Research on structural innovation of intelligent tree planting robot

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Abstract. This paper introduces an intelligent tree-planting robot, which belongs to the technical field of agricultural and forestry machinery and equipment, and the innovative features of its structure are hollow rotary drill and seedling storage and delivery device. This tree planting robot realizes the integration of autonomous movement, drilling, seedling delivery, mulching, compaction and watering functions, with a coherent workflow, which greatly improves the efficiency of tree planting. This robot will replace the traditional manual tree planting, greatly improve the survival rate of seedling planting and reduce labor cost.

Keywords: Intelligent tree planting robot; environmental protection; agriculture and forestry field.

1. Introduction

For a long time, land desertification has been regarded as a major problem that threatens the survival and development of human beings. The global desertification problem has become more and more serious. Due to natural factors and unreasonable human activities, the global desertified land area once reached 4 billion hectares, accounting for about 30% of the global land area, and according to the report of the United Nations Environment Program (UNEP), the direct economic loss caused by global desertification is about 250 billion dollars per year [1-2], which seriously hinders the global economic and social development. In addition, desertification also leads to the decline of social stability, the increase of poverty, and the increase of migration. Therefore, preventing and combating desertification is one of the important tasks of global environmental protection and sustainable development. In recent years, governments have invested hundreds of billions of yuan, formulated many laws and policies, vigorously implemented key projects such as wind and sand source control and desertification control, launched the construction of sandy land closure reserves and desert parks, and made remarkable control of desertification and sanding, with the whole sandy land effectively controlled and reduced by an average of 4,800 square kilometers per year, and the ecological conditions, economic and social conditions and farmers' living standards in sandy areas[3].The ecological conditions, economic and social conditions and living standards of farmers in the sandy areas have improved significantly.

In recent years, with the increasing awareness of environmental protection, greening work has received more and more attention and focus. As a new type of greening tool with the advantages of high efficiency, precision and automation, tree planting robots have received wide attention and research. However, the existing tree planting robots have some structural problems [4], such as large size, complicated operation and low precision, which limit their performance in practical applications. Therefore, it is of great research significance and practical application value to innovate and optimize the structure of tree planting robots. Traditional tree planting methods relying on human labor are costly and have low work efficiency in harsh terrain environments. Therefore, there is an urgent need for a group of intelligent tree planting robots to replace human labor, reduce costs, and improve work efficiency [5].

In this paper, the structure of tree planting robots will be innovatively designed and optimized. Through the analysis of existing tree planting robots and the application of new materials, sensors, control systems and other technologies, a new structure of tree planting robots is proposed, which has the advantages of easy operation, simplified planting process and high accuracy. The purpose of this

study is to explore a more efficient, accurate and reliable tree planting robot structure to contribute to the development of greening.

2. Structural innovation of intelligent tree planting robot

2.1. Tree planting robot development history

Since the 21st century, technology has continued to advance and the level of intelligence has increased, and there has been a significant improvement in the intelligent tree planting robot [6].

In 2009, Penn State University developed the first tree-planting robot "TREEMOTE", which weighs about 14 kg and can dig holes in the soil, sow seeds and cover the soil. In 2013, the Dutch robotics company EPC Engineering & Projects Company developed a tree-planting robot that can plant trees in arid areas such as deserts and automatically clean up the work site. In 2020, Japanese robotics company MU-ROBOTICS developed a crawling tree planting robot that can plant trees in rugged mountainous terrain, making it more flexible and efficient than previous robots.

2.2. Machine description

The equipment consists of a wheeled chassis, a drilling and planting mechanism, a backfilling mechanism, a sapling transfer device and auxiliary mechanisms. The wheeled chassis consists of a wheeled structure with electric motor, which is responsible for driving the robot during operation; the drilling and planting mechanism adopts a hollow auger spiral type auger, which is convenient for loosening the soil and throwing around, and also convenient for seedling delivery; the seedling delivery mechanism adopts an innovative design, which cleverly uses the characteristics of the hollow auger movement to complete the delivery of seedlings through the hollow head; the backfill mechanism is connected to the lower surface of the seedling delivery cylinder, and the backfill mechanism The backfilling mechanism is connected to the lower surface of the seedling feeding cylinder, and the backfilling mechanism can efficiently complete the compaction of the soil[7].

2.2.1 Overall Structure

This intelligent tree planting robot, as shown in Fig. 1 and Fig. 2, consists of 1 wheel structure, 2 drilling seedling planting mechanism, 3 transferring seedling mechanism, 4 irrigation and watering system, 5 signal indicator, 6 infrared camera system equipment. The specific structure and working principle are as follows [8-9]:

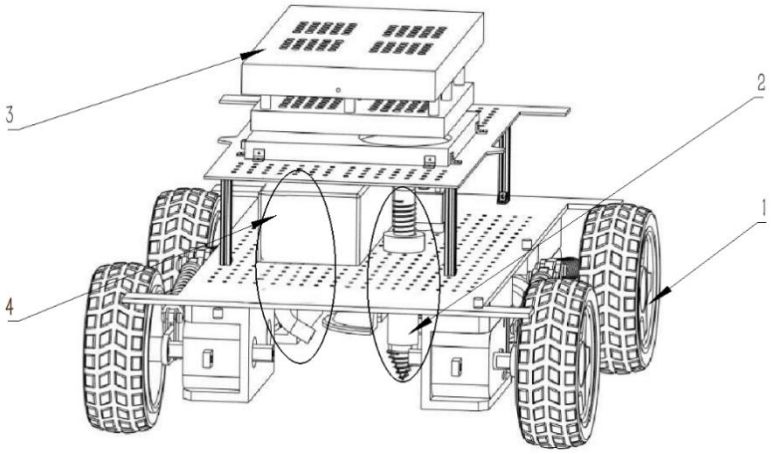


Figure 1. Overall schematic

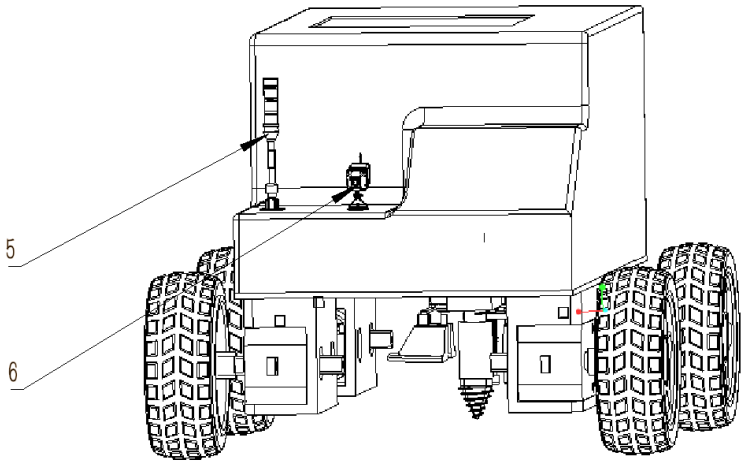


Figure 2. Overall schematic

2.2.2 Core structure 1 (drilled seedling planting structure)

The drilling planting mechanism consists of 2-1 guide rail, 2-2 housing, 2-3 screw, 2-4 worm gear, 2-5 hollow drill bit (with hollow flexible structure inside), 2-7 threaded sleeve, 2-8 gear, 2-9 similar slider structure, and 2-6 backfill mechanism. Two sliders on the outer wall of the threaded sleeve are connected to the slide ring on the inner wall of the threaded sleeve, and the slide ring is connected to four hinges, and the hinges are connected to the push rod, and the four opening and closing drill blades are connected to the hinges, and the push rod is connected to the hinges on the corresponding blades respectively. After finishing drilling and planting [10].

The backfilling mechanism includes a vertical guide rail fixed in the frame, a lifting drive motor, a vertical screw, and a nut fixed in the mounting base of the backfilling drive mechanism; the vertical guide rail runs through the mounting base to guide it to move in the vertical direction; the nut lifting drive motor drives the vertical screw to rotate so that the nut drives the mounting base to lift. The structure of the drilled seedling planting is shown in Figures 3, 4 and 5.

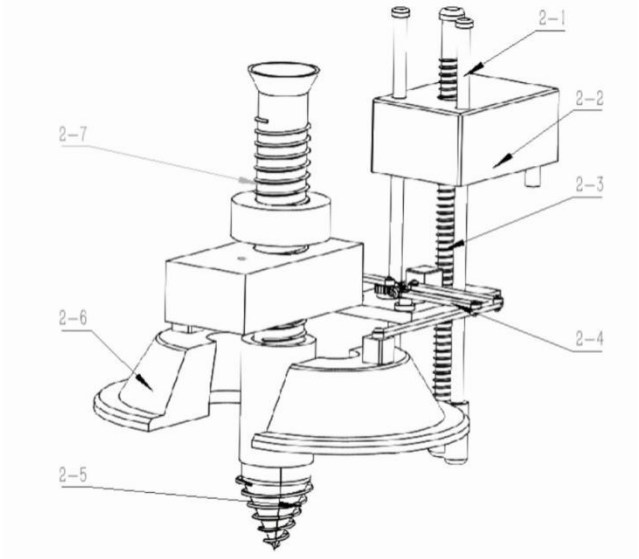


Figure 3. Diagram of drilling and planting mechanism

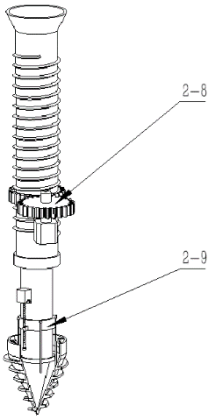


Figure 4. Diagram of drilling seedling planting mechanism

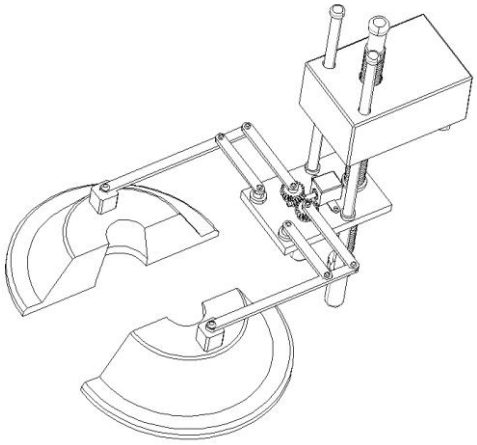


Figure 5. Backfill mechanism

2.2.3 Core structure 2 (seedling storage and transfer device)

The seedling storage transfer device consists of 3-1 baffle plate, 3-2 bracket, 3-3 filament rod, 3-4 lower seedling plate, 3-5 upper seedling plate, 3-6 thrust bearing, 3-7 receiving device (including box structure, funnel-like structure). The multilayer seedling tray behind the bracket is stored with seedlings, the large filament rod rotates to make the longitudinal baffle move to push the seedling tray to realize the seedling tray moving forward to the top of the funnel, the small filament rod rotates to make the folding baffle compress to realize the staggered movement of the baffle to complete the orderly fall of the seedlings into the funnel, the bottom of the funnel reaches into the sleeve of the drilling planting device, when the seedlings in the tray are planted, the filament rod rotates to continue to let the seedling tray move forward to the empty seedling tray stored in front of the bracket, the large filament rod Reversing the longitudinal stopper to return to the original position, the seedling tray card moves a certain distance under the action of the filament rod, the large spring directly below the multi-layer seedling tray pops up the remaining seedling tray to the specified position, the seedling tray card returns to the original position under the reverse rotation of the filament rod to achieve the fixation of the seedling tray, as shown in Figure 6 and Figure 7.

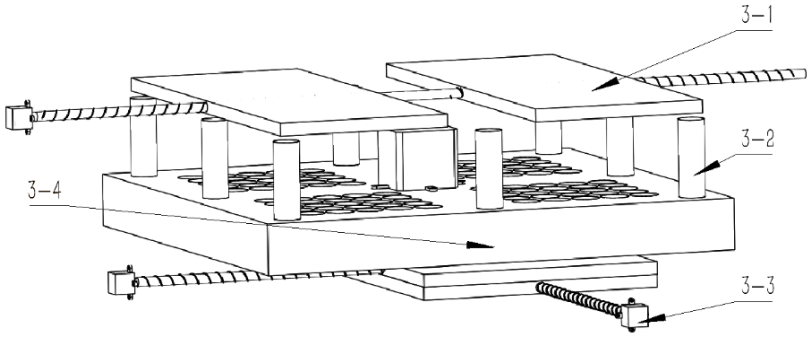


Figure 6. Schematic diagram of the device for transferring saplings

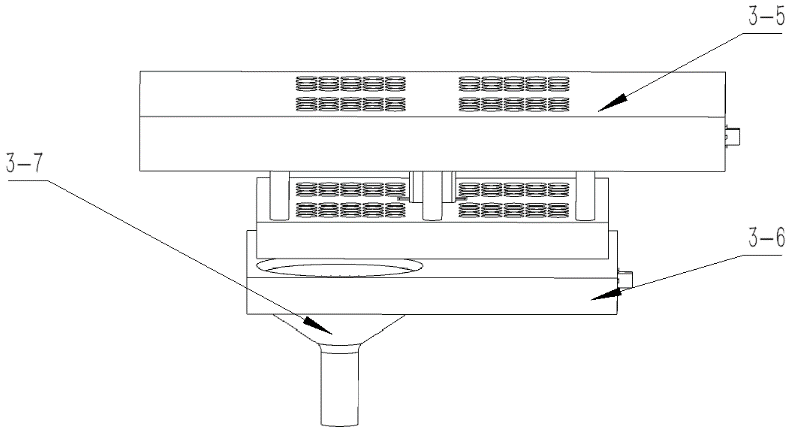


Figure 7. Schematic diagram of the sapling transfer device

2.2.4 Auxiliary structure

The irrigation and watering system consists of water tank, water pump, piping system, and nozzle. The irrigation and glue system in this tree planting robot mainly provides water to the trees that have just been planted.

The signal indicator consists of a light cover, LED lights, and a connector (the part that connects the light source to the power source). The signal indicator can be used to indicate different states of the equipment in this tree planting robot, such as power on, standby, failure, etc. In addition, it can be used for warning, for example, when the machine is running and there is a failure, the light will turn red.

The infrared camera system consists of an infrared camera and an infrared light source. The infrared camera system in this tree planting robot is mainly used to capture the surrounding environment by emitting infrared light, thus realizing the night vision function.

2.2.5 Path planning algorithm

In order to achieve the task of planting trees more accurately we have made innovations on the path planning algorithm. The traditional A* algorithm function applied to the robot path planning has some low efficiency problems, so the A* algorithm is improved and optimized into a two-way search A* algorithm, which makes the path searched by the algorithm more accurate and greatly improves the efficiency of robot path planning.

The two-way search A* algorithm is improved on the basis of the traditional A* algorithm. The traditional A* algorithm starts searching from the starting point to the end point, which is less efficient, and the two-way search A* algorithm starts searching from the starting point and the end point at the same time, that is, searching from the starting point to the end point and searching from the end point to the starting point at the same time, until the two search points intersect and end the search. Two-

way search A* algorithm has a relatively high search efficiency and can greatly reduce the search path time, the algorithm steps are as follows:

1. initialization: the starting point and the ending point are put into two queues, and the values of the estimation functions of the starting point and the ending point (i.e., the estimated distance from the starting point to the ending point) are set to f1 and f2, respectively.

2. Search: Take out a node from the start and end queues respectively, calculate their valuation function values f1 and f2, and select the node with the smallest f1+f2 for expansion. If the expanded node has already appeared in another queue, then it means that a path from the starting point to the end point has been found and the search is finished.

3. Expansion: For the currently selected node, calculate the valuation function values of all its neighboring nodes and add them to the corresponding queue. At the same time, update the valuation function values from the starting point to the current node and from the end point to the current node.

4. Repeat: Repeat steps 2 and 3 until a path from the starting point to the end point is found or both queues are empty.

5. Path reconstruction: If a path is found from the starting point to the end point, then the path can be reconstructed by going back to the parent node of each node.

The two-way search A* algorithm starts searching from both ends of the path, which greatly improves the path search efficiency compared to the traditional A* algorithm. The algorithm flowchart is shown in Figure 8:

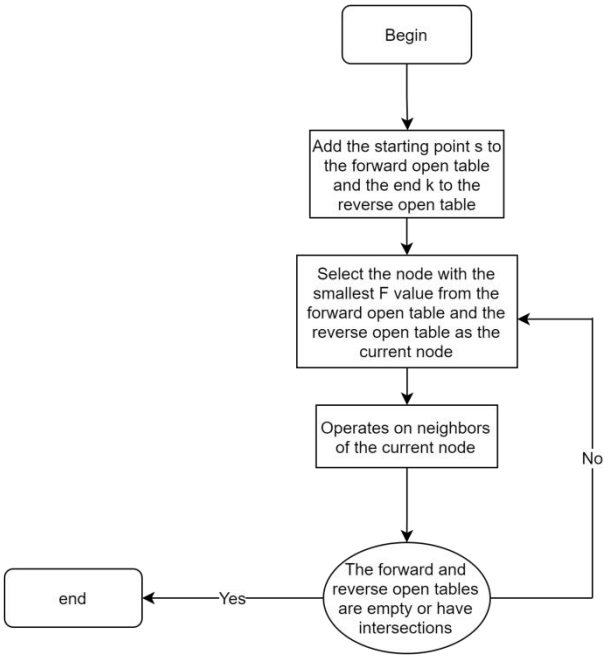


Figure 8. Algorithm flow chart

2.2.6 Machine workflow

After being placed in a specific planting environment, the planting robot starts to identify the environment and move to the designated target location efficiently. After drilling, the plants in the seedling tray fall into the funnel in an orderly manner, and then the funnel drops the plants vertically into the hollow drill, then the drill opens and rises, and the seedlings are placed directly in the trench holes; the backfilling mechanism fills the soil from the holes back into the pit and compacts it, and the watering equipment starts to water the planted plants; a tree planting workflow is thus completed, and then moves to the next position and Then move to the next location and repeat the planting workflow, Workflow diagram of tree planting robot is shown in figure 9. The following product parameters can be obtained through repeated testing of the tree planting machine, see Table 1:

Table 1. Tree planting robot parameters table

Working hours	Work efficiency	Sapling carrying capacity	Sapling specifications	Working speed	Operating Voltage
4—9h	>7000m2/h	140-370 plants	30—70cm	30s/plant	36v

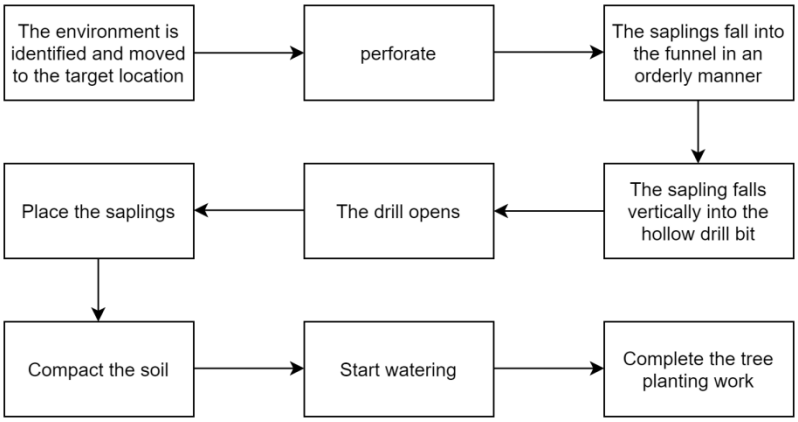


Figure 9. Workflow diagram of tree planting robot

2.3. Advantages of Desert Tree Planting Robot

The drilling and planting mechanism adopts the rotary drilling method with mixed rigid and flexible drive, and its key structure, hollow drill bit, realizes both drilling and planting functions. It greatly simplifies the workflow and improves the planting efficiency. The double-layer seedling tray is used in the seedling transfer mechanism, which greatly improves the storage capacity of seedlings. The rotating seedling tray is used for orderly placement of seedlings, which greatly improves work efficiency. It enables the robot to complete the tree-planting operation in a large area. The sapling receiving mechanism adopts two layers of staggered baffles, which can realize the orderly drop of saplings in the seedling tray and ensure the single hole and single planting rigor of tree planting. The traditional method of sand control is cleverly combined with robot technology, and the integrated design of machine instead of human to move independently, punching holes, handing seedlings, mulching, compacting and watering functions makes the work flow coherent and improves the efficiency of tree planting.

2.4. Future development route of tree planting robot

Intelligent maintenance system: The tree planting robot can be equipped with an intelligent maintenance system that can automatically monitor the growth of trees and timely adjust the growth environment of trees, such as adjusting light, water and temperature, to ensure the health and growth of trees. Multifunctional operations: In addition to planting trees, tree planting robots can also perform a variety of other operations, such as weeding, pruning branches and collecting fallen leaves, to ensure the balance and stability of forest ecology. Precise planting technology: The tree planting robot can use advanced sensor technology to precisely measure information such as soil water content, soil quality and light intensity, so as to select the most suitable location for planting trees and ensure the health and survival rate of tree growth. Considering that there are sufficient solar energy resources in the desert, we designed the energy supply equipment with solar energy as the main source and battery as the supplement. It can ensure the tree planting robot to operate normally in both sunny and cloudy days.

3. Conclusions

The intelligent tree planting robot designed in this paper uses a hollow rotary drill to significantly improve the efficiency of planting and a multi-layer seedling tray to greatly increase the carrying capacity of seedlings. The above two innovations provide a new way of thinking for the development of intelligent tree planting robot. At the same time, the robot is dedicated to the integrated design of autonomous movement, drilling, seedling delivery, mulching, compaction and watering functions, realizing the "one-stop service" of desert tree planting, simplifying the tree planting process, requiring low operator requirements, and facilitating promotion. Of course, the robot still has certain shortcomings or needs to be improved, we will further research along the proposed direction in the future, and strive to achieve intelligent maintenance and automatic monitoring of trees, to ensure the healthy growth of trees and improve the survival rate of trees. This is also the future research direction of the tree planting robot.

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