E3S Web of Conferences **493**, 01003 (2024) https://doi.org/10.1051/e3sconf/202449301003
ABR 2024

Multifunctional Robotic Device with Intelligent Positioning System

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Abstract. At the present stage of agricultural production development, Smart farming is widely used as a systematic transition from managing a separate technological operation to managing processes that ensure the achievement of the required level of overall profitability of production through the use of new decision-making tools and automated management technologies. This approach involves expanding the scope of machines, equipment and software, including the widespread use of robotic tools in horticultural production and processing technologies, in order to increase production efficiency, eliminate the "human factor" in the production of products, replace human participation in production processes with a large proportion of heavy manual labor and minimize harmful effects chemical protection products for humans and the environment. Another reason for the intensification of the development and implementation of robotic tools with intelligent control systems in agriculture is the shortage of technologists and engineers in farms, due to the unattractiveness of labor in the agro-industrial complex. The article discusses the issues of increasing the efficiency of industrial gardening, through the development and implementation of robotic systems and electric drive transformer modules in various technological processes. The features of the designs and practical application of robots with intelligent motion control systems on garden plantations are analyzed. The application of the block-modular principle of the layout of robotic machines is justified to increase the efficiency and productivity of their work in industrial gardening in various technological operations: plant care (spraying, milling of aisles) and harvesting.

1 Introduction

The Digital Gardening scientific and production system involves expanding the scope of machines, equipment and software, including the widespread use of robotic tools in horticultural production and processing technologies, in order to increase production efficiency, eliminate the "human factor" in the production of products, replace human participation in production processes with a large proportion of heavy manual labor and minimizing the harmful effects of chemical protection products on humans and the environment [1-5]. Another reason for the intensification of the development and implementation of robotic tools with intelligent control systems in horticulture is the acute

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shortage of technologists and engineers in farms, due to the unattractiveness of work in the agro-industrial complex [6-8].

In the agroengineering center of «VIM» together with the "AURORA ROBOTICS" company developing a multifunctional robotic tool with an intelligent vision system designed to implement intelligent agrotechnologies of "precision gardening" and provides:

- movement with a different range of combined units on agricultural plantations in an autonomous mode;
- the possibility of aggregation with various mounted and trailed adapters for the use of several technological operations at the same time;
- compilation of electronic field maps, including yield maps.

The novelty of the development lies in the intelligent autonomous robot movement system, which uses data from the GLONASS navigation system and the method of visual location determination and motion control to control the robot, which makes possible all-weather and round-the-clock use of the robot [9-12].

The sprayer chassis with an intelligent motion control system based on the use of sensor technology (sensors, 3D video cameras) provides the ability to position relative to plants using spectral imaging technologies [13,14].

Fig. 1. Multifunctional robotic device with an intelligent vision system

Table 1. Technical specifications

Name of indicators	The value of the indicators
Curb weight, kg	980
Load capacity, kg	700
Characteristics of the running system:	wheel type
Wheel size, mm:	
- diameter, no more	750
- width, no more than	300
Wheel formula	4*4
Machine dimensions, not more than, mm:	
-length	2900
-width, adjustable	1800-2200
- wheelbase	1690
Track width	1260-1410
Ground clearance, mm	390

Requirements for a multifunctional robot:

1. The ability to promptly receive, analyze and process a large amount of information about the state of agricultural system facilities and implement control actions during technological operations.

2. The possibility of operational remote control mode change.

3. The possibility of continuous battery life for 10...12 hours.

4. Increased cross-country ability.

5. All-season operation.

6. The possibility of group application.

2 Materials and Methods

Theoretical research is carried out using the laws and methods of theoretical mechanics, mathematics, modern methods of computer modeling and programming are used. Experimental data processing and computer modeling were carried out using CAD software COMPASS-3D v17, Autodesk fusion 360, MathCad 15, Excel, PlanExp B-D13, Elcut Professional 6.3, Coil 32. Laboratory and field experimental studies were conducted in accordance with current state standards using experimental planning techniques. When researching digital technologies in horticulture, it is necessary to take into account and control about 60 parameters, including 8 environmental parameters, 9 parameters of plant condition and crop quality, 15 parameters of the technical condition of robotic machines and 9 parameters of motion control of a robotic chassis.

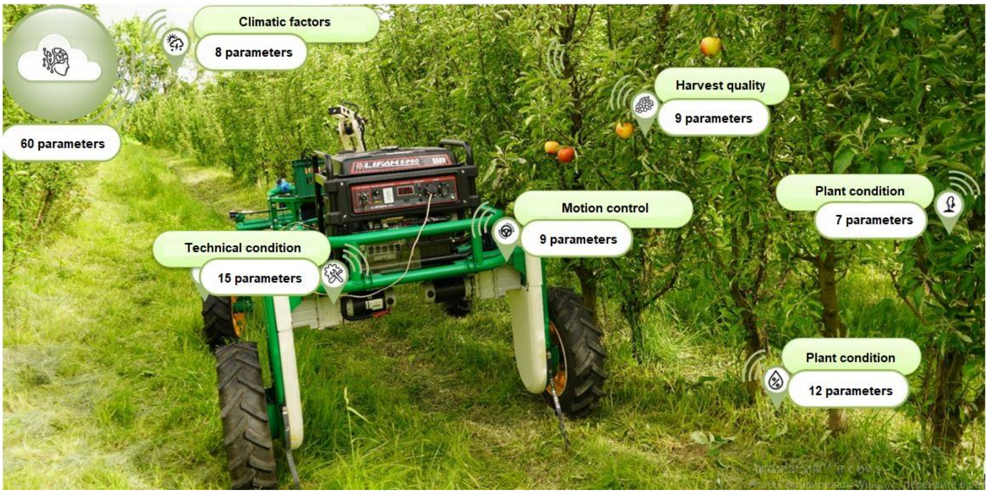

Fig. 2. Digital Garden Parameter System.

3 Results and Discussion

One of the innovative approaches to the development of intelligent machines is the development of electric drive transformer modules as energy integrals (Fig.3). On the basis of the block-modular principle, robotic technical means have been designed that allow, without human intervention, to perform technological operations for caring for plants in row spacing gardens with a row width of 2.5-4 m and planting strawberries in the open ground.

Fig. 3. Electric drive transformer models: energy integrals.

The basic electronic circuit represents the interconnection of blocks of electric drive and actuating devices. (Fig. 4).

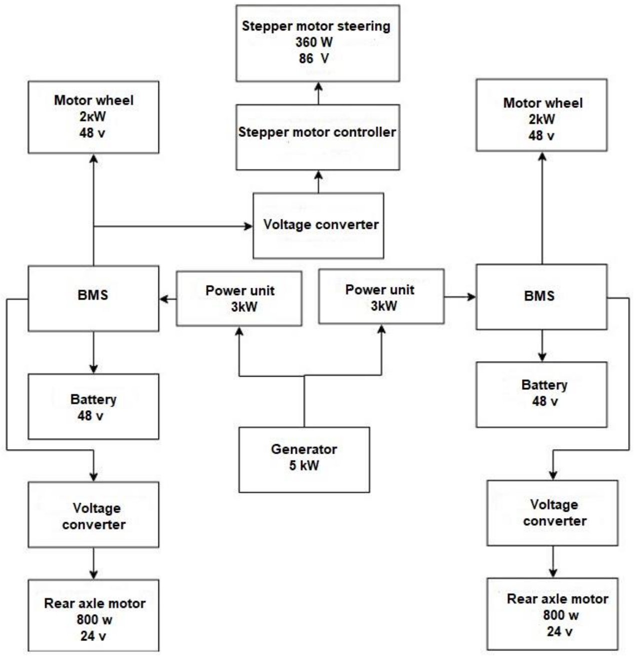

Fig. 4. Schematic electronic diagram of a robotic platform.

To control the rotation of the front axle wheels, the Autonics EP50S8-1024-2R-N-5 absolute encoder is used, the characteristics of which are provided below (Table 2):

Table 2. Technical specifications encoder.

Name of indicators	The value of the indicators
Encoder Type	Absolute, optical
Output Type	NPN open collector
Output code	Binary code
Optical resolution (imp/revolution)	1024
Supply voltage	5 in
Shaft Type	Round protruding
Shaft diameter	8mm
Installation method	On the body
Connection method	Cable
Cable length	2 m
Size	50x50x91.5 mm
Operating temperature	-10...70 °C

The control output circuit is shown in (Fig. 5):

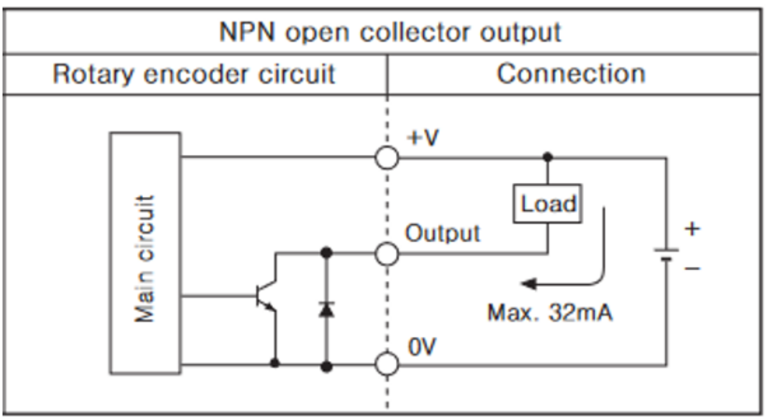

Fig. 5. Encoder control circuit.

The output signal from the encoder is a binary signal, where a certain wire is responsible for a certain digit in the number. So, 10 wires are used to connect the encoder to the microcontroller. To save the inputs of the microcontroller, a cascade of shift registers SN74HC165N is used, the technical characteristics of which are presented in Table 3.

Table 3. Characteristics of the SN74HC165N.

Name of indicators	The value of the indicators
Housing type	PDIP-16
The bit depth of the parallel input	8 bits
Supply voltage	2-6 in
Current consumption	80 μA

The connection diagram of the encoder through a cascade of shift registers may look like this and is shown in Figure 6:

In this scheme, two shift registers are used, which are connected in a cascade. The encoder outputs are connected to the inputs of the first register, and the outputs of the second register are connected to the microcontroller via the SPI interface.

The encoder inputs are connected to power and ground via resistors to protect against short circuits and interference. The outputs of the first register are connected to the inputs of the second register to transmit data over the cascade.

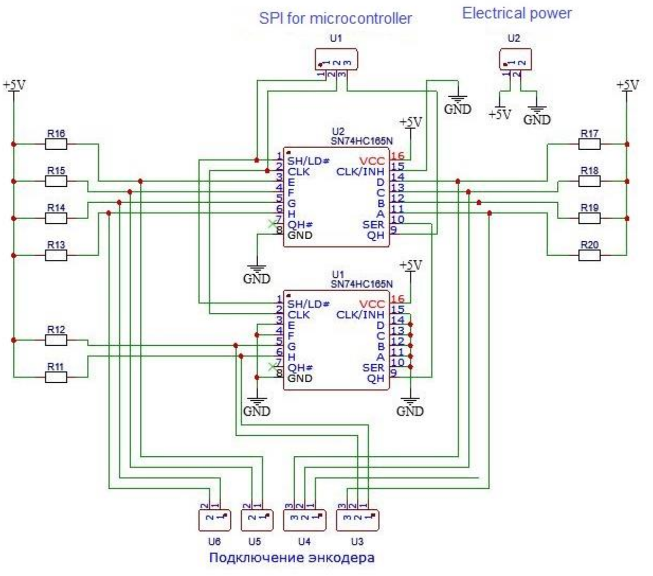

Fig. 6. The connection diagram of the encoder via a cascade of shift registers.

Connecting the encoder to the shift registers, which are connected to the ATmega168 microcontroller via the SPI data transfer protocol, allows the microcontroller to receive information about the position of the encoder shaft and use it to control other systems. When the encoder shaft rotates, the state of its outputs changes, which are read by shift registers and transmitted via the SPI interface to the microcontroller. Next, the microcontroller processes the received data and decides on further actions depending on the task. The technical parameters of the controller are shown in Table4.

Table 4. ATmega168 features.

Operating voltage	5 in
Input voltage	5-12 In
Digital Inputs/Outputs	14 (6 of which can be used as PWM outputs)
Analog inputs	6
Direct current through the input/output	40 mA
Flash memory	16 KB (2 are used for the loader)
RAM	1 KB
EEPROM	512 bytes
Clock frequency	16 MHz

The LineDriver, SPI and SPI_Bus libraries are used to get data from the cascade of shift registers.

The encoder returns a value from 0 to 1024 depending on its position. The data obtained is translated into the value of the angle of rotation of the wheels of the front axle according to the formula:

$$(x - in\_min) * (out\_max - out\_min) / (in\_max - in\_min) + out\_min \quad (1)$$

where
x is the current value from the encoder
in_min – the minimum possible value of the encoder
in_max – the maximum possible value of the encoder
out_min – the minimum possible angle of rotation
out_max – the maximum possible angle of rotation

4 Conclusions

The proposed designs of robotic technical means for performing technological operations in horticulture differ from analogues in increased power of electric drives, cross-country ability and a high-precision automatic control system using GLONASS navigation, technical vision and remote control. The developed technical means make it possible to significantly increase the efficiency of technological operations through the use of inexpensive components, high mobility and the possibility of group work.

It is also planned to expand the technological capabilities of robotic hardware by equipping sensors and control systems that will monitor the condition of soil, plants and the environment. This will allow you to make more accurate decisions when choosing technological operations and optimize the use of chemicals in plant care operations in the garden.

The application of the block-modular principle of the layout of technical means will allow for a rapid change of technological modules depending on the required operation, while promptly transforming the overall dimensions of the mobile platform, which will reduce the monetary and time costs of carrying out various technological operations and the qualitative characteristics of technological operations when using the main running module.

In addition, thanks to the introduction of robotic technical means, it is possible to reduce the number of seasonal workers on the gardening site, which will increase the efficiency and quality of operations and reduce production costs.

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