Published online: 17 October 2024 DOI: 10.54254/2977-3903/12/2024124

Research on modular design and intelligent maintenance systems for small smart lawn mowers

Junlin Ji

Tarim University, Xinjiang Uygur Autonomous Region, China

379692802@qq.com

Abstract. With the increasing demand for garden landscaping, the development and application of small smart lawn mowers have become particularly important. This paper presents a series of innovative design concepts and maintenance strategies through an in-depth study of the modular design and intelligent maintenance systems of small smart lawn mowers. The article first outlines the basic concepts of modular design and, combined with the actual needs of smart lawn mowers, details the specific implementation of the design. Next, the article discusses the construction methods of the intelligent maintenance system, emphasizing technical applications in fault diagnosis and remote monitoring. Through theoretical analysis and empirical research, this paper aims to provide more efficient and reliable smart mowing solutions for modern garden landscaping.

Keywords: Small Smart Lawn Mower, Modular Design, Intelligent Maintenance System, Performance Optimization, Garden Landscaping

1. Introduction

In modern garden landscaping management, the application of small smart lawn mowers is becoming more widespread, becoming an important tool to improve efficiency and reduce labor costs. With the continuous advancement of technology, the functions and efficiency of traditional lawn mowers can no longer fully meet the complex needs of modern gardens, especially in large-scale or variable terrain application scenarios. Therefore, developing a small smart lawn mower that combines modular design and intelligent maintenance systems can not only improve the adaptability and flexibility of the machine but also reduce maintenance difficulty and cost in practical operations. This paper conducts an in-depth analysis of the deficiencies of existing technologies, exploring a new design and maintenance method in hopes of bringing innovation and breakthroughs to the field of garden landscaping, as well as providing practical application value and development directions for related technological fields.

2. The concept and framework of modular design

Modular design, as a modern design methodology, has been widely applied in the development of many industrial products, especially in the field of mechanical equipment. Modular design can significantly improve the maintainability, expandability, and customization of products. As a mechatronic product for specific applications, small smart lawn mowers can effectively meet the diverse garden landscaping needs and complex operating environments by adopting modular design principles [1].

2.1. Basic concepts of modular design

The core of modular design lies in decomposing complex systems into several independent, functionally specific modules. Each module has a complete function and can be manufactured, tested, and maintained separately, while they are connected through standardized interfaces. This design strategy not only facilitates the assembly and disassembly of the system but also greatly simplifies the process of fault diagnosis and component replacement. For small smart lawn mowers, modular design enables the machine to quickly adjust or upgrade its functional modules according to different usage environments and user needs, such as the cutting system, drive system, navigation system, etc.

Copyright: © 2024 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

2.2. Structural composition of modular design

In the modular design of small smart lawn mowers, the main modules can be divided into power modules, navigation modules, control modules, and maintenance modules. The power module is responsible for providing mechanical power; the navigation module relies on GPS or other sensors for precise positioning and path planning. The control module controls the entire machine's operation through an integrated microprocessor, and the maintenance module includes fault detection and reporting systems, all designed to be interchangeable and upgradable to adapt to technological advancements and changing user needs.

2.3. Application cases of modular design in smart lawn mowers

For example, a new type of small smart lawn mower might feature a detachable battery module, allowing users to choose different capacity battery packs based on the size of the lawn [2]. Additionally, the lawn mower is equipped with an upgradeable navigation module that can be easily replaced or upgraded when new sensor technology or software algorithms are released, without the need to replace the entire machine. This design not only extends the product's life but also significantly reduces maintenance costs.

3. Key technology analysis of smart lawn mowers

The efficiency and reliability of smart lawn mowers largely depend on their built-in key technologies. These technologies include the use of sensors, navigation and path planning algorithms, and the integration of communication technologies, which together form the core operating system of smart lawn mowers.

3.1. Sensor technology and data acquisition

Sensors are an indispensable part of smart lawn mowers, responsible for collecting environmental information around the machine, such as the size, shape, terrain changes, and obstacle locations of the lawn. Common sensors include distance sensors, collision sensors, tilt sensors, and humidity sensors. The data from these sensors are used to optimize the mowing path and adjust mowing strategies, ensuring the lawn mower operates efficiently and safely in complex environments.

3.2. Navigation and path planning technology

Navigation technology is key to the autonomous operation of smart lawn mowers. Using GPS and geomagnetic sensors, the lawn mower can accurately locate its position and, combined with a preset lawn map, plan the optimal mowing path. Additionally, by analyzing past mowing data through machine learning algorithms, the lawn mower can automatically learn and adjust its path planning to accommodate different lawn conditions and obstacle layouts, thus maximizing work efficiency and energy utilization.

3.3. Application of communication technology

In smart lawn mowers, communication technology is primarily used for interaction between the machine and the user and for collaborative work with other smart devices. Through wireless networks (such as Wi-Fi or Bluetooth), users can remotely control the lawn mower, setting work times, areas, mowing heights, and other parameters. Moreover, more advanced communication technology allows the lawn mower to interact with home automation systems, such as automatically returning to the charging station on rainy days or sending emergency alerts to the user [3].

4. Construction of intelligent maintenance systems

Intelligent maintenance systems are key to ensuring the long-term stable operation of small smart lawn mowers. By implementing intelligent maintenance strategies, it is possible to effectively prevent failures, reduce maintenance costs, and extend equipment life. The system mainly includes system architecture design, fault diagnosis technology, and remote monitoring maintenance functions.

4.1. System architecture design

The architecture design of the intelligent maintenance system needs to ensure all components can cooperate seamlessly, enabling immediate data transmission and processing. The architecture typically includes sensor modules, data processing units, communication interfaces, and user interfaces. Sensors monitor the machine's operational parameters and status in real time, the

data processing unit analyzes these data to identify potential anomalies or signs of failure, and the communication interface supports data exchange with external systems or maintenance personnel.

4.2. Fault diagnosis technology

Fault diagnosis is a core function of intelligent maintenance systems, relying on advanced algorithms and models to predict and identify failures. Using machine learning and artificial intelligence technologies, the system can learn from a large amount of operational data and optimize the accuracy of fault diagnosis. For instance, by analyzing the lawn mower's operating speed, battery consumption rate, and sensor feedback of abnormal data, the system can provide early warnings of impending technical issues, allowing for proactive maintenance.

4.3. Remote monitoring and maintenance

The remote monitoring and maintenance function allows users or technicians to check the status and troubleshoot faults without physical contact with the lawn mower. Using a mobile app or web interface, users can view the machine's operational status, receive maintenance reminders, adjust settings, or directly send commands for fault repair. Additionally, the remote monitoring system can automatically update software and firmware, ensuring the lawn mower operates at optimal conditions.

5. Performance evaluation and optimization strategies

To ensure that small smart lawn mowers work stably and efficiently in various environments, the formulation of performance evaluation and optimization strategies is particularly important. This section mainly covers the construction of performance evaluation indicators, the performance optimization of modular design, and the efficiency improvement of intelligent maintenance systems [4].

5.1. Performance evaluation indicator system

The performance evaluation indicator system is the basis for measuring the performance of small smart lawn mowers, including but not limited to machine work efficiency, energy consumption, fault rate, service life, and user satisfaction. By setting clear evaluation standards, the actual operating conditions of the lawn mowers can be quantitatively analyzed, thereby identifying performance bottlenecks and optimization points. For example, by analyzing the mowing efficiency against battery consumption ratio, energy management strategies can be optimized to improve energy use efficiency.

5.2. Performance optimization of modular design

The performance optimization of modular design focuses on enhancing the overall machine performance by adjusting and improving the functions of individual modules. This may include enhancing the collaborative capabilities of modules, reducing energy loss, and improving fault self-recovery capabilities [5]. For instance, by optimizing the control algorithms of the drive module, the stability and agility of the lawn mower in complex terrains can be enhanced, reducing machine stalling and failure rates.

5.3. Efficiency improvement of intelligent maintenance systems

The efficiency improvement of intelligent maintenance systems mainly focuses on how to reduce maintenance costs and enhance maintenance response speeds through technological upgrades and process optimizations. Implementing remote diagnostics and maintenance updates can significantly reduce the need for on-site maintenance and maintenance cycles, especially in fault prediction and preventive maintenance. Furthermore, integrating advanced data analysis tools can help technicians more accurately diagnose problems and improve the first-time repair success rate.

6. Application examples and market analysis

To fully understand the market potential and actual application effects of small smart lawn mowers, it is essential to conduct application example analyses and market analyses. This section will delve into the application cases of small smart lawn mowers in different environments, evaluate their market status, and analyze future development trends and market promotion strategies[6].

6.1. Current market situation domestically and internationally

Currently, small smart lawn mowers have begun to gain recognition in both domestic and international markets, especially in North America and Europe, where the demand for such products continues to grow due to their high automation and labor-saving advantages. In the Chinese market, with the acceleration of urbanization and the improvement of residents' living standards, more and more families and commercial facilities are also starting to use smart lawn mowers for garden landscaping management. Market research indicates that within the next five years, the market size for smart lawn mowers is expected to double.

6.2. Analysis of typical application cases

A successful application case is the use of small smart lawn mowers at a large sports venue. The venue employs several lawn mowers equipped with advanced navigation systems and automatic charging functions. These mowers autonomously complete the mowing of the entire green space, greatly alleviating the pressure of manual maintenance. Additionally, these lawn mowers can adjust the mowing frequency based on the grass growth rate and weather conditions, ensuring the grass remains in optimal condition.

6.3. Market promotion strategies and future

Trends Facing an increasingly competitive market, effective market promotion strategies are particularly crucial. Developing targeted marketing strategies, such as showcasing the high-tech features and environmental benefits of the products on online platforms, can attract more environmentally conscious young consumers. Additionally, collaborating in smart home exhibitions or gardening events can further expand the product’s visibility and market impact. In the future, as IoT technology develops and consumer demand for smart home devices increases, the market potential for smart lawn mowers is expected to continue expanding.

Conclusion: As intelligent technologies continue to evolve, small smart lawn mowers are demonstrating significant advantages in the field of garden landscaping, especially in improving work efficiency and reducing maintenance costs. This paper, through in-depth research on the modular design and intelligent maintenance systems of small smart lawn mowers, has clarified how these technologies collaboratively enhance the machine's performance and level of operation automation. Additionally, from practical application cases and market analyses, it is evident that these devices are gradually becoming a market favorite, thanks to their adaptability and excellent user experience. Looking ahead, as technology further innovates and market demand increases, small smart lawn mowers are expected to be promoted globally, bringing revolutionary changes to garden landscaping management. This not only aligns with the modern garden concepts of environmental protection and efficiency but also indicates that intelligent devices will play an increasingly important and widespread role in everyday life.

References

[1] Liu J, Qiu Z, Wang L, et al. Intelligent floor plan design of modular high-rise residential building based on graph-constrained generative adversarial networks [J]. *Automation in Construction*, 2024, 159 105264-.

[2] Wei G, Xiaomin C, Xiaoning L, et al. Application of modular mathematical modeling in intelligent design of 3D digital substation [J]. *Applied Mathematics and Nonlinear Sciences*, 2023, 8 (2): 1765-1772.

[3] Kunming Z, Qiuju Z. Research on configuration design and intelligent compliance control of reconfigurable modular flexible upper limb rehabilitation robot [J]. *International Journal of Advanced Robotic Systems*, 2023, 20 (3):

[4] Yuan G, Yuanyuan H, Yonggui W, et al. A Modular Hardware Design of an Intelligent Distributed Feeder Terminal Unit [J]. *Journal of Physics: Conference Series*, 2023, 2477 (1):

[5] Zheng H, Zuo F, Xu H, et al. Modular Design of Missile Electrical System [J]. *Journal of Physics: Conference Series*, 2023, 2460 (1):

[6] Wu S. Modular Furniture Design by Using Intelligent Platform and Wireless Sensors [J]. *Computational Intelligence and Neuroscience*, 2022, 2022 2586711-2586711.