Features of Building a Forestry Intelligent Robotic System

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Abstract—**The autonomous movement problem is a hot topic in robotics, especially when the movement needs frequent decision-making. We follow the artificial intelligence (AI) approach when a robot decides on movement and manipulation actions like human. The reference application domain is reforestation work, where robots replace the labor of human in planting trees. This paper introduces the architecture and intellectual functions of an autonomous robotic system to operate in deforestation area. The robotic system consists of two devices: a robotic mobile platform (movement function) and a local control station (manipulation function). The robotic system operates autonomously (with no control by human) or in distant control by the operator if the movement action cannot be decided by the system.**

I. Introduction

Robotic systems with autonomous movement and manipulation are required in Industrial Internet applications [1], including manufacturing, healthcare, smart home, territory monitoring.

The reforestation process is an important part of forest management. The forest is not only a resource for a number of industries, but also performs environmental and social functions. Restoration of forests after deforestation is carried out mainly with the involvement of manual labor, which is ineffective. This paper considers development of a robotic system to replace human labor and increase the duration and efficiency of work is urgent.

At the present stage, such systems do not exist for full-autonomous reforestation. An overview of the approaches to solving the problem and the developed robotic devices that are similar in their functionality is presented in [1]. This paper introduces the architecture and intellectual functions of an autonomous robotic system to operate in deforestation area. There are to basic functions:

1) movement (on large territory of the forest area),

2) manipulation (planting tree operation in small area).

We focus on advanced AI-based solutions [2] when each unmanned function is implemented as if the function is under human control. That is, the robot makes movement and manipulation decisions like human. When the robot cannot make a decision (e.g., how to bypass an obstacle), the operator (human) takes the control.

The rest of the paper is organized as follows. Section II introduces the main problems for implementing such a robotic system for reforestation work. Section III describes the architecture and the functions that the robotic system realizes. Section IV summarizes this initial research study.

II. Reforestattion problems

Carrying out reforestation works is associated with a number of problems:

- Technological issues:
    - Reforestation works are mostly performed manually, which leads to low productivity.
    - Reforestation works are seasonal. They are performed at a time when the planting of forest crops has favorable conditions for further growth and development of plants. It makes no sense to carry out planting operations in winter, when the ground is covered with a thick layer of snow. Planted plants will inevitably die.
    - Places for reforestation operations may be located far enough from populated areas, which entails additional costs for providing transfer and accommodation of employees, delivery of equipment and forest crops.
- Economic issues:
    - Forestry operations do not generate operational profit.
    - It will take several decades for the planted crops to grow and be involved in a profitable production process.
- Social issues:
    - Work is performed in places with sparsely populated areas.
    - Manual labor is poorly paid.
    - The regional economy depends on forestry operations.

- Scientific issues:
    - The problem of autonomous movement of a technical device in a wooded area has not been solved. Currently, autonomous mobile devices can move on a flat surface without stumps, holes, large stones, strong gradients on paved roads with road markings. All these conditions are absolutely not met in the forest.
    - The problem of forest management automation has not been solved. Mechanical actions for forming the hole, introducing forest culture and closing the hole can be solved in ideal conditions for planting. In the conditions of a forest that is not specially prepared for work, the implementation of an automatic solution is a difficult task.

All these factors pose a difficult task for researchers to develop a robotic mobile system that can work in hard-to-reach areas at any time of the day, in any weather, and perform the following operations automatically:

- Soil preparation;
- Planting of forest crops;
- Applying fertilizers;
- Collecting information and monitoring the state of forests.

The tasks of the robotic system include:

- Shooting the terrain of a forest plot;
- Mapping the territory of a forest plot;
- Creating target points for performing work (for example, for landing);
- Creating a traffic route for bypassing target points;
- Route traffic management;
- Evaluation of the ability to perform work at the target point;
- Managing the local adjustment of changes in the position of the robotic platform at the target point;
- Managing the execution of work at the target point.

The robotic system should operate in automatic and semi-automatic modes, performing work both without the operator's participation and under the operator's control, but taking into account the context of the situation, continuing to process information received from sensors, responding quickly and sending messages to the operator about critical situations.

III. Architecture of the Robotic System

Technically, a robotic system is a software and hardware complex consisting of two devices: a robotic mobile device (RMD) and a local control station (LCS). The robotic mobile device is a four-wheeled all-wheel-drive platform with a variable lift for each wheel (Fig. 1). The platform is equipped with attachments for mounted technological equipment with a sufficiently large load capacity. The equipment may include a multispectral camera for shooting the territory, a system of sensors (position, humidity, temperature, etc.), hole forming device, hole closing device, fertilizer application device, seedling feeding system, lighting system, communication system, and other devices.

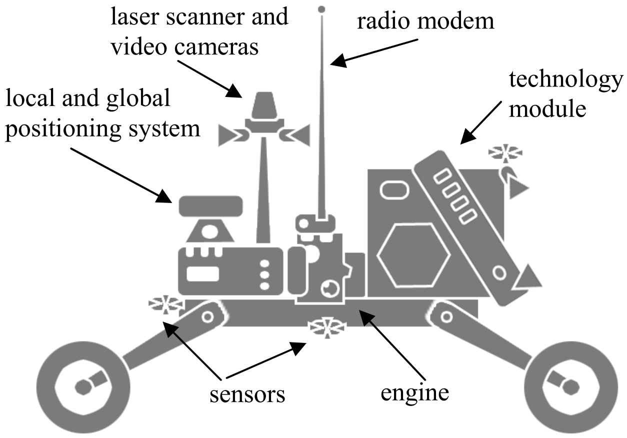

Fig. 1. Robotic mobile device (RMD)

The local control station that provides the operator's workplace is a stationary system that includes a computer, screen, control system and communication system (Fig. 2).

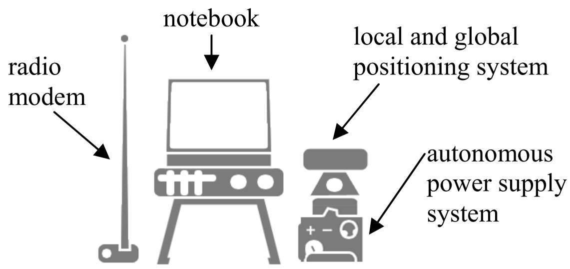

Fig. 2. Local control station (LCS)

The robotic mobile device includes:

- platform management module that implements:
    - transmission of control signals to platform thrusters;
- attachment management module that implements
    - reading and processing signals from sensors;
    - transmitting control signals to attachments;
- module for solving local platform management problems:
    - receiving and processing operator commands from the local control station;
    - transmitting signals to the operator (local control station);
    - coordinating the operation of all submodules of the robotic mobile device;
    - tracking traffic on a route;
    - automatically avoiding obstacles that are not included in the route;
    - evaluating the ability to perform work at the target point;
    - automatically correcting the location of the target point if it is impossible to perform work in it.

The local control station includes:

- module for operator control that provides:
  - loading source data;
  - sending commands to a robotic mobile device;
  - receiving and displaying operational data (readings of attachments' sensors);
  - generating a progress report;
- module for intelligent problems:
  - plotting a map;
  - creating a plan for the location of target points;
  - creating a route for bypassing target points.

Some of the listed functions of the modules are implemented by well-known methods (technical and software) [3-5], but some tasks require the use of a complex mathematical apparatus to solve them. Such intellectual tasks include surveying the terrain and mapping the territory of a forest plot, including determining the coordinates of the site boundaries based on global positioning systems, RFID tags, determining heights, slopes, determining the state of the site, the presence of natural and artificial obstacles in the form of stumps, stones, trunk fragments, etc.

The second intellectual task is the task of determining the places of work for planting seedlings or applying fertilizers (forming a set of target points for performing specified work in them). The formation of target points depends on many factors: the technical capabilities of the equipment and platform, the requirements of regulatory documents, and the natural and industrial conditions of the site. When forming target points, the results of plot mapping are taken into account. The resulting points are then plotted on the map (Fig. 3).

The next task is to build a route for the platform to bypass the target points, taking into account the characteristics of the territory, the stock of the cassette with seedlings. The problem is related to optimization problems. The objective function of the problem can minimize the distance traveled, minimize the impact of equipment on the ground, minimize the cost of moving and performing work, etc.

When driving along the route, robotic mobile device needs to solve several more intelligent tasks in real time. First of all, the robotic mobile device must move along the route. To do this, it is necessary to determine its location and compare it with the route. In the process of driving, obstacles may appear that are not marked on the map, and, as a result, are not taken into account in the route. This means that the route needs to be adjusted quickly with an aim to returning to the previously set route as soon as possible.

When the target point is reached, before performing the planned work, the robotic mobile device must evaluate the possibility of performing work at this point based on the analysis of sensor readings at the research site. If there are any obstacles to the work (for example, the presence of a stone at the puncture site), adjust the location of the point, move to a new position and perform the work as close as possible to the planned point, so as not to disrupt the entire system of target points and the route of their bypass.

In semi-automatic mode, the movement of the robotic mobile device is controlled by the operator. In this case, the task of building a route can be solved by the system, but the movement along the route is tracked manually by the operator. At the same time, the automated mobile device continues to collect information about the surrounding space. to warn the operator about possible problems and prevent him from making a mistake, for example, to run over a rock and break the sensor.

Currently, research is underway to build a project of mechanical elements of a robotic mobile device, and to develop algorithms for solving the described intellectual tasks.

IV. Conclusion

This paper introduced the architecture and intellectual functions of an autonomous robotic system to operate in deforestation area. The studied problem of robotic system development for autonomous movement and manipulation is needed in many application areas, not for forest industry only. The system construction requires integration of solutions from many areas: mechanics, sensorics, mathematical modeling, AI algorithms, and software engineering. The main advantages of the proposed system are all-weather conditions, round-the-clock operation (working in light and dark hours), the possibility of applying fertilizers and growth stimulants, obtaining systematic information about the state of forests and soils of the animal world.

V. Acknowledgment

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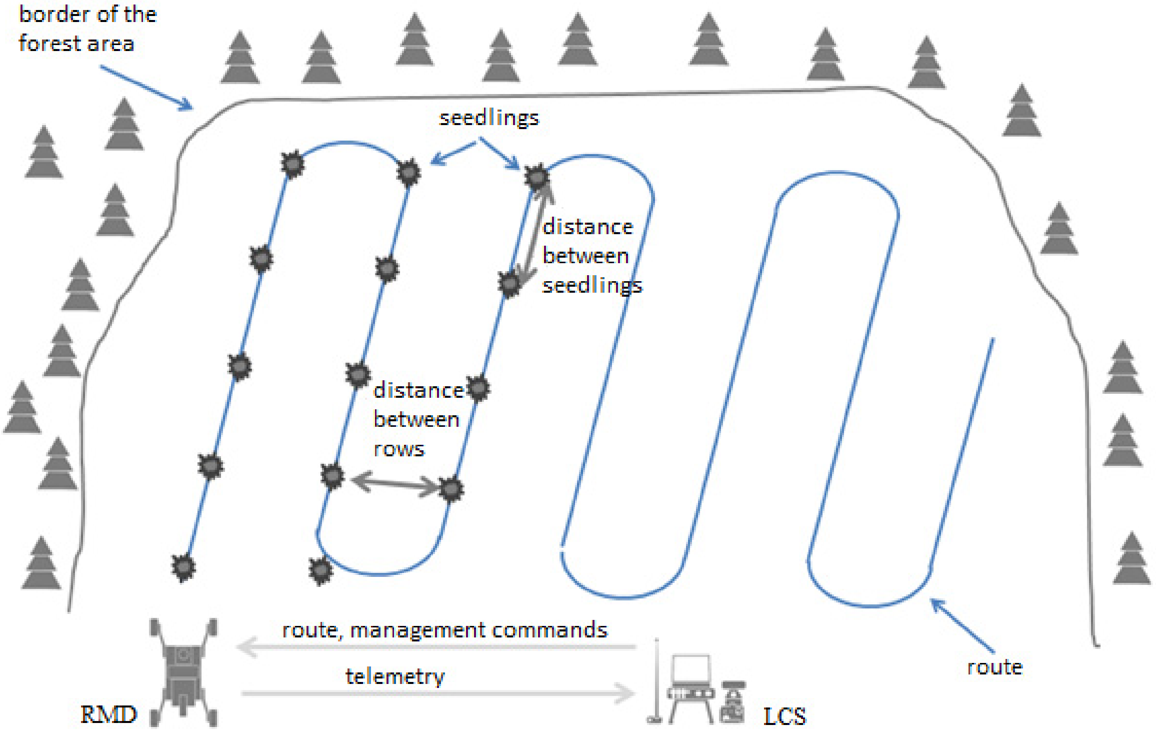

Fig. 3. Diagram of interaction between a robotic mobile device (RMD) and a local control station (LCS)