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UNMANNED LEAF SWEEPING AND CRUSHING VEHICLE

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Abstract: In urban and campus environments, fallen leaves accumulate extensively. The research team has developed an unmanned leaf sweeping vehicle to improve cleaning efficiency and reduce labor costs. The innovative features of this unmanned leaf sweeping vehicle lie in its unmanned driving software technology and built-in navigation function. The hardware design adopts corrosion-resistant hard materials, high-speed and energy-saving motors, adjustable cleaning brushes, vacuum cleaners, and large-capacity lithium batteries, enabling the sweeping vehicle to achieve intelligence, high performance, high efficiency, energy saving, and environmental protection. The core contents of the unmanned leaf sweeping vehicle include: control of driving speed and sweeping speed; calculations for movement and sweeping to minimize leaf sweeping time and movement path; mathematical model prediction; real-time sensor feedback; intelligent machine learning; and predicted movement path. The control system includes driving control, sweeping control, and crushing control. The motor provides power, the ball screw converts motion, and the sensor provides real-time feedback. Autonomous navigation technology and deep learning algorithms are introduced to enhance intelligence. Users can control the vehicle and realize remote monitoring through a mobile phone APP.
Keywords: Autonomous driving; Intelligent systems; Shortest path

1 INTRODUCTION

In urban and campus environments, fallen leaves accumulate extensively during late autumn and early winter, creating significant challenges for environmental maintenance. While seasonal foliage is a natural phenomenon, its accumulation often leads to cluttered public spaces and potential safety hazards, necessitating frequent and labor-intensive cleaning operations. Currently, the management of fallen leaves relies heavily on manual labor, which is not only inefficient but also costly and physically demanding for sanitation workers. As the demand for cleaner and more sustainable urban environments grows, there is an urgent need to transform traditional cleaning methods through technological innovation. Against this backdrop, the primary objective of this research is to design and develop an unmanned leaf sweeping and crushing vehicle tailored for complex environments such as university campuses[1-2]. The significance of this study lies in its potential to alleviate the work pressure of cleaning personnel, enhance sweeping efficiency, and reduce operational costs. By integrating advanced automation technologies, this project aims to provide a sustainable solution that aligns with the pursuit of environmentally friendly technology and improved campus environmental quality.

The innovative features of the proposed unmanned vehicle are manifold, distinguishing it from conventional cleaning equipment. Firstly, it integrates unmanned driving software with built-in navigation functions, enabling autonomous operation without the need for constant manual intervention. Secondly, the hardware design prioritizes durability and performance, utilizing corrosion-resistant materials, high-speed energy-saving motors, and large-capacity lithium batteries to ensure long-term operation in adverse conditions. Thirdly, the system incorporates intelligent control strategies, including PID control technology, lidar detection, and visual detection algorithms. These technologies allow the vehicle to perform real-time environmental perception, automatic obstacle avoidance, and intelligent path planning. Furthermore, the introduction of deep learning algorithms enhances the vehicle's intelligence, allowing it to identify leaf types and adjust sweeping intensity dynamically[3].

The core research focuses on the optimization of the vehicle's kinematic parameters, including the precise control of driving speed and sweeping speed. Through mathematical model predictions, real-time sensor feedback, and intelligent machine learning inference, the vehicle determines the most efficient movement trajectory to minimize sweeping time. The control system is meticulously designed to manage driving, sweeping, and crushing functions, supported by a remote monitoring interface for user convenience. Ultimately, this project represents a significant step forward in the application of autonomous driving technology within the sanitation sector, offering a smart, efficient, and eco-friendly alternative to manual leaf sweeping[4-5].

2 SOFTWARE AND HARDWARE DESIGN SCHEMES OF THE LEAF SWEEPING VEHICLE

The project team has studied the leaf sweeping vehicle from aspects such as working principle and workflow, and developed a complete set of new sweeping vehicle technology software. The sweeping vehicle can be controlled autonomously to improve sweeping efficiency. This paper introduces the workflow of the sweeping vehicle, highlights the key points of the workflow, and summarizes and analyzes the working principles and applications of automatic navigation and positioning technology, lidar detection technology, visual detection technology, PID control technology, etc. For example: automatic navigation and positioning technology realizes accurate environmental positioning of the leaf sweeping vehicle through GPS and inertial navigation. Lidar detection technology: uses a high-precision laser

scanner to detect the environment and avoid obstacles in a timely manner. Visual detection technology identifies fallen leaves through cameras and high-speed image processing algorithms, improving sweeping efficiency and pertinence. PID control technology improves the stability and accuracy of the sweeping vehicle's driving, adapting to different road traffic environments. The application of these technologies enables the unmanned leaf sweeping vehicle to complete sweeping autonomously, improves the sweeping efficiency and quality of the sweeping vehicle, and contributes strong technical support to the cleanliness and tidiness of the city[3]. Technical Architecture and Operational Framework for Autonomous Leaf Sweeping Vehicle is shown in Figure 1.

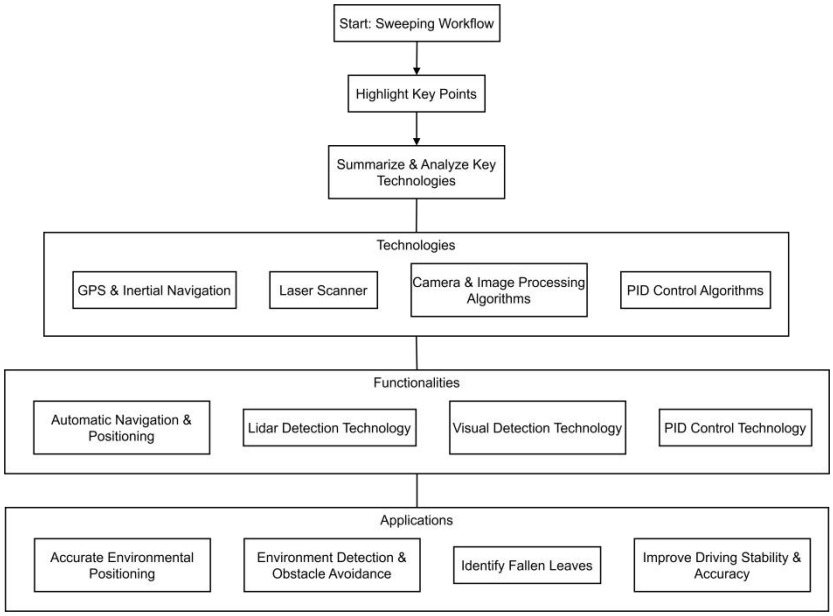

Figure 1 Technical Architecture and Operational Framework for Autonomous Leaf Sweeping Vehicle

In terms of hardware, this research also achieves innovation and practicality. The body of the unmanned leaf sweeping vehicle is made of wear-resistant and high-strength materials to ensure that the unmanned sweeping vehicle can operate in adverse environments. In terms of power, a high-efficiency and low-energy-consuming motor is selected, and a carefully designed transmission device ensures that the sweeping vehicle has continuous power during the sweeping process. In terms of sweeping, the cleaning brush and vacuum device are designed to automatically adjust the height of the cleaning brush and vacuum device according to the distribution of fallen leaves on the ground, ensuring no dead corners in sweeping. In terms of energy, a large-capacity lithium battery is adopted to realize long-term continuous operation with fewer charges. From the hardware perspective, the unmanned leaf sweeping vehicle of this research achieves high-efficiency, intelligent, and environmentally friendly sweeping, helping to purify and manage the urban environment.

In addition, the leaf sweeping vehicle of this project is designed with an environment adaptation system, which can perform intelligent control according to the sweeping environment. When there is rain in the environment and the ground is wet, the sweeping vehicle starts the slow anti-skid sweeping mode with a slow sweeping speed; when the environment is dry, the sweeping vehicle starts the normal speed sweeping mode with fast and clean sweeping. The sweeping vehicle is designed with an intelligent scheduling system, which can intelligently plan the sweeping path according to the difficulty and scope of sweeping, resulting in high sweeping efficiency[4-5].

For maintaining operation, this project tries to design the sweeping vehicle to be simple, making it easy to use and maintain. The project is designed with a control interface to facilitate maintenance personnel to monitor the operation status of the sweeping vehicle and operate it. The sweeping vehicle has short operation and maintenance time, easy access to maintenance locations, and extremely low maintenance costs and time costs. This project is designed with a remote monitoring and fault diagnosis system for the sweeping vehicle, which is convenient for maintenance personnel to monitor the status of the sweeping vehicle. When the sweeping vehicle breaks down, maintenance personnel can reach the sweeping vehicle to handle the fault in the first time, ensuring the normal operation of the sweeping vehicle.

3 CORE CALCULATIONS AND KINEMATIC ANALYSIS OF THE UNMANNED LEAF SWEEPING VEHICLE

The key technologies of the unmanned leaf sweeping vehicle include the control of the vehicle's driving speed and the calculation of the sweeping speed. On this basis, the kinematic parameters of the unmanned leaf sweeping vehicle are analyzed to realize that the unmanned leaf sweeping vehicle sweeps fallen leaves with the most reasonable route and the fastest speed. The unmanned sweeping vehicle is an intelligent tool to improve sweeping efficiency and an application of modern science and technology. The unmanned sweeping vehicle avoids obstacles through sensors and algorithms, can adapt to a variety of ground environments, and completes leaf sweeping in parks, streets, and large public places

without manual labor. The key technologies of the unmanned sweeping vehicle include environmental detection and perception, intelligent decision-making and control, and power system, which require researchers to have interdisciplinary knowledge and innovative spirit. According to the working principle of the unmanned leaf sweeping vehicle, it is necessary to control the speed of the unmanned vehicle during the leaf sweeping process, and the normal working speed of the unmanned leaf sweeping vehicle needs to reach 0.5m/s. To ensure the good working state of the unmanned leaf sweeping vehicle, it is necessary to conduct kinematic analysis of the unmanned leaf sweeping vehicle.
Among them, the determination of the trajectory refers to the determination of the movement trajectory. The determination of the movement trajectory mainly refers to the speed, distance, time, etc. of the vehicle. There are mainly the following ways to determine the movement trajectory:
The first is to use a mathematical model as the prediction premise. Construct a kinematic model of the unmanned leaf sweeping vehicle, and predict the movement trajectory of the vehicle through the mathematical model. This method requires accurate parameter values of the model, including the initial movement speed, acceleration, steering angle of the vehicle, etc., and can calculate the subsequent trajectory of the vehicle. This method has high requirements for the accuracy of the model. In the actual use process, it is affected by various parts, and the prediction accuracy varies.

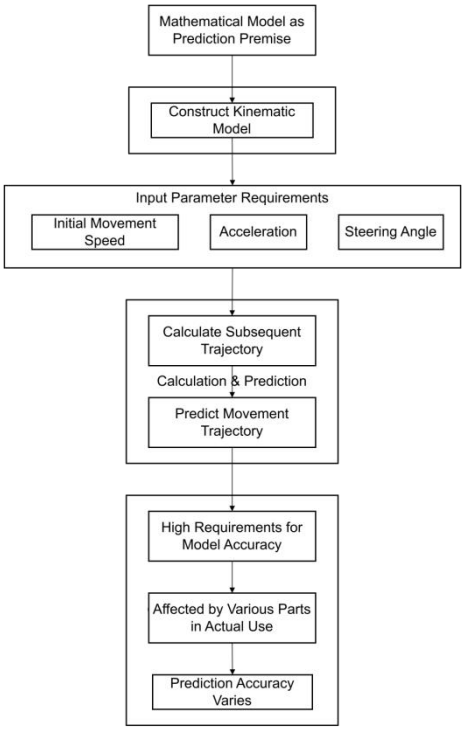

Figure 2 Mathematical Prediction Model and Kinematic Analysis for Unmanned Leaf Sweeping Vehicle Trajectory

Mathematical Prediction Model and Kinematic Analysis for Unmanned Leaf Sweeping Vehicle Trajectory is shown in Figure 2. The second method is the real-time sensor data feedback method. The unmanned leaf sweeping vehicle is equipped with various sensors, such as speed sensors and distance sensors. These sensors receive the movement data of the vehicle in real time, and adjust the movement trajectory of the vehicle in real time by analyzing and processing the sensor data. This method has high requirements for the accuracy and real-time performance of the sensors, but the movement trajectory of the vehicle can be adjusted in real time, and the sweeping is timely and in place[6].
The third is intelligent inference based on machine learning. A large amount of historical data is learned and trained through machine learning models, and the movement trajectory of the unmanned leaf sweeping vehicle is inferred through the learned machine model. This intelligent inference method has no requirements for mathematical models, but only performs statistical learning on historical data information, and has a certain degree of adaptability. In practical applications, the movement trajectory of the unmanned sweeping vehicle can be inferred and controlled through sensor data information and machine learning models.

4 CONTROL PART OF THE UNMANNED LEAF SWEEPING AND CRUSHING VEHICLE

The control part is the core of the unmanned leaf sweeping and crushing vehicle, including driving control, sweeping control, and crushing control. Driving control refers to the vehicle's internal infrared sensor perceiving external changes, and the vehicle choosing the corresponding path to travel according to the data collected by the infrared sensor; sweeping control refers to the infrared sensor perceiving fallen leaves on the ground, and when there are fallen leaves, the infrared sensor sends a signal to the main controller, which judges after receiving the signal and selects the fastest sweeping route; crushing control refers to crushing the fallen leaves collected by the infrared sensor. The control part is mainly composed of three parts: motor, ball screw, and sensor[7-8].

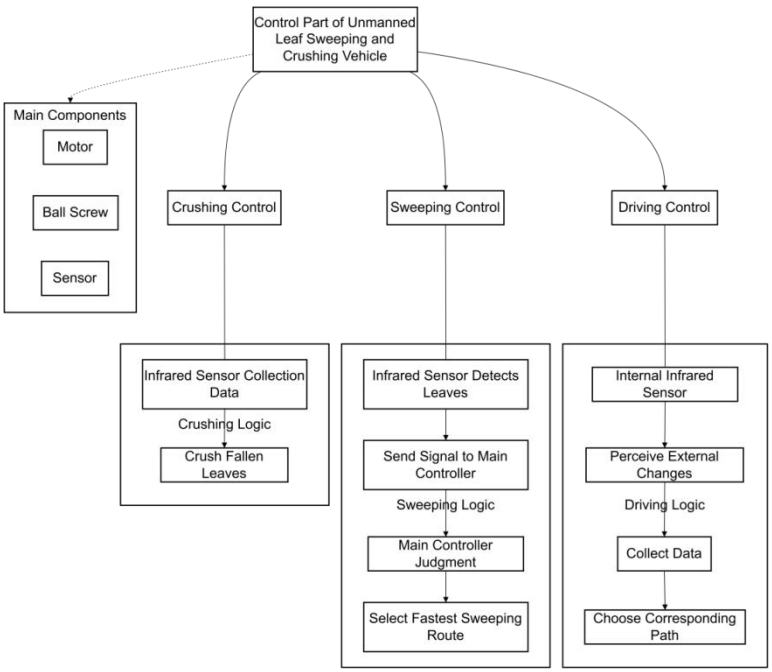

Figure 3 Control System Architecture and Functional Logic of the Unmanned Leaf Sweeping and Crushing Vehicle

Control System Architecture and Functional Logic of the Unmanned Leaf Sweeping and Crushing Vehicle is shown in Figure 3. The control part is powered by the motor to control the vehicle's forward, backward, and steering actions. The ball screw converts the rotational motion provided by the motor into linear motion of long and short distances to assist the vehicle's sweeping and crushing actions. The sensor detects and feeds back the correct sweeping and crushing actions of the vehicle in a timely manner. Through the correct control algorithm, the accurate control and realization of the vehicle's walking, sweeping, and crushing actions are achieved, and the sweeping speed and quality are improved. The control part includes the vehicle's missing detection and alarm function. When the vehicle malfunctions, the system alarms in a timely manner to ensure that the vehicle can operate normally at all times[9-10].

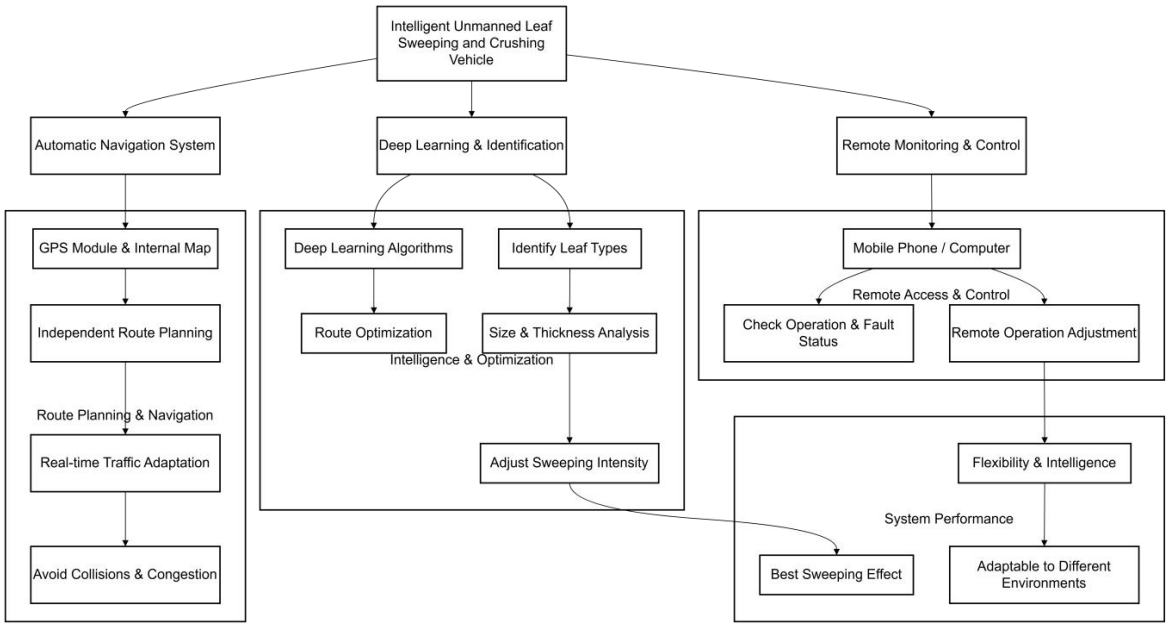

Figure 4 Intelligent Navigation, Deep Learning, and Remote Control Framework for Unmanned Sweeping Vehicles

Intelligent Navigation, Deep Learning, and Remote Control Framework for Unmanned Sweeping Vehicles is shown in Figure 4. To further enhance the intelligence level of the unmanned leaf sweeping and crushing vehicle, the vehicle is equipped with an automatic navigation system with independent route planning, which autonomously plans the sweeping route according to its own GPS module information and its own map, and can plan the route at any time according to the real-time road traffic conditions to avoid collisions and congestion. At the same time, it uses deep learning algorithms to learn and optimize its own sweeping route, further realizing the unmanned sweeping and

crushing function of the unmanned leaf sweeping and crushing vehicle. It can identify the types of fallen leaves during sweeping, and adjust the sweeping intensity according to information such as the size and thickness of the fallen leaves to ensure the best sweeping effect. At the same time, it is equipped with remote monitoring and remote control functions. Through a mobile phone or computer, you can remotely check the operation status, sweeping status, and fault status of the unmanned leaf sweeping and crushing vehicle, and you can also remotely control the vehicle to adjust its operation, making the vehicle more flexible, fast, and intelligent, and usable in different environments.

5 CONCLUSION

This study successfully designed and developed an unmanned leaf sweeping and crushing vehicle tailored for complex environments such as university campuses. By integrating autonomous driving software, navigation systems, and durable hardware, the vehicle achieves intelligent operation with high efficiency and low energy consumption. The core innovations include the optimization of kinematic parameters for precise path planning, real-time obstacle avoidance using lidar and visual detection, and deep learning algorithms for dynamic sweeping intensity adjustment.

Experimental results demonstrate that the proposed system effectively solves path planning and leaf recognition challenges, significantly improving cleaning efficiency while reducing labor costs and secondary pollution. The inclusion of remote monitoring and fault diagnosis further ensures operational stability and ease of maintenance. Looking forward, this technology presents broad application prospects in parks, streets, and highways, offering a sustainable and intelligent alternative to traditional manual cleaning methods.

COMPETING INTERESTS

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