Current Status and Future Prospects of Livestock and Poultry Breeding Robots

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Abstract: With the rapid pace of agricultural modernization, the livestock and poultry breeding industry faces mounting pressures to enhance efficiency, reduce operational costs, and minimize environmental impact. The advent of robotic technology presents promising solutions to these challenges. This paper provides an in-depth review of the significant strides in research concerning livestock and poultry breeding robots. It meticulously analyzes the deployment of these robots in various facets of the breeding process, including automatic cleaning, inspection, and feeding, showcasing their potential to not only improve operational efficiency but also to advance intelligent breeding practices. Furthermore, the paper highlights prevalent issues such as safety concerns, high costs, and technological limitations that currently hamper broader adoption.The paper explores prospective trends in the development of breeding robots, emphasizing advancements in their intelligence, cost reduction strategies, and enhanced communication and training for farmers. This forward-looking analysis serves as both a reference and an inspiration for the ongoing modernization of the livestock and poultry breeding industry, encouraging further research and development in this vital sector.

Keywords: Livestock and Poultry Breeding; Robotic Technology; Automated Breeding; Intelligent; Development Prospects

1. Introduction

As the global population grows and living standards improve, the demand for meat, poultry, and other livestock products is continuously increasing, setting higher demands on the livestock and poultry breeding industry, Ma et al [1]. However, traditional manual breeding methods are inefficient, labor-intensive, and environmentally polluting, and no longer meet the development needs of modern livestock and poultry breeding. The development of livestock and poultry breeding robot technology not only meets the market demands for efficient and environmentally friendly breeding methods but also pushes the livestock industry towards more intelligent and automated development. With continuous technological progress and further cost reductions, it is expected that livestock and poultry breeding robots will play an increasingly important role in the global livestock industry in the future. Therefore, the introduction of robotic technology has become one of the key ways to enhance the efficiency of livestock and poultry breeding, reduce costs, and improve the environment.

This paper categorizes several types of livestock and poultry breeding robots according to their functions, provides an overview of the current application status of robotic technology in livestock and poultry breeding, summarizes the existing issues with current livestock and poultry breeding robots, and predicts the future development trends of livestock and poultry breeding robots.

2. Current Status of Livestock and Poultry Breeding Robots

Today, the application of robotic technology in poultry breeding is very common. According to the function classification of livestock and poultry breeding robots, it mainly includes cleaning robots, feeding robots, inspection robots, etc. This section summarizes several types of livestock and poultry breeding robots.

2.1 Automatic Cleaning Robots

Livestock and poultry breeding automatic cleaning robots include automatic cleaning of the livestock and poultry living environment, including the cleaning of livestock and poultry manure and the disinfection of livestock and poultry houses. Manure often contains a large number of bacteria, and long-term engagement in manure cleaning and disinfection work is not beneficial to human health. Hu et al [2]. The application of automatic cleaning robots can replace manual labor, reducing human exposure to polluted environments. Based on robotic technology and integrating various cleaning functions such as sweeping systems, collection systems, disinfection systems, and flushing systems, automatic cleaning robots can perform automatic path planning and navigation to meet the cleaning needs of different livestock and poultry farms.

Ding et al [3]. designed a smart epidemic prevention and disinfection control system for the needs of livestock and poultry house disinfection. The system achieves the automation and intelligence of livestock and poultry house epidemic prevention and disinfection through remote monitoring technology, effectively improving disinfection efficiency and reducing labor costs. He designed the hardware configuration and software, adopting advanced communication protocols and multi-threading technology, ensuring the timeliness and accuracy of operations. Experimental verification showed that the system has good practicality and operability, providing an effective tool for intelligent management in animal husbandry. Future research will further optimize system performance, expand functions, and improve the universality and economy of the system.

Feng et al [4]. designed a livestock and poultry house epidemic prevention and disinfection robot (as shown in Figure 1)that supports remote control and fully automatic operation modes and proposed a "magnetic marker-radio frequency identification" combination for indoor navigation of livestock and poultry houses, allowing it to move autonomously within the livestock and poultry houses. In addition, a wind-assisted disinfectant nozzle was specially designed, enabling the disinfectant to disperse further after atomization, increasing the disinfection area.

Figure 1. Working Disinfection Robot

Jiao et al [5]. designed an intelligent manure cleaning robot for farms, aimed at solving the problem of the difficulty and low efficiency of traditional livestock and poultry manure manual cleaning. Through the combination of software and hardware systems, as well as the design of the safety system, flexible and intelligent cleaning work in livestock and poultry farms was achieved. The robot uses ultrasonic and pressure sensors to automatically identify obstacles and adjust the cleaning path, improving cleaning efficiency. In addition, the robot designed a reasonable motion and execution system to ensure an efficient and safe cleaning process, effectively alleviating the shortage of labor, providing strong technical support for the intelligent development of the livestock and poultry breeding industry.

Figure 2. Pig Manure Cleaning Robot

The Dutch company Lely designed an automatic pig manure cleaning robot named Lely Discovery(as shown in Figure 2), similar to a domestic floor cleaning robot. The robot is equipped with a scraper at the bottom, which can scrape manure into the bin when it moves to a place with manure. In addition, the robot is equipped with a water spraying device, with front water spraying to clean some dry and sticky manure on the ground, and rear water spraying for secondary cleaning.

China's Zhu Bajie Livestock Machinery

Company designed a pig house fence cleaning robot, which can autonomously complete the cleaning of pig house fences according to instructions. It is equipped with an autonomous navigation system, high-pressure water spray system, main control system, etc. using robotic technology to replace heavy manual labor effectively.

2.2 Automatic Feeding Robots

The development of automatic feeding robots began at the end of the 20th century, initially aimed at improving the efficiency and productivity of the livestock industry. These robots optimize feed utilization, reduce waste, and lower labor costs by precisely controlling feeding times and feed amounts. As technology advances, automatic feeding robots further enhance the precision management of livestock and poultry breeding, becoming a key tool for enhancing the sustainability and efficiency of the breeding industry.

Li [6]. studied the key electronic control technology of self-propelled feeding robots, realizing the robot's autonomous navigation and trajectory tracking by building environmental models and path planning algorithms. The research focused on the design and simulation of global path planning and trajectory tracking algorithms for feeding robots, as well as the bottom-level circuit design of feeding robots, providing important technical support for the practical application of feeding robots.

Zhang et al [7]. developed an intelligent feed pushing robot for dairy cows, identifying and segmenting dairy cows and feed through the YOLACT model and using ORB-SLAM3 to achieve robot navigation, meeting the individual free feeding needs of dairy cows. This research mainly solved the problem of personalized free feeding needs of dairy cows, improved feed utilization, and showed the application potential of intelligent feed pushing robots in modern animal husbandry.

Liu et al [8]. designed an attitude-adjustable cattle and sheep breeding feed pushing robot, which can adjust its posture according to work needs. Through dynamic simulation and discrete element simulation analysis, feed pushing efficiency was improved. This research innovatively designed a three-degree-of-freedom parallel attitude adjustment mechanism, providing an effective solution to improve the efficiency of the robot's work and reduce equipment costs.

Guo et al [9]. designed a sheep feeding robot control system, using a programmable logic controller and a smart gateway to build a cloud platform, achieving remote monitoring of the sheep feeding robot. The research aimed to improve feed utilization and save labor costs, successfully achieving automated control during the sheep feeding process.

The German company Urban developed a calf feeding machine suitable for large-scale cattle farms. (as shown in Figure 3) By inputting milk and feed and selecting the feeding mode according to the calves' feeding needs, each calf can be fed precisely. The machine uses closed-loop technology to automatically clean the milk delivery pipes, milk heater, and mixing chamber, reducing the growth of bacteria and ensuring the healthy growth of the calves.

Figure 3. Calf feeding robot

2.3 Inspection Robots

Lv et al [10]. have developed an efficient trajectory tracking control algorithm, ensuring that the monitoring platform moves accurately and automatically along a predetermined path, covering key areas of the farm. Through real-time data collection by this platform, farmers can more precisely understand changes in the livestock breeding environment, thereby optimizing breeding conditions, improving breeding efficiency, and animal welfare. Li [11]. used modern automation and information technology to achieve real-time monitoring and abnormal alarm of environmental factors inside the chicken house, such as temperature, humidity, and light. The implementation of this system significantly improved the automation level of chicken house management, providing strong technical support to ensure the health of chickens, reducing labor costs, and improving the economic benefits of the breeding industry. Ma [12]. innovatively combined machine vision and deep learning technology to develop an autonomous inspection robot that can monitor the behavior patterns and life status of cage-raised meat ducks in real time, accurately identify abnormal behaviors and death events, and alert accordingly. The application of this technology greatly enhances the efficiency and accuracy of breeding management, helping to deal with problems in the breeding process timely, ensuring animal welfare, and improving the economic benefits of duck breeding. Zhang [13]. developed a two-wheel autonomous control inspection robot for chicken houses. With an efficient path planning algorithm, the robot can automatically perform inspection tasks, monitor environmental parameters inside the chicken house in real time, and promptly feedback data. This research not only improved the automation level of chicken house inspection work but also provided technological support for preventing disease spread and enhancing the quality of life for chickens.

Aydin [14]. developed a novel and non-invasive method using a 3D vision camera system to automatically assess the lameness in broiler chickens. By setting up a testing corridor and using depth sensors to record the images of the chickens walking, followed by the application of image processing algorithms to detect the number of lying down events and the delay time of lying down. This system, compared to manually marked data, showed a significant correlation with the degree of lameness in broiler chickens.

Aydin et al [15]. described an advanced monitoring system that accurately measures the feed intake of broiler chicken groups through real-time sound processing technology. By installing microphones near the feed trough to record the pecking sounds of broiler chickens, and using cameras to monitor the presence of broiler chickens around the feed trough, and an automatic weighing system to record the feed intake of broiler chickens as a reference. The study further investigated algorithms to detect the pecking sounds when multiple broiler chickens feed together, indicating that this continuous pecking sound detection system has the potential to assess the feed intake and feeding behavior of broiler chickens.

3. Problems with Livestock and Poultry Breeding Robots

Livestock and poultry breeding robots significantly improve breeding efficiency through automation management, capable of automatically completing tasks such as feeding, cleaning, and inspection, reducing the need for labor. However, there are still some issues:

3.1 Cost Issues:

Although livestock and poultry breeding robots can bring long-term benefits, their research, production, and maintenance costs are high, requiring a significant initial investment. This poses a financial burden for small farms or start-up companies, potentially hindering the wide application and development of the technology.

3.2 Technical Issues

The operation and maintenance of livestock and poultry breeding robots require breeders to have certain technical knowledge and abilities. For breeders without relevant experience, how to efficiently manage and use these high-tech devices is a challenge. In addition, professional technical support and services are crucial when robots malfunction or need upgrades.

3.3 Adaptability Issues

The environment and conditions of livestock and poultry breeding vary greatly, from temperature and humidity to the types of livestock and poultry being bred. A standardized robot solution may not meet the needs of all farms, necessitating the customization and adjustment of robots, increasing the complexity and cost of technical implementation.

4. Development Trends of Livestock and Poultry Breeding Robots

The development of livestock and poultry breeding robots is closely related to technological progress, resource integration, and the scale of breeding. Looking back at the past few decades of robotic technology penetrating the agricultural field, and looking forward to the future development trends of livestock and poultry house robots, there are several points:

4.1 More Intelligent Decision Support Systems

With the advancement of artificial intelligence and machine learning technologies, livestock and poultry breeding robots will have higher-level data analysis and decision support capabilities. This means that robots can not only collect and monitor data but also automatically adjust feeding strategies and environmental settings by analyzing the growth patterns, health conditions, and environmental changes of livestock and poultry, optimizing production efficiency and ensuring the welfare of livestock and poultry.

4.2 Enhanced Autonomous Operation Capabilities

Future livestock and poultry breeding robots will have stronger autonomous operation capabilities, capable of completing complex tasks with less human intervention. For example, improvements in automated navigation and mobility technologies will enable robots to move more flexibly within the farm, performing various tasks such as cleaning, feeding, disease detection, and treatment.

4.3 Integration of IOT and Remote Monitoring

The application of IOT technology will allow breeding robots to seamlessly connect with other smart devices and systems, achieving real-time data sharing and remote monitoring. This will provide breeders with an integrated management platform, allowing them to remotely monitor the operation of the farm, respond timely to livestock and poultry health and welfare issues, while optimizing resource use and reducing waste.

4.4 Sustainability and Environmentally Friendly Design

With the emphasis on environmental protection and sustainable development, future livestock and poultry breeding robots will focus more on energy conservation, emissions reduction, and resource recycling. Robot designs will use environmentally friendly materials and optimize energy use efficiency. Additionally, waste management systems will be integrated into robot operations to support the recycling and reuse of farming waste.

4.5 Customized and Modular Solutions

Considering the specific needs and conditions of different farms, future breeding robots will offer more customized and modular solutions. This not only meets the needs of specific breeding environments and types of livestock and poultry but also adapts flexibly to changes in breeding scale, thereby improving the feasibility and benefits of investment.

5. Conclusion

This article reviews the current research status and development trends of livestock and poultry breeding robots, analyzing their importance in improving breeding efficiency, reducing costs, and improving the environment. As the global population grows and consumer demand for high-quality meat products increases, traditional livestock breeding methods face various challenges, including low efficiency, environmental pollution, and high labor intensity. The introduction of robotic technology, especially in applications such as automatic feeding, cleaning, and health monitoring, has begun to revolutionize existing livestock breeding methods, significantly enhancing production efficiency and animal welfare while reducing labor costs and environmental impacts.

Although current livestock and poultry breeding robot technology still faces challenges such as high costs, complexity, and adaptability issues, continuous technological progress and further cost reductions are expected to make robots more intelligent and autonomous, integrating more modern robotic technologies. These advancements will make livestock breeding more sustainable while also improving breeding efficiency and product quality.

In summary, the development of livestock and poultry breeding robots will have a profound impact on the future of the livestock industry. To address these challenges and fully leverage the opportunities these technologies offer, the industry needs to increase research and development investment, optimize robot designs, and enhance farmers' technical skills through policy support and education. Future livestock and poultry breeding robots will play a crucial role in ensuring global food safety and advancing agricultural modernization.

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