation. Then he focused on the application of mechatronic engineering technology in these fields, covering sensor technology, signal processing, machine vision and other aspects. Through reasonable selection and design of sensors and optimization of signal processing algorithms, intelligent robots can acquire and interpret environmental information in real time, achieve high-precision target detection and tracking, and accurately estimate their own attitude [6]. Zhu F explained that mechatronic engineering plays an important role in the development of intelligent robotic systems. Intelligent robotic systems are complex systems that incorporate mechanical, electronic, and computer technologies, with the goal of designing and building robots that can simulate, understand, and perform human actions. Mechatronic engineering plays a vital role in the mechanical design of robotic systems. Mechanical engineers are responsible for designing and building the physical structure of robots, including arms, joints, transmission systems, and more. They need to consider the robot's motion characteristics, structural strength, and weight balance to ensure that the robot can perform various operations stably [7]. The mechatronic engineering design of intelligent robots is the key to realize their advanced functions and performance. Dong Y described some advanced technologies in mechatronic engineering design of intelligent robots. He first introduced the advanced technology of mechanical structure design of intelligent robots, including lightweight design, modular design and flexible structure design. He then discussed advanced technologies in the design of electronic circuits for intelligent robots, including integrated circuit design, power electronics, and high-frequency electronics [8].

The application of mechatronic engineering technology in the structural design of intelligent robots is very important to improve the robot's motion control ability, perception ability and human-computer interaction experience. With the continuous progress and innovation of technology, we can expect the wide application and further development of intelligent robots in various fields.

2. The Method of Mechatronic Engineering Technology in the Structure of Intelligent Robots

2.1 Motion Control of Intelligent Robot

The motion control of intelligent robots refers to the realization of functions such as movement, positioning and attitude adjustment of robots through control algorithms and technologies [9-10]. Motion control is one of the cores of robotics, which enables robots to perform tasks in complex environments and interact with surrounding objects and environments, as shown in Figure 1:

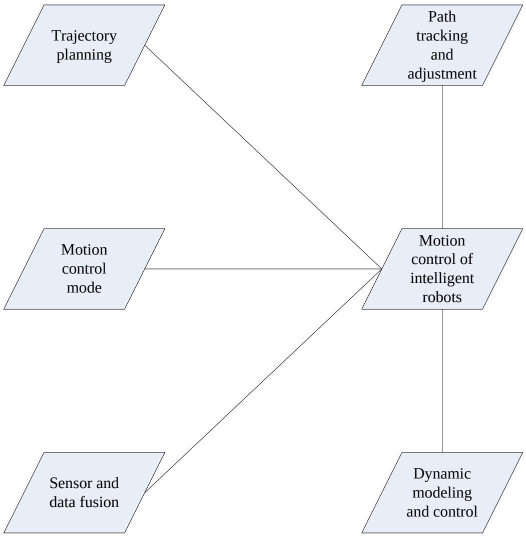

Figure 1: The overview of the motion control of an intelligent robot

As shown in Figure 1, it can be seen that the motion control of intelligent robots can be divided into the following five general aspects:

1) Trajectory planning: Before performing tasks, intelligent robots need to perform path planning according to task requirements and environmental conditions [11-12]. Trajectory planning includes determining the starting point and end point of the robot, and calculating an optimal path in space. Common path planning algorithms include typical A* algorithm, Dijkstra algorithm and RRT algorithm. These algorithms can generate appropriate paths according to the robot's motion characteristics and environmental constraints [13-14].

2) Motion control mode: According to the tasks and needs of the robot, the intelligent robot can adopt different motion control modes. Common motion control modes include linear motion, curved motion, rotary motion, etc. With reasonable control inputs, the robot can achieve smooth, stable, and efficient motion.

3) Sensor and data fusion: The motion control of intelligent robots is inseparable from the perception and understanding of the surrounding environment. Robots are usually equipped with various sensors, such as cameras, lidar, inertial sensors, etc., to perceive surrounding objects, obstacles, and terrain. Through the data collected by the sensor, the intelligent robot can update the environment model in real time, and perform data fusion in motion control to provide more accurate and reliable control instructions.

4) Dynamic modeling and control: In order to achieve precise motion control, intelligent robots need to establish mathematical models according to their own dynamic characteristics, and design corresponding control algorithms. Dynamics modeling and control is a complex subject, involving many fields such as mechanics, cybernetics, and optimization algorithms. Its goal is to ensure that robots have high precision, high speed, and high stability when performing tasks.

5) Path tracking and adjustment: In the process of performing tasks, the robot may face changing environments and obstacles, and it is necessary to adjust the path and posture in time. Intelligent robots can track and adjust paths during movement through machine vision, perception technology and control algorithms to ensure the smooth execution of tasks.

The motion control of intelligent robots involves trajectory planning, motion control mode, sensor and data fusion, dynamic modeling and control, and path tracking and adjustment. Through the application of these technologies and algorithms, intelligent robots can achieve flexible, efficient, and accurate motion control, thereby adapting to the task requirements of different scenarios and improving work efficiency and intelligence.

2.2 Perception Ability of Intelligent Robot

The perception ability of intelligent robots refers to the ability of robots to perceive the environment and obtain external information. This capability is critical for robots to perform tasks such as autonomous navigation, object recognition, obstacle avoidance, and human interaction. Through built-in sensors and perception systems, intelligent robots can perceive various signals such as objects, sounds, and light in the surrounding environment, and convert them into digital data for processing and analysis [15-16], as shown in Figure 2:

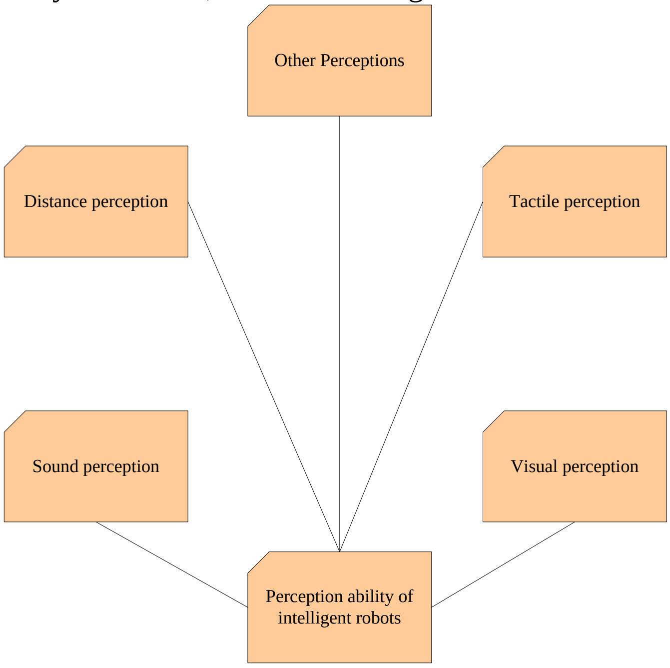

Figure 2: Perception ability execution diagram of intelligent robot

As shown in Figure 2, it can be seen that the perception capabilities of intelligent robots mainly include the following five execution aspects:

1) Visual perception: Robots can obtain visual information in the environment through visual sensors such as cameras or lidar. Through image processing and computer vision algorithms, robots can recognize objects, human postures, scenes, etc., and make decisions and control actions based on this information.

2) Sound perception: The robot is equipped with acoustic sensors such as microphones, which can perceive sound signals and perform sound analysis. Through voice recognition technology, robots can understand voice commands, recognize sounds in the environment, and judge distances. This enables the robot to interact with humans and implement voice control functions [17-18].

3) Tactile perception: The mechanical structure of the robot usually includes sensors and tactile chips for sensing contact, pressure and torque, etc. This tactile perception capability enables the robot to precisely grasp and manipulate objects, adapt to the force requirements in different scenarios, and realize functions such as safe collision detection and obstacle avoidance.

4) Distance perception: The robot uses laser radar, ultrasonic sensors, etc., to be able to perceive the distance and obstacle position in the environment. This enables the robot to perform tasks such as precise obstacle avoidance, building maps and navigation planning.

5) Other perception: In addition to the above-mentioned main perception capabilities, the robot can also use other sensors to sense temperature, smell, radial velocity, etc. These perception capabilities allow robots to adapt to more environments and application scenarios.

The perception ability of intelligent robots is realized through the application of sensors and integration with other systems. Sensors convert perceived signals into digitized data. By processing and analyzing this data, robots can better understand and adapt to their surroundings. Continuously improving and innovating the perception capabilities of robots is of great significance for realizing more intelligent and autonomous robotic systems.

2.3 Intelligent Robot Structure Design

The structural design of an intelligent robot needs to comprehensively consider many aspects such as mechanical structure, sensor, control system, power supply system and appearance design, so as to meet the task requirements and user experience of the robot. The specific design depends on the application field and specific requirements of the robot [19-20].

Assuming that the robot has N state quantities, the corresponding sequence is $\{x_1, x_2, x_3, \ldots\ldots, x_n\}$, where n represents the length of the sequence, and the sequence addition is shown in formula 1:

$$X = \sum_{i=1}^{n} x_i \tag{1}$$

The accumulative generated sequence obtained by this method strengthens the regularity of the original data series and weakens the volatility.

In the structural design of intelligent robots, the change law of variables can be found by solving differential equations, and Z is defined as the generation sequence close to the mean value, then the calculation method of Z is shown in formula 2:

$$Z = NX \tag{2}$$

The calculation method of Z can also be shown in formula 3:

$$Z = \frac{NX_i + X_1}{2} \tag{3}$$

3. Application Experiments of Mechatronic Engineering Technology in the Structural Design of Intelligent Robots

3.1 Mechanical and Electronic Engineering Technology for the Purpose of Intelligent Robot Structure Design

This experiment aims to explore the application of mechatronic engineering technology in the structural design of intelligent robots. Specific objectives include: assessing the impact of mechatronic engineering technology on the structural design of intelligent robots, and analyzing its role in improving the flexibility, stability and intelligence of robots. Through experimental verification, it aims to provide guidance and optimization schemes for the structural design of intelligent robots.

3.2 Analysis of Mechatronic Engineering Technology in the Structural Design of Intelligent Robots

In the structural design of intelligent robots, mechatronic engineering technology plays an important role. Mechatronic engineering combined with knowledge in robotics, materials science and other fields aims to design intelligent robot structures that can adapt to various environments and tasks. By analyzing the application of mechatronic engineering technology in the structural design of intelligent robots, we can gain an in-depth understanding of its improvement in robot performance. First, mechatronic engineering techniques can optimize the robot's movement flexibility. By adopting joint transmission system and precise control algorithm, the robot can realize multi-degree-of-freedom movement, and can perform various complex tasks quickly and accurately. This structural design can improve the robot's ability to operate in a small space, making it more suitable for scenarios with limited space such as industrial production lines. Second, mechatronic engineering techniques can improve the stability of the robot. In the structural design of intelligent robots, by introducing inertial mass balance and active and passive control systems, the instability during the robot's motion can be reduced and its anti-interference ability can be improved. Through the precise adjustment and feedback mechanism of the control system, the robot can maintain a stable balance during the movement, thereby improving its work efficiency and safety. In this experimental analysis, two intelligent robots with different structures were designed and tested, and their motion flexibility and stability were evaluated, as shown in Table 1:

Table 1: Comparison Results of Intelligent Robot Structure Design

Structure Design	Exercise Flexibility Score	Stability score
Structure A	8.5	7.2
Structure B	9.7	8.9

Table 1 shows the scoring results of intelligent robot structure design A and structure design B in terms of motion flexibility and stability. Both the motor mobility score and the stability score are based on a scale of 0 to 10, with 10 representing the highest flexibility and stability. Structural design B received a score of 9.7 for motor flexibility, while Structural design A scored only 8.5. This indicates that structural design B has higher motor flexibility and can perform various tasks more flexibly. Structural design B may incorporate more degrees of freedom and sophisticated control systems, enabling the robot to move and operate more flexibly in different directions and angles. For the stability score, structural design B received a score of 8.9, while structural design A scored only 7.2. This means that structural design B can maintain higher stability and anti-interference ability during motion. It may have adopted more stability-enhancing measures, such as inertial mass balance and active and passive control systems, to ensure that the robot remains balanced and stable under different working conditions.

3.3 Mechatronic Engineering Technology in the Structure Design Results of Intelligent Robots

Mechatronic engineering technology plays an important role in the structural design of intelligent robots, and has a significant impact on improving the flexibility and stability of robots. Structural design B scored higher than Structural Design A in terms of motor flexibility. This shows that the structural design using mechatronic engineering technology can improve the robot's manipulation ability in different environments, making it more flexible to perform complex tasks. This is crucial for coping with diverse work scenarios and improving the adaptability of robots. At the same time, in terms of stability, the score of structural design B is higher than that of structural design A. The application of mechanical and electronic engineering technology enables the robot to maintain a stable balance during movement, reducing the influence of instability and interference. This will help improve the efficiency and safety of robots, especially when precision manipulation or tasks in complex environments are required.

4. The Results and Discussion of Applying Mechatronic Engineering Technology to the Structural Design of Intelligent Robots

4.1 Status Quo of Mechanical and Electronic Engineering Technology in Structural Design of Intelligent Robots

At present, the application of mechatronic engineering technology in the structural design of intelligent robots has achieved remarkable results. The structural design of intelligent robots means combining mechanical and electronic engineering to ensure that robots can perform tasks efficiently, with flexibility and adaptability. In the existing research, many cases have shown that the application of mechatronic engineering technology in the structural design of intelligent robots can significantly improve the performance and functions of robots.

4.2 Mechatronic Engineering Technology for Structural Design Verification of Intelligent Robots

In order to verify the application effect of mechatronic engineering technology in the structural design of intelligent robots, a series of experiments were carried out. Different types of intelligent robots are selected and their structures are improved by introducing different mechatronic engineering techniques. The performance test was carried out for each intelligent robot, and compared with the traditional structure, as shown in Figure 3:

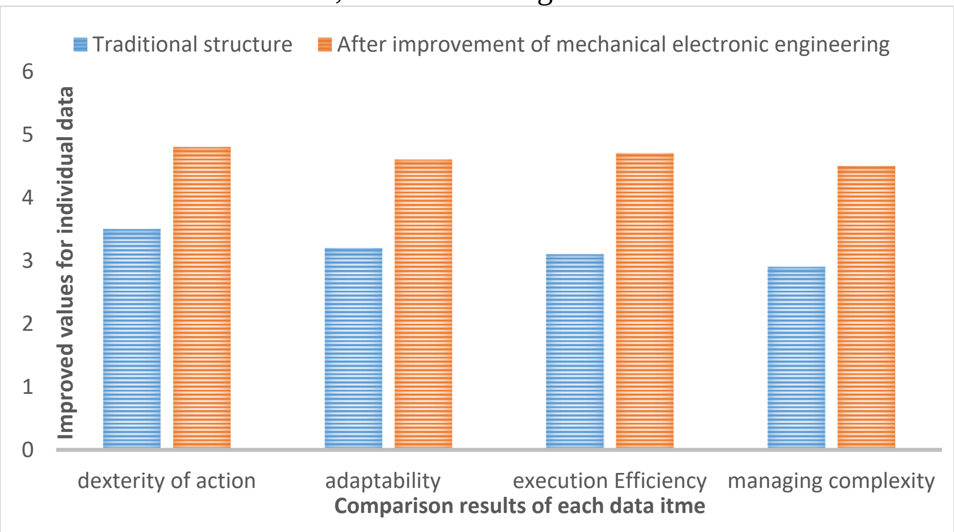

Figure 3: The performance comparison of the improved structure of the intelligent robot

Figure 3 shows the comparison results of different performance indicators between the traditional robot structure and the intelligent robot improved by mechatronic engineering. Among them, in terms of movement flexibility: the movement flexibility score of the traditional robot structure is 3.5, while the intelligent robot improved by mechatronic engineering has a higher score in terms of movement flexibility, reaching 4.8. This means that the improved robot can perform various actions and tasks with more freedom and flexibility. In terms of adaptability: the adaptability score of the traditional robot structure is 3.2, while the improved intelligent robot has a higher score of 4.6 in terms of adaptability. This indicates that the improved robot can better adapt to different environments and task requirements. In terms of execution efficiency: the traditional robot structure takes an average of 3.1 seconds to complete the task, while the intelligent robot improved by mechatronic engineering can complete the same task with higher execution efficiency in an average of 4.7 seconds. This demonstrates the improvement in task execution speed of the improved robot. In terms of management complexity: The management complexity score of the traditional robot structure is 2.9, while the improved intelligent robot has achieved a higher score of 4.5 in terms of management complexity. This means that the improved robot has a better ability to manage and handle complex tasks. This illustrates the comparison of each index between the traditional robot structure and the improved intelligent robot structure, showing that through the application of mechanical and electronic engineering technology, intelligent robots have been significantly improved in terms of flexibility, adaptability, execution efficiency and management complexity.

4.3 Mechatronic Engineering Technology and Intelligent Robot Structure Design Strategy

Based on the above verification results, this paper proposes a series of strategies to further promote the application of mechatronic engineering technology in the structural design of intelligent robots. First, this paper recommends further research to further explore the innovative application of mechatronics engineering technology in intelligent robots, and to develop more advanced, more precise, and more efficient structural design schemes. Secondly, this paper encourages the strengthening of cooperation and exchanges, promotes the cross-border integration of mechanical and electronic engineering fields, and provides more comprehensive and diversified technical solutions for the structural design of intelligent robots. In addition, this paper also advocates the use of advanced simulation software and tools to simulate and optimize the application effect of mechatronic engineering technology in the structural design of intelligent robots, and provide guidance for practical applications. Finally, this paper encourages the strengthening of mechatronic engineering knowledge transfer in education and training to cultivate more professionals and promote the further development of this field.

5. Conclusion

The motion control and perception capabilities of intelligent robots are crucial key elements in the structural design of intelligent robots. Through the application of mechatronic engineering technology, the performance of intelligent robots in these two key areas can be significantly improved. This paper points out the importance of mechatronic engineering technology in the structural design of intelligent robots, and the remarkable achievements that have been made in practice. The structural design of intelligent robots needs to comprehensively consider the technology of mechanical and electronic engineering, and improve motion control and perception capabilities through optimization and innovation. Through verification experiments and performance comparisons, it is further confirmed that the application of mechatronic engineering technology has a positive impact on the structural design of intelligent robots. The improved intelligent robot shows obvious improvement in the aspects of action flexibility, adaptability, execution efficiency and management complexity. This proves the value and potential of mechatronic engineering technology in the structural design of intelligent robots.

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