Original Research Article

Design and control strategy of robot arm for intelligent irrigation robot

Tonggang Shao

Henan Agricultural University, Zhengzhou City, Henan Province, 450046, China

Abstract:This article focuses on the intelligent irrigation robot arm and explores its design and control strategy in depth.On the basis of elaborating on the development background and significance of intelligent irrigation robot arms, a detailed analysis of mechanical structure design is conducted, including arm configuration, joint design, and material selection;In depth research on control strategies, covering motion control algorithms, sensor applications, and intelligent decision-making systems;And test and evaluate its performance.The research aims to provide theoretical and practical support for the optimization design and wide application of intelligent irrigation robot arms, and promote the development of intelligent agricultural irrigation.

Keywords: Intelligent irrigation robot; Mechanical arm design; Control strategy; Sensor technology; Sports planning

1. Introduction

With the continuous advancement of technology and the acceleration of agricultural modernization, intelligent irrigation technology has become an important means to improve agricultural production efficiency and save water resources.The intelligent irrigation robot arm, as a key executing component of the intelligent irrigation system, can achieve precise and efficient irrigation operations, which is of great significance for improving the automation and intelligence level of agricultural irrigation.

2. The development background and significance of intelligent irrigation robot arm

The traditional artificial irrigation method not only consumes a lot of manpower and time, but also has difficulty ensuring the uniformity and accuracy of irrigation, which can easily lead to the waste of water resources.Against the backdrop of increasingly scarce water resources and agricultural labor shortages, intelligent irrigation technology has emerged.The intelligent irrigation robot arm can automatically adjust the irrigation position, angle, and water amount based on information such as soil moisture and crop water demand, achieving precise irrigation.This can not only improve irrigation efficiency and reduce water resource waste, but also reduce labor intensity and enhance the economic and ecological benefits of agricultural production.

3. Mechanical structure design of intelligent irrigation robot arm

3.1. Arm configuration selection

The configuration of the intelligent irrigation robot arm directly affects its working performance and application scope.Common configurations include Cartesian coordinates, cylindrical coordinates, polar coordinates, and joint coordinates.Articulated robotic arms have the advantages of compact structure, large workspace, and high flexibility, making them suitable for irrigation operations in complex agricultural environments.The circuit board design mainly involves initializing with the STM32CubeMX microcontroller and configuring relevant

GPIO ports, timers, PWM outputs, etc.to meet the motion control requirements of the robotic arm.In software design, modular programming is adopted to independently design functional modules such as joint motion control, sensor data acquisition, and intelligent decision-making algorithms to improve code readability and maintainability.At the same time, considering the real-time and reliability requirements of agricultural irrigation operations, a real-time operating system RTOS is used for task scheduling and resource management to ensure that various functional modules can work together and achieve efficient and stable operation of intelligent irrigation robot arms.

3.2. Joint design

Joints are key components of robotic arms, and their performance directly affects the accuracy and stability of arm movement.In joint design, high-precision rotary joints and linear joints were selected.The circuit board design mainly uses the single-chip microcontroller stm32cubeMX to achieve joint motion control.The STM-32CubeMX microcontroller has powerful processing capabilities and can efficiently execute complex control algorithms to ensure precise joint movements.In addition, the circuit board design also considers electromagnetic compatibility to reduce the impact of external interference on joint motion and improve system stability. The reliability and durability of joint design are ensured through reasonable circuit layout and component selection.

3.3. Material selection

In order to reduce the weight of the robot arm, improve its motion performance and energy utilization efficiency, high-strength and low-density aluminum alloy materials are preferred in material selection.Aluminum alloy materials have good mechanical properties and corrosion resistance, which can meet the requirements for the use of robot arms in agricultural environments.Meanwhile, for some key components such as joint bearings and lead screws, high-quality alloy steel materials are selected to ensure their strength and wear resistance.

4. Control strategy of intelligent irrigation robot arm

4.1. Motion control algorithm

The motion control algorithm of the intelligent irrigation robot arm is the key to achieving its precise motion.Using inverse kinematics algorithm based on Cartesian space, convert the target position and posture of the end effector of the robot arm into angle values for each joint.By controlling the angle of each joint, precise movement of the robot arm can be achieved.At the same time, in order to improve the accuracy and stability of motion control, the programming software keiluvision5 algorithm is used for closed-loop control of joint motors.The programming software Keiluvision5 algorithm can automatically adjust the output torque of the motor based on the deviation between the actual position of the joint and the target position, enabling the joint to quickly and accurately reach the target position.

4.2. Sensor applications

Sensors are an important component of intelligent irrigation robot arms for achieving intelligent control. Install various sensors on the robot arm, including position sensors, force sensors, humidity sensors, etc.Position sensors are used to monitor the angle and position of joints in real time, providing feedback information for motion control;Force sensors are used to detect the force between the end effector of the arm and crops or other objects, preventing the arm from causing damage to crops during movement;Humidity sensors are used to detect soil moisture and provide a basis for irrigation decisions.By real-time collection and analysis of sensor data, the robotic arm can automatically adjust irrigation strategies based on actual conditions, achieving precise irrigation.

4.3. Intelligent decision-making system

The intelligent decision-making system is the core of the intelligent irrigation robot arm, which can automatically make irrigation decisions based on data collected by sensors and preset irrigation rules.The intelligent decision-making system adopts intelligent detection methods/approaches.To analyze and evaluate multiple factors such as soil moisture, light intensity, plant species, and growth cycle, in order to determine the optimal irrigation plan.The system can adjust irrigation strategies in real-time to adapt to different environmental conditions and crop needs, ensuring the accuracy and efficiency of irrigation.In addition, the intelligent decision-making system also has self-learning ability, which can continuously optimize irrigation strategies and improve irrigation efficiency based on historical irrigation data and crop growth conditions.

5. Performance testing and evaluation of intelligent irrigation robot arm

5.1. Testing platform construction

In order to test and evaluate the performance of the intelligent irrigation robot arm, a dedicated testing platform was built.The testing platform includes the robot arm body, control system, sensor system, simulated farmland environment, and other parts.Set different types of crops and soil conditions in a simulated farmland environment to simulate actual irrigation scenarios.

5.2. Performance testing indicators

The performance testing indicators of the intelligent irrigation robot arm mainly include motion accuracy, load capacity, irrigation uniformity, water resource utilization rate, etc.The motion accuracy is evaluated by measuring the deviation between the actual position of the arm end effector and the target position;The load capacity is determined by testing the maximum load that the arm can withstand;Irrigation uniformity is evaluated by measuring the amount of irrigation water at different locations;The utilization rate of water resources is evaluated by calculating the ratio of actual irrigation water to crop water demand.

5.3. Test results and analysis

A series of test data were obtained through performance testing of the intelligent irrigation robot arm.The test results show that the motion accuracy of the robot arm can meet the requirements of irrigation operations, and the load capacity can adapt to different irrigation tools and operating conditions;Good irrigation uniformity can ensure that crops receive uniform water supply;The utilization rate of water resources has been significantly improved, and compared to traditional irrigation methods, the water-saving effect is obvious.At the same time, the problems that occurred during the testing process were analyzed and summarized, providing a basis for further optimizing the design and control strategy of the robot arm.

6. Conclusion

The design and control strategy research of intelligent irrigation robot arm is of great significance for promoting the intelligent development of agricultural irrigation.By designing a reasonable mechanical structure and selecting appropriate arm configurations, joints, and materials, it provides a guarantee for the efficient movement of robot arms;Through advanced control strategies, including motion control algorithms, sensor applications, and intelligent decision-making systems, precise control of robot arms and intelligent irrigation operations have been achieved.The performance testing and evaluation results indicate that the intelligent irrigation robot arm has good performance indicators and can meet the actual needs of agricultural irrigation. In future research, it is necessary to further optimize the design and control strategies of robot arms, improve their intelligence and adaptability, and promote the widespread application of intelligent irrigation robot arms in agricultural production.Meanwhile, with the continuous development of technologies such as artificial intelligence and the Internet of Things, intelligent irrigation robot arms will collaborate with other intelligent agricultural equipment to build a more comprehensive intelligent agricultural irrigation system, making greater contributions to the modernization of agriculture.

References

[1] Bio-inspired affordance learning for 6-DoF robotic grasping:A transformer-based global feature encoding approach[J].Zhao Zhenjie; Yu Hang; Wu Hang; Zhang Xuebo.Neural Networks.2024

[2] A visual imitation learning algorithm for the selection of robots’grasping points[J].Zhang Shuai; Li Shiqi; Li You; Li Xiao; Wang Zhiguo.Robotics and Autonomous Systems.2024

[3] Robot autonomous grasping and assembly skill learning based on deep reinforcement learning[J].Chen Chengjun; Zhang Hao; Pan Yong; Li Dongnian.The International Journal of Advanced Manufacturing Technology.2024

[4] Peduncle collision-free grasping based on deep reinforcement learning for tomato harvesting robot[J].Li Yajun; Feng Qingchun; Zhang Yifan; Peng Chuanlang; Ma Yuhang; Liu Cheng; Ru Mengfei; Sun Jiahui; Zhao Chunjiang.Computers and Electronics in Agriculture.2024

[5] Efficient reinforcement learning with least-squares soft Bellman residual for robotic grasping[J].Lan Yixing; Ren Junkai; Tang Tao; Xu Xin; Shi Yifei; Tang Zixin.Robotics and Autonomous Systems.2023

[6] A review on reinforcement learning for contact-rich robotic manipulation tasks[J].Elguea-AguinacoÍñigo; Serrano-Muñoz Antonio; Chrysostomou Dimitrios; Inziarte-Hidalgo Ibai; Bøgh Simon; Arana-Arexolaleiba Nestor.Robotics and Computer-Integrated Manufacturing.2023