CONCEPTION OF AUTONOMOUS ROBOT FOR SOWING AND WIDE ROW PLANTING

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Abstract: The aim of the paper was to propose conception of autonomous robot for sowing and wide row planting. Autonomous work of the robot in range of traction and agronomic processes will be implemented on the basis of data from a many sensors (cameras, sensors position, sensors distance, and others). Positive test results will allow for the use of the robot in organic crops requiring mechanical removal of weeds or in crops with application of selective liquid agrochemicals limited to the minimum. The use of a vision system, based on the map coordinates of the position of the sown seeds, will allow for their care on an early stage of plant development. The applicability of the robot to onerous work in organic farming may encourage farmers to discontinue the use of herbicides in crops include sugar beet, corn, etc.

Keywords: AGRICULTURE ROBOT, CARE OF PLANTS, AUTONOMOUS WORK, ECOLOGY

1. Introduction

Syndicate of Industrial Institute of Agricultural Engineering in Poznań, with the Institute of Vehicles of Warsaw University of Technology and PROMAR company from Poznan started a design of autonomous farm robot for sowing and cultivation of wide row planting.

The aim of the project is to develop structures and operation procedures autonomous robot for sowing and wide row planting and conducting laboratory and exploitation tests on an experimental model. Autonomous work of the robot in range of traction and agronomic processes will be implemented on the basis of data from a many sensors (cameras, sensors position, sensors distance, and others). Positive test results will allow for the use of the robot in organic crops requiring mechanical removal of weeds or in crops with application of selective liquid agrochemicals limited to the minimum. The use of a vision system, based on the map coordinates of the position of the sown seeds, will allow for their care on an early stage of plant development. The applicability of the robot to onerous work in organic farming may encourage farmers to discontinue the use of herbicides in crops include sugar beet, corn, etc.

Achieving the objectives of the project will require the achievement of the following specific objectives of the practice:

- development of robot platform,
- selection of precision drill and develop methods of position sown seeds,
- develop tools to allow the processing of weeding both the surface and the surface spacing between crops in a row,
- development of tools to selectively spray the surface and the surface of the soil
- develop of the control system and control algorithms autonomous robot field in terms of traction and agronomic processes

2. Initial assumptions for robot

The autonomous farm robot should work in following working conditions:

- terrain: empowered field, field roads, mud, sand, grassy ground, rocky ground or other hardened,
- work in the open 24 hours / day,
- work in areas with varying degrees of lighting and visibility,
- temperature: 5 to 40 ° C,
- weather: average rainfall, moderate wind, fog,
- typical obstacles in the open area;

Projected robot enables complex care field crops including:

- red beet,
- sugar beet,
- sweet corn,
- cabbage,
- lettuce,
- forest nurseries, orchard
- production of vegetables and ornamental plants.

It enables the mechanical destruction of weeds and, if necessary, precise application of crop protection formulations and fertilizers.

2.1. The construction of the robot

The robot will have a modular design:

**The carrier**

The basic module is a stand-alone carrier cooperating with specialized modules. The carrier will be 4 wheeled vehicle, able to work remotely and autonomous. The drive wheels provide hydraulic motors and planetary gears. This way of transfer of power will get the high ground clearance of the machine (free space for tools) and independent suspension - important when working in difficult terrain. In addition, the speed differentiation of individual wheels and their appropriate setting will result in high maneuverability.

**Sprayer**

Sprayer will be able to to realize during the sowing or weeding dosage of liquid fertilizer or other liquid preparations of plant protection. The application will be executed surfactants (for plants or soil), or to the soil (of the depth below the surface of soil) in a continuous or selective based on the optical identification and location of objects.

**Seeder**

For precision seeding seeder will be applied with the seed position recording system in the field.

**Hoe**

The main working unit will be active hoe robot for precise control of weeds in both the inter-rows and row crops.
2.2. Robot Drive System
The use of hydrostatic drive system is based on:
- availability of different solutions,
- susceptibility to control,
- solutions common used in modern power transmission systems of agricultural machinery,
- ease of transmission from engine to the wheels,
- smooth gear shifting,
- elimination of mechanical transmission components,
- the ability to implement a reverse drive,
- drive motor protection against overload,

Wheel drive circuit
Wheel drive circuit will be equipped with a bent axis variable axial pump working in a closed circuit system with pressure compensated load "load-sensing". Such dispel the robot chassis is optimal, because the power absorbed by the chassis is strongly varies depending on the scope of the work carried out, the quality of the preparation of the field, pressure and other factors interfering with the robot. Hydrostatic drive systems with load compensation will maintain constant parameters of the hydraulic system regardless of the size and nature of its load, and also allow for precise control of the actuators. Furthermore, the use of a closed system makes it possible to take over the function of the brake wheels. The robot drive wheels are independently driven by hydraulic motors powered by variable speed pump controlled by servo valve. The flexibility of this approach allows trials traction in virtually any configuration, the position of the wheels, both from without and from slipping.

Power steering and actuators circuit
For power steering and external receivers installed for the main pump fixed speed auxiliary pumps.

The system uses valves, control blocks axles allow:
- including and excluding engines,
- synchronization of the drive wheels;
- turn on the spot,
- selection of the direction of the vehicle,
- directing the sprayer,
- hoe position control.

2.3. Robots model
First conception of the robot was presented at figure 1.

![Fig. 1 Model of the robot stage 1](image1)

It's very simply build: two separate frames with differential steering, a pivot and four wheel drive.

But there will be problems with steering, because of:
- two separate frames with differential steering and a pivot.
- may need a hydraulic jack for position control.
- constant wheel slip during ride on rough surface.

So the next conception was four wheel drive and steering, autonomous agricultural robot (Fig. 2).

![Fig. 2 Model of the robot stage 2](image2)

3. Robot guidance system
Main sensor system based on a specialized GPS receiver providing position information with an accuracy of less than 100 mm. This system will be used to:
- control speed of the robot,
- guidance and maintenance robot on the designated path,
- precision seeding - the exact information on where sowing the seeds will be used to build maps of seeds, which will be used as supporting information for precision weeding,
- to control the position of and operation of key components.

![Fig. 3 NI Vision System](image3)

To increase the accuracy of the robot will be used cameras system image (Fig. 3) before a robot that allows precise entry robot between the rows of plants and to correct direction of the robot. Simultaneously the system will also be used cameras image immediately before hoes active and sprayer. Also, information from the acceleration sensors and encoders built-in wheels will be used. To determine the angular acceleration will be required units of the IMU (Inertial Measurement Unit) This will enable a:
- trajectory correction of the robot,
- precise work of active hoe,
- position adjustment and precise dosing of liquid fertilizer plant health products.
3.1. Robot control system problems

There will be some problems with robot control system, first problems associated with the robot motion:

- Transfer of the robot to the field (and back)
- Field mapping
- Irregular field shape
- Obstacles
  - Inside the field
  - Outside the field (field borders)
  - Moving objects (e.g. people walking)
- Route (path) planning
- Automatic manoeuvres, especially at the end of the field
- Obstacles avoidance (collision detection)
- Navigation (GPS & inertial)

Second problems will be problems associated with the agricultural tasks:

- Precise detection of the position of the seeds & plants.
- Distinguishing between weeds and crops appropriate at different stages of growth in different rows.
- Control of the agricultural sets.
- Merging robot control and agricultural tasks.

So main problems to be resolved are connected with:

- Precise navigation (GPS + inertial).
- Integration of the vision system and robot movement control for obstacle avoidance.
- Housekeeping precise maps of seeds.
- Integration of vision system for guiding agricultural sets and robot movement control.
- Selection of proper, distributed architecture (vision systems, movement control, databases).

4. Conclusions

In the next stages of the project design tasks are planned:

- Selecting the target concept robot based on numerical analysis. Developing the concept of the control system and autonomous robot control algorithms.
- Development of the 3D model and the documentation necessary for the construction of the experimental model. The construction of selected teams require a preliminary verification of the solutions
- Development of 3D CAD models tool modules for sowing, weeding and spraying. Drafting and implementation of an electronic control system for robot experimental model.
- The construction of the experimental model allows autonomous robot to carry out laboratory and functional testing.
- Commissioning, testing and validation of the electronic control system robot.
- Laboratory tests and functional model of the experimental work.

References


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