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The Design of Small Multi-Functional Tree Planting Machine Based on PID Controuer Main Control Drive System

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Abstract: In order to improve the efficiency of tree planting and solve the problem of lack of automation and intelligence of tree planting machines at home and abroad, this design proposes a design scheme of multi-functional small tree planting machine based on intelligent control. Based on the kinematics analysis of the planting mechanism and the driving mechanism of the tree planting machine, a system scheme based on ' PID Controuer ' programming controller control is proposed. The mechanical device integrates the joint operation of drilling mechanism, seedling feeding mechanism, backfilling mechanism, irrigation mechanism, seedling storage mechanism and driving control mechanism, and can realize the tasks of drilling, seedling feeding, backfilling and irrigation. The experimental results show that the tree planting machine has the advantages of simple structure, functional integration and automation. The robot is used to replace the manpower, which greatly improves the efficiency and ensures higher accuracy, stability, safety and environmental adaptability.

Keywords: Tree planting machine, structure design, intelligent control, automation

1 INTRODUCTION

In recent years, China has actively advocated the concept of green development and made afforestation one of its core initiatives. However, traditional artificial afforestation methods have been difficult to cope with the growing demand for ecology and development strategies due to high labor intensity and low efficiency. Therefore, the development and application of tree planting machinery is particularly important. These machines not only significantly improve the efficiency of tree planting, but also help to make full use of the classification advantages of forestry ecological resources, further optimize the relationship between forestry ecological resources and natural resources in the regional environment, promote the development and utilization of sustainable forestry ecological resources, and contribute to green development [1].

The research teams at home and abroad have developed a series of continuous ditching tree planting machines, such as ZS-45[2] multi-functional tree planting machine, KDE ditching tree planting machine specially designed for large seedlings, flexible and convenient JZX-30 hanging tree planting machine and JKZ-70 ditching tree planting machine[3]. However, these existing machines still have room for improvement in terms of reliability and operational efficiency. In order to solve these problems, this design has introduced a full-process integrated multi-functional tree planting machine with integrated intelligent control through in-depth improvement and optimization of existing technologies. The machine can realize a series of operation steps from seedling storage and transportation to drilling, backfilling, irrigation, etc., which greatly improves planting efficiency and significantly reduces labor costs. At the same time, it ensures the high precision, stability, safety and good environmental adaptability of the operation, and effectively promotes the modernization and automation of afforestation work.

2 DESIGN CONCEPT

The purpose of this design is to develop a small tree planting machine that can adapt to planting trees in various complex environments. The design goal is to realize the automation and intelligence of drilling, seedling feeding, backfilling and irrigation tasks.

The small multifunctional tree planting machine consists of two parts : mechanical components and control system. The mechanical parts include seedling storage, transportation, drilling, backfilling and irrigation, as well as their respective drive motors. The control system is further divided into two subsystems : hardware and software. The hardware system is

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based on the core circuit board, supplemented by DC motor drive module and wireless data transmission module. The software system is composed of Mini Balance software and a custom program equipped with Arduino Mega 256 microcontroller. The driving mechanism program of the tree planting machine is the key to ensure the coordinated operation of the institutions. It responds to the instructions of the functional buttons through serial communication technology. Start the tree planting machine, the program immediately sends commands through the serial port, activates the corresponding subroutine, and issues execution instructions to the specified port, thereby accurately controlling each motor and coordinating the completion of various tree planting actions. This design not only optimizes the operation process, but also improves the efficiency and accuracy of the machine[4].

3 MECHANICAL STRUCTURE DESIGN

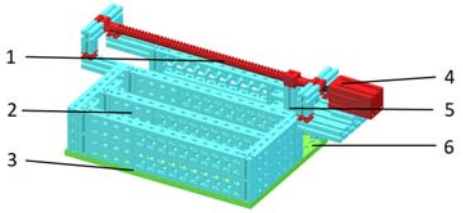
3.1 DESIGN REQUIREMENT

According to the needs of the current tree planting conditions, the designed small multi-functional tree planting machine should have the following functions: automatic multi-row tree planting, adapting to various planting environments, simple operation, single operation, miniaturization, low manufacturing cost, and low maintenance cost.

3.2 DESIGN OF SEEDLING STORAGE MECHANISM

In order to maximize the seedling loading capacity of this small multifunctional tree planting machine, the seedling storage box is designed as a regular cuboid space with a size of 1500mm × 1200mm × 1200mm. In order to make effective use of this space, the multi-row and multi-column configuration is adopted inside the seedling storage box, and it can move in both directions along the x-axis and y-axis. After careful consideration of the size of other components, the seedling storage box was finally determined to be arranged in 5 rows and 4 columns. The front end of the seedling storage box is designed with a fixed slide rail, and the slide rail is equipped with a push rod. The sliders on these push rods are connected to the seedling storage box through a worm. A transfer barrel is set at the front end of the seedling pushing mechanism to receive and transfer seedlings. The push rod and the baffle on the front side of the seedlings work together to accurately limit the position of the seedlings. The pushing seedling rod is driven by an electric worm to ensure that the seedlings can be pushed smoothly into the seedling divider. In order to protect the seedlings from being toppled due to bumps or speed changes during transportation, a baffle is specially installed around the seedling storage box to ensure the stability of the seedlings during movement. This well-designed storage box structure not only improves the storage capacity of seedlings, but also ensures the safety and accuracy of seedlings in the mechanical operation process[5].

A motor box is arranged in a large frame at the rear of the tree storage box, and the rack is fixed at the bottom of the tree storage box. Driven by a DC motor, the transmission belt drives the bottom slide rail to rotate at a constant speed, thus driving the tree seedling movement. As shown in Figure 1.



1-WORM ; 2-BAFFLE ; 3-FLOOR ; 4-MOTOR ;

5-PUSH, BLOCK SEEDLING ROD ; 6 - FIXED SLIDE RAIL

FIG.1 SEEDLING STORAGE MECHANISM

3.3 DESIGN OF SEEDLING SENDING AND SEPARATING MECHANISM

The seedling storage box is above the mechanism, and the seedling will fall into the pushing space directly below from the opening at the bottom of the seedling storage box. The seedling separator rotates at a constant speed under the drive of the motor, and the seedling will be pushed into the seedling conveyor belt at a constant speed by the seedling separator. The front end of the conveyor belt is connected with a barrel controlled by the motor to complete the process of seedling separation and seedling delivery.

The seedling divider is composed of a cylinder, and the cylinder is divided into six parts with a fan-shaped blade to ensure that the seedlings are evenly distributed and the planting spacing is consistent. The motor drives the fan-shaped blade to rotate and push the seedlings into the conveyor belt. The motor drives the conveyor belt to pass the seedlings into the bucket, and the bucket moves up and down under the drive of the motor to complete the seedling task.

3.4 DESIGN OF DRILLING MECHANISM

Through the analysis of the drilling structure of various existing tree planting machinery and the actual needs, the drilling machine designed in this paper adopts the long spiral drilling[6]. Long spiral drilling can be drilled in different types of soil, which can be used to deal with foundation problems under complex geological conditions, such as soft soil foundation, silt foundation and rock foundation. In the process of drilling with drilling rig and spiral drill bit, the depth and diameter of the hole can be determined according to the design requirements.

As shown in Figure 2, there is a motor connected to the rack on the outside of the bracket and placed vertically. After receiving the operation command, the motor starts to work to drive the drill up and down, and the drill starts to work under the drive of the motor to complete the drilling task.

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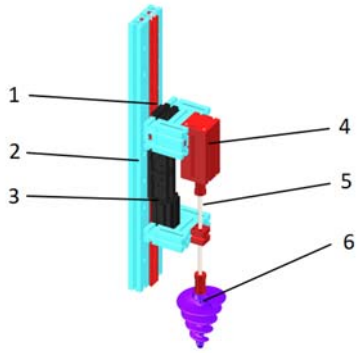
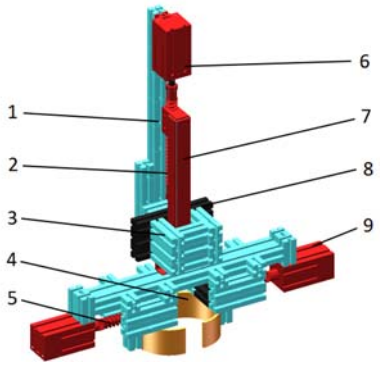


1 - SLIDE RAIL ; 2-STENT ; 3-MOTOR ; 4-MOTOR ;

5-CONNECTING ROD ; 6 - DRILL BIT ;

FIG. 2 SEEDLING MECHANISM



1-STENT ; 2-WORM ; 3 - FIXED FRAME ; 4 - MUD PLATE ; 5-WORM ;

6-MOTOR ; 7-CONNECTING ROD ; 8 - BACKING PLATE ; 9-MOTOR

FIG. 3 BACKFILLING MECHANISM

3.5 DESIGN OF BACKFILL MECHANISM

The backfill device is mainly composed of the main body of the backfill device, the pressure mud plate, two worm gear lifts and a deceleration motor that control the height of the pressure mud plate and the soil backfill platform respectively. The main body of the backfill device is made of 3D printing, with a height of 600 mm, a maximum diameter of 800 mm, a minimum diameter of 320 mm, an outer diameter of 600 mm and an inner diameter of 320 mm. By using the screw transmission mechanism, the soil filling device of the tree planting machine can move horizontally to squeeze the soil. The slider makes oblique reciprocating motion in the groove, and the filling indenter beats the ground circularly, compacts the soil around the seedlings, and completes the backfilling function.

As shown in Figure 3, the structure of ' large upper diameter and small lower diameter ' in the main body of the backfill device allows the container to hold more soil and improves the space utilization rate. The size difference of ' large upper diameter and small lower diameter ' can improve the accuracy of soil backfilling and ensure the survival rate of seedlings. The structure uses a geared motor, which mainly changes the speed through the transmission ratio of the gear, and can provide greater torque for the soil backfill action when working[7].By simulating the stress of the filling indenter in actual use, the maximum stress of the filling indenter is made through many improvements. The structure of the mechanism is more stable, the force is greater and the efficiency is higher. This design enables the backfilling mechanism to move back and forth in the vertical and horizontal directions to achieve the effect of multiple backfilling.

3.6 DESIGN OF IRRIGATION MECHANISM

The irrigation mechanism is composed of water tank, water pump and support frame. When the backfill mechanism begins to backfill, the pump starts to work, and the water completes the irrigation action along the backfill mechanism through the water pipe. It realizes the integration of backfilling and irrigation, completes the tree planting task efficiently, and helps to improve the survival rate of tree seedlings.

3.7 DESIGN OF DRIVING MECHANISM

Omni-directional mobile robots based on the Mecanum wheel[8] have the basic motion capabilities of forward, sideways, and 360 ° in-situ steering, and can even perform complex combined actions to move and circle in any direction on a two-dimensional plane and easily cope with changing terrain. Therefore, this study decided to use the Mecanum wheel as the main power system.

The bottom rotation drive of the robot is fixedly connected through the bracket, and the drive motor is connected to the worm through the drive shaft to realize the overall steering function of the equipment. In addition, the steering wheel can make other parts except the drive system rotate 360 ° to ensure the flexible mobility of the robot.

3.8 THREE-DIMENSIONAL MODELING AND ASSEMBLY

The core mechanical part of this design is composed of drilling mechanism, seedling feeding mechanism, backfilling mechanism, irrigation mechanism, seedling storage mechanism and corresponding drive motor. The tree storage box, bracket and filling device are mainly made of acrylic plates and 3D printing materials, which are accurately made by laser cutting technology. In order to adapt to the complex and changeable

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planting environment, the bottom drive mechanism adopts a wheat wheel device. The three-dimensional model and physical model of the multifunctional tree planting machine are shown in Fig.4.

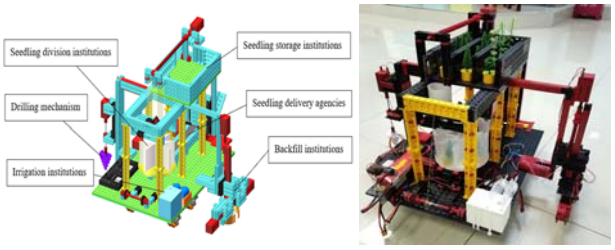

FIG.4 THREE-DIMENSIONAL MODEL, PHYSICAL MODEL

4 CONTROL PROGRAM DESIGN

4.1 MAIN PROGRAM DESIGN

When the tree planting machine reaches the tree planting position, the drilling mechanism starts drilling. After completion, the rotating mechanism transfers the drilling mechanism to the next hole position. At the same time, the seedling storage mechanism sends the seedlings to the seedling separator, and the seedling feeding mechanism sends the seedlings into the seedling bucket. After completing the seedling throwing task of the first hole, the rotating mechanism transfers the drilling mechanism to the third hole position. At this time, the irrigation mechanism and the backfill mechanism backfill and irrigate at the first hole position. Next, each hole completes the tasks of seedling delivery, backfilling and irrigation in turn. In this way, the planting of three seedlings was completed at one point, and the purpose of walking a straight line and planting three rows of trees was realized. So repeat the planting. The flow chart of the main program is shown in Figure 5.

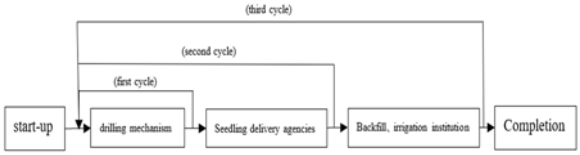

FIG. 5 PROGRAM FLOW CHART OF MAIN PROGRAM

4.2 DRIVE CONTROL MECHANISM PROGRAM DESIGN

The drive control mechanism of this design uses Mini Balanc software to execute the ' PID Controuer ' program to control, and uses the Arduino Mega 2560 of the microcontroller as the main control board to drive the walking.

Based on the kinematics characteristics of the Mecanum wheel, a PID controller is introduced into the speed control loop. The controller is designed to reduce the interference to the whole control system due to the frequent changes of the input, so as to accelerate the convergence of the angular velocity of the Mecanum wheel and improve the stability of the control system. Figure 6 shows the overall design framework of the controller, which consists of an external position control loop and an internal speed control loop, forming a PID Controuer double closed-loop control system. By analyzing the actual terrain, the system can output the predicted axial velocity and angular velocity under the condition of satisfying various motion constraints. Then, through the iterative solution of the program, we can get the angular velocity ωi of the McNamee wheel. Finally, the IDFPID controller of the internal speed control loop will complete the angular velocity control of the DC motor, so as to realize the movement of the mobile platform to the target position[9].

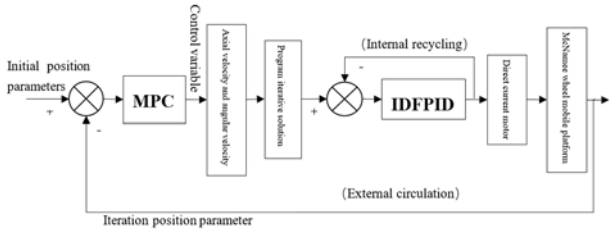

FIG. 6 PRINCIPLE OF CONTROL MECHANISM

The motion control of the mobile platform based on the Mecanum wheel relies on four independent motors, which are responsible for adjusting the start, stop and speed change of the wheel to achieve flexible movement in any direction. In order to move accurately along the established path and angle, the platform needs to be equipped with a control unit that can respond quickly and maintain the stability of the system. In conventional control logic, when the system starts, stops or the input instruction changes drastically in a short time, the response of the system often produces significant errors, which may lead to excessive oscillation and adjustment beyond the expected range. In contrast, the proportional-integral-differential (PID) control law processes the output by differential operation, which effectively avoids the high-frequency vibration problem of the system caused by frequent changes in the set value, thereby enhancing the smooth operation performance of the entire system[10].The principle of the whole control system is shown in Fig.7.

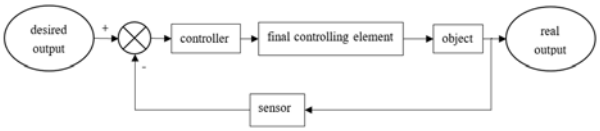

FIG.7 CONTROL SYSTEM SCHEMATIC DIAGRAM

5 CONCLUSION

With the rapid progress of artificial intelligence technology, intelligent robots are constantly emerging, and the concept of " machine substitution " that is deeply rooted in the hearts of the people is gradually changing our way of life. In this context, the market demand for automatic tree planting robots has increased dramatically, aiming to solve the problems of low efficiency and poor environmental adaptability of traditional artificial tree planting. Therefore, a small multi-functional tree planting robot is designed, which can adapt to the changing environmental conditions and complete the tree planting task efficiently.

The highlight of this design is its unique function of walking while planting. It can complete the planting of three rows of trees in one pass, which greatly improves the planting efficiency. In addition, the tree planting robot has low manufacturing cost, simple maintenance, intuitive operation and flexible steering, which makes it have broad market application potential.

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Xia Lilong (2000-), male, Zunyi, Guizhou, undergraduate student, the main research areas is mechanical transmission, or digital design.

REFERENCES

[1]Li Wenchun, Bu Haoran, Wu Xun et al., Application and development trend of tree planting machinery [J].Xinjiang Agricultural Mechanization, 2022, (05) : 26-28 + 44.

[2]Development of ZS-45 multifunctional tree planting machine [J].Research on agricultural mechanization, 2013,35 (01) : 83-85.

[3]Hou Rongguo, Wang Xiangtian, Lu Ping, etc. Design of whole process integrated tree planting engineering vehicle and its key components [J].Mechanical design and manufacturing, 2021 (10) : 62-65.

[4]Yin Jinsong, Ni Wenbin. Design of a small automatic tree planting machine [J]. Jiangsu Agricultural Science, 2018, 46 (18) : 208-212.

[5]Wang Hui, Hong Chen, Chen Anyu, et al. Design and coordination test of automatic salix planting machine [J]. Journal of Jiangsu University (Natural Science Edition), 2023, 44 (03) : 309-317.

[6]Ma Zhichao. Analysis of Technical Points of Long Spiral Bored Pile [J]. Theoretical Research on Urban Construction (Electronic Edition), 2023 (32) : 96-98.

[7]Liu Xiaoxian, Yu Jiang, Zhong Yuming, et al. Design of a Mangrove Intelligent Tree Planting Robot [J]. Southern Agricultural Machinery, 2023, 54 (14) : 128-131.

[8]Zhang Peng, Niu Zijie, Wang Longning, et al. Research on fuzzy PI control of omnidirectional mobile robot [J].Computer simulation, 2021, 38 (10) : 353-360.

[9]Huang Xiaoyu, Sun Yongzhi, Li Jinrong, et al. MPC-based trajectory tracking control for McNamee wheeled mobile platform [J]. Mechanical transmission, 2023, 47 (11) : 22-29

[10]Huang Xiaoyu.Research on AGV path planning and trajectory tracking algorithm of Mecanum wheel [D].Zhejiang University of Science and Technology, 2022. DOI : 10.27840 / d.cnki.gzjkj. 2022