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MOBILE ROBOT FOR AGRICULTURAL RESEARCH USING SENSORS AND COMPUTER VISION SYSTEMS

Arkatov Yerikzhan, Angarbekov Ulan

Introduction. In recent decades, agriculture has become one of the most dynamically developing sectors of the global economy. With the growth of the world's population and the limited availability of natural resources, there is a need to increase crop yields and the efficiency of agricultural production. Traditional methods of studying soil and plant conditions require significant labor and do not always provide sufficient accuracy of the data obtained.

Modern technologies come to the rescue — robotics, sensor systems, computer vision, and artificial intelligence. Their integration into agricultural research allows for the automatic collection and analysis of information, significantly improving the quality of research and contributing to the development of the concept of 'smart farming' [1-5].

Mobile robots equipped with sensors and computer vision systems are already being used in developed countries. They monitor soil conditions, detect plant diseases, predict crop yields, and help optimize agricultural processes.Цель и задачи исследования

The goal is to analyze the possibilities and prospects of using mobile robots with sensors and computer vision for conducting agricultural research.

Tasks:

- Consider the principles of operation of a mobile robot in the agricultural sector.
- Study sensor systems and computer vision algorithms.
- Evaluate existing platforms for robot development.
- Provide examples of applications in global practice.
- Identify the advantages, limitations, and prospects for technology development.

- Principles of mobile robot operation

The mobile robot for agricultural research is an autonomous platform equipped with a set of sensors, cameras, and computing modules.

Sensor systems

Sensors provide data collection on soil and environmental conditions:

- Soil moisture and temperature sensors;
- pH meters and soil composition sensors;
- Spectral sensors for analyzing the photosynthetic activity of plants;
- Air moisture and temperature sensors.

Computer Vision

A key element is the computer vision system, which analyzes images of plants:

- RGB cameras – capture the visual condition of plants;

Hyperspectral cameras – detect plant stress that is invisible to the human eye;

Thermal imagers – determine water balance and early signs of diseases.

Machine learning algorithms make it possible to automatically detect the presence of diseases, pests, nutrient deficiencies, or damage [2].

Navigation and movement

To move around the field, the robot uses:

- GPS and RTK-GPS for precise positioning;
- LiDAR and ultrasonic sensors for obstacle avoidance;
- Inertial modules for maintaining course.

Data processing

The data is processed in real time on an embedded computer (e.g., Raspberry Pi or NVIDIA Jetson) and can be transmitted to the cloud for analysis and storage.

Platforms and technologies used

Hardware part:

Arduino – control of simple sensors.

Raspberry Pi – image processing.

NVIDIA Jetson Nano – analysis of large data sets and working with neural *networks.*

Software:

ROS (Robot Operating System) – motion control and component interaction.

OpenCV – image processing and object recognition.

TensorFlow / PyTorch – training and applying neural network models

IoT platforms – data storage and visualization.

Development stages

Selection of a mobile chassis (wheeled or tracked).

Integration of sensors and cameras.

Connection of the computing module.

Software development.

Testing in laboratory conditions.

Trials in field conditions.

Examples of applications in global practice

Japan – mobile robots help monitor the condition of rice fields by controlling humidity and water levels.

USA – in California, robots are used to monitor vineyards, where they assess the ripeness of grapes and predict yields.

Europe – in the Netherlands, robots are employed in greenhouses for automatic detection of diseases in tomatoes and cucumbers.

Kazakhstan and the CIS – such technologies are just beginning to be implemented, but they are especially relevant for large agricultural areas.

Economic efficiency and advantages

Reduction of labor costs.

Increased accuracy of research.

Possibility of round-the-clock monitoring.

Reduction of crop losses through early detection of problems.

Creation of a database for yield forecasting.

Problems and limitations

High cost of equipment and maintenance.

Dependence on weather conditions.

Need for specialists in programming and robotics

Limited autonomy when operating over large areas.

Conclusion and prospects

Mobile robots equipped with sensors and computer vision are opening new horizons for agricultural research. They enable the automation of information collection, minimize errors, and increase the efficiency of agriculture. In the future, such systems will be integrated with drones, autonomous vehicles, and the Internet of Things, leading to the creation of fully digital farms. The development of such technologies is a strategic direction that will help ensure food security, optimize resource use, and move towards sustainable agriculture.

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