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ANALYSIS OF TASKS OF MONITORING AND AUTOMATIC CONTROL OF AGRICULTURAL MOBILE ROBOT

Abstract. *The work is devoted to the consideration and analysis of a set of tasks of monitoring and automatic control of modern mobile robots, designed for automation of various types of technological operations in agriculture. Studies indicate high activity of manufacturing companies and scientists in the development of structures and remote control systems for various types of agricultural robots due to the general increase in demand for food in conditions of limited unleavened water reserves, high prices for mineral fertilizers and wages of the staff. The paper presents the classification of modern agricultural robots according to the degree of mobility, type of control system, working environment, industry and functional purpose. It is determined, that such robots are equipped with built-in development boards with microcontrollers or microprocessors, which everyone has on board, regardless of the design and type of the control system. In addition, remote control methods and tools are most often used to automate agricultural works, but automatic and autonomous mobile robots independently perform a much wider list of tasks, because they work on the basis of adaptive-intelligent control methods. The authors formulate the main tasks of monitoring and automatic control for the generalized agricultural mobile robot, in particular monitoring and automatic control of vectors of spatial motion parameters, operating parameters of technical equipment of movers, manipulators, gripping devices, as well as parameters of specified agricultural works and operations. The functional structure of the generalized agricultural mobile robot as a multi-coordinate control object, which takes into account the interaction of controlled coordinate vectors, control signals of propulsors, manipulators, grippers and process equipment, as well as perturbing effects on its individual components (body, propulsions, manipulators, gripping devices and technological equipment) is proposed in the paper.*

Keywords: agricultural mobile robot; control system; agriculture; automation; controlled coordinates

Problem statement

Food security is one of the most important factors in the sustainable development of any country in the world from ancient times and to this day. According to experts [1], the population of the planet will reach 9 billion people by the end of 2050, so the agricultural sector of the economy must develop the appropriate capacity to meet the basic needs of adequate nutrition for everyone.

Complicating this task is the tendencies to reduce soil fertility, pesticide contamination, reduce bee populations, increase the total number of diseases and pests of cereals, fruits and other crops, and so on. In such conditions, success in increasing the volume of agricultural production is possible with the involvement of more highly qualified specialists: agronomists, machine operators, gardeners, etc. However, to increase productivity and reduce costs for a number of technological operations in the agricultural sector without involving a significant number of additional staff is possible with the introduction of modern automation, including mobile robotic systems equipped with reliable propulsors, modern information control systems and appropriate technological equipment.

Latest research and publications analysis

About 40% of all robots produced in Europe are used in agriculture, and their total number is constantly increasing according to statistical estimates [2, 3]. But, the latest developments of scientists from around the world are devoted mainly to certain types of robotic systems, which are designed to perform a single task in the agricultural sector despite the rapid development of robotics for agriculture [4 – 7]. The functional purpose of the agricultural robot determines its construction, structure of the control system and algorithms of functioning.

Modern agricultural robots can be classified according to the following features [2; 8]:

– the degree of mobility (stationary, mobile);

– working environment (ground – field, garden and greenhouse, water, air);

– industry purpose (for crop and livestock);

– functional purpose (crop caretakers, inspectors, sprayers, harvesters, pruners, etc.);

– type of control system (remote-controlled, automated, automatic);

– specialization (specialized and universal/multi-purpose).

At the same time, agricultural robots are equipped with small built-in development boards with microcontrollers or microprocessors [9-11], which each robot has on board, regardless of the design and type of control system.

The same principles are used to control agricultural mobile robots (MRs) as for other systems and equipment. By the way, software control and remote control have become the most common [6, 9-11], they solve the problem of overcoming and bypassing obstacles, moving along a given trajectory with the simultaneous execution of the tasks, achieving a given position.

Features of the control object in the form of an agricultural MR add specific tasks to be solved due to changing operating conditions (current weather, soil condition, amount of crop grown, workload and other factors), so the most promising are adaptive and intelligent systems [1; 7; 8]. Processing of sensory information from the robots' devices; formation of static and dynamic models of the environment; traffic control; decision-making and planning of further actions "in current placement"; development of an intelligent communication interface between the operator and the robot are the main tasks of adaptive-intelligent control. However, such methods of MR control are not widespread due to the complexity of developing such systems, so they are at the stage of intensive research and engineering development. In addition, the literature pays a little attention to the principles of the general functioning of systems with agricultural robots as control objects. Therefore, the set of tasks of monitoring and automatic control for further synthesis of structures, models, control devices and programs for agricultural MRs control systems remains the subject of proper analysis by scientists.

The article aim

Existing analytical publications rather superficially cover the important tasks of automation of various types of technological operations in agriculture with the help of MRs and don't provide generalized practical recommendations for determining the controlled coordinates for them. *The purpose of this article* is to analyze and formalize a set of tasks for monitoring and automatic control of the generalized agricultural MR for its movement and execution of various types of technological operations.

Basic material

Leading companies and laboratories of the world are engaged in the development of modern MRs for agriculture. To solve the aim of the paper it is advisable to consider the features of such robots for different functional purposes for animal husbandry and crop production.

A large category includes robotics for livestock farms, namely: milking (Fig. 1, a); feed equalizers; manure cleaning robots; mixers and feed distributors; robots for shearing animals; washing robots (Fig. 1, b); robots for sorting, loading and packing eggs; robotic pasture systems [2; 12; 13]. The vast majority of such robots are stationary, equipped with manipulators, mixing and dosing mechanisms.

In contrast to the previous category a characteristic feature of robots for crop production is the presence of requirements for a high level of mobility and autonomy of operation, as well as reliable means of communication. The most common tasks performed in crop production are sowing crops, transportation, watering, tillage (Fig. 2, a), spraying plants, weed control, loosening, germination monitoring, mowing, harvesting (Fig. 2, b), pruning, etc. [2; 14 – 17].

The main tasks of monitoring and automatic control of the agricultural MR. Execution of the above works in animal husbandry and crop production of appropriate quality while ensuring reliability, accuracy, speed and safety of MR movement in the work area (indoors, field or greenhouse conditions) must automatically monitor and control of the main operating parameters of the robot and its technological equipment, which are directly responsible for the quality and performance of operations [18 – 20] and can be grouped mathematically in the form of appropriate vectors or matrices.

Considering the generalized agricultural mobile robotic complex of universal application as a multi-coordinate object of monitoring and control, the following main tasks of its monitoring and automatic control can be formulated:

a *b*

Figure 1 – Typical applications of robotics in animal husbandry: milking (a) and washing (b) robots

a *b*

Figure 2 – Typical applications of robotics in crop production:
autonomous cabinless multipurpose tractor (a) and apple harvesting robot (b)

– monitoring and automatic control of the $\mathbf{Q}_{\mathrm{MR}}$ vector of the parameters of the MR's spatial motion

$$\mathbf{Q}_{\mathrm{MR}}=\left\{X_{\mathrm{MR}},Y_{\mathrm{MR}},Z_{\mathrm{MR}},V_{X\mathrm{MR}},V_{Y\mathrm{MR}},V_{Z\mathrm{MR}},\alpha_{\mathrm{MR}}\right\},$$

where X_{MR}, Y_{MR}, Z_{MR} – spatial coordinates of the MR; $V_{X\mathrm{MR}}$, $V_{Y\mathrm{MR}}$, $V_{Z\mathrm{MR}}$ – the speeds of change of the corresponding spatial coordinates of the MR; α_{MR} – course angle of the MR;

– monitoring and automatic control of vectors of working parameters of technical equipment of separate propulsors $\mathbf{W}_{\mathrm{MR}}$, manipulators $\mathbf{M}_{\mathrm{MR}}$, gripping devices $\mathbf{G}_{\mathrm{MR}}$ of the MR

$$\mathbf{W}_{\mathrm{MR}}=\{W_{\mathrm{P}1,1},W_{\mathrm{P}1,2},...,W_{\mathrm{P}1,i}\;\;W_{\mathrm{P}2,1},W_{\mathrm{P}2,2},...,$$
$$...,W_{\mathrm{P}2,i}\;\;...\;\;W_{\mathrm{P}k,1},W_{\mathrm{P}k,2},...,W_{\mathrm{P}k,i}\},$$

where $W_{\mathrm{P}1,1}$, $W_{\mathrm{P}1,2}$,…, $W_{\mathrm{P}1,i}$ – 1st, 2nd,…, *i*-th parameters and variables for the first propulsor; $W_{\mathrm{P}2,1}$, $W_{\mathrm{P}2,2}$,…, $W_{\mathrm{P}2,i}$ – 1st, 2nd,…, *i*-th parameters and variables for the second propulsor; $W_{\mathrm{P}k,1}$, $W_{\mathrm{P}k,2}$,…, $W_{\mathrm{P}k,i}$ – 1st, 2nd,…, *i*-th parameters and variables for the *k*-th propulsor;

$$\mathbf{M}_{\mathrm{MR}}=\{M_{\mathrm{M}1,1},M_{\mathrm{M}1,2},...,M_{\mathrm{M}1,j}\;\;M_{\mathrm{M}2,1},M_{\mathrm{M}2,2},...,$$
$$...,M_{\mathrm{M}2,j}\;\;...\;\;M_{\mathrm{M}l,1},M_{\mathrm{M}l,2},...,M_{\mathrm{M}l,j}\},$$

where $M_{\mathrm{M}1,1}$, $M_{\mathrm{M}1,2}$,…, $M_{\mathrm{M}1,j}$ – 1st, 2nd,…, *j*-th parameters and variables for the first manipulator; $M_{\mathrm{M}2,1}$, $M_{\mathrm{M}2,2}$,…, $M_{\mathrm{M}2,j}$ – 1st, 2nd,…, *j*-th parameters and variables for the second manipulator; $M_{\mathrm{M}l,1}$, $M_{\mathrm{M}l,2}$,…, $M_{\mathrm{M}l,j}$ – 1st, 2nd,…, *j*-th parameters and variables for the *l*-th manipulator;

$$\mathbf{G}_{\mathrm{MR}}=\{G_{\mathrm{GD}1,1},G_{\mathrm{GD}1,2},...,G_{\mathrm{GD}1,n}\;\;G_{\mathrm{GD}2,1},G_{\mathrm{GD}2,2},...,$$
$$...,G_{\mathrm{GD}2,n}\;\;...\;\;G_{\mathrm{GD}m,1},G_{\mathrm{GD}m,2},...,G_{\mathrm{GD}m,n}\},$$

where $G_{\mathrm{GD}1,1}$, $G_{\mathrm{GD}1,2}$,…, $G_{\mathrm{GD}1,n}$ – 1st, 2nd,…, *n*-th parameters and variables for the first gripping device; $G_{\mathrm{GD}2,1}$, $G_{\mathrm{GD}2,2}$,…, $G_{\mathrm{GD}2,n}$ – 1st, 2nd,…, *n*-th parameters and variables for the second gripping device; $G_{\mathrm{GD}m,1}$, $G_{\mathrm{GD}m,2}$,…, $G_{\mathrm{GD}m,n}$ – 1st, 2nd,…, *n*-th parameters and variables for the *m*-th gripping device;

– monitoring and automatic control of $\mathbf{D}_{\mathrm{MR}}$ vector of the parameters of specified agricultural works and operations (for planting, spraying, harvesting, etc.)

$$\mathbf{D}_{\mathrm{MP}}=\{D_{\mathrm{TO}1,1},D_{\mathrm{TO}1,2},...,D_{\mathrm{TO}1,c}\;\;D_{\mathrm{TO}2,1},D_{\mathrm{TO}2,2},...,$$
$$...,D_{\mathrm{TO}2,c}\;\;...\;\;D_{\mathrm{TO}v,1},D_{\mathrm{TO}v,2},...,D_{\mathrm{TO}v,c}\},$$

where $D_{\mathrm{TO}1,1}$, $D_{\mathrm{TO}1,2}$,…, $D_{\mathrm{TO}1,c}$ – 1st, 2nd,…, *c*-th parameters and variables for the first technological operation; $D_{\mathrm{TO}2,1}$, $D_{\mathrm{TO}2,2}$,…, $D_{\mathrm{TO}2,c}$ – 1st, 2nd,…, *c*-th parameters and variables for the second technological operation; $D_{\mathrm{TO}v,1}$, $D_{\mathrm{TO}v,2}$,…, $D_{\mathrm{TO}v,c}$ – 1st, 2nd,…, *c*-th parameters and variables for the *v*-th technological operation.

The functional structure of the agricultural MR as a multi-coordinate control object is shown in Fig. 3, where the following control signals are indicated:

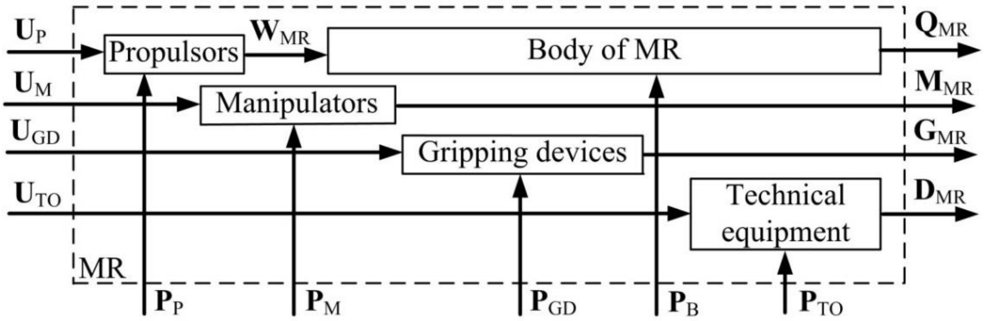

Figure 3 – Functional structure of agricultural MR as a multi-coordinate control object

– vector of control signals of propulsors $\mathbf{U}_{\mathrm{P}}$

$$\mathbf{U}_{\mathrm{P}}=\{U_{\mathrm{P}1,1},U_{\mathrm{P}1,2},...,U_{\mathrm{P}1,i}\ U_{\mathrm{P}2,1},U_{\mathrm{P}2,2},...,$$
$$...,U_{\mathrm{P}2,i}\ ...\ U_{\mathrm{P}k,1},U_{\mathrm{P}k,2},...,U_{\mathrm{P}k,i}\},$$

where $U_{\mathrm{P}1,1}$, $U_{\mathrm{P}1,2}$,…, $U_{\mathrm{P}1,i}$ – 1st, 2nd,…, i-th control signals for the first propulsor; $U_{\mathrm{P}2,1}$, $U_{\mathrm{P}2,2}$,…, $U_{\mathrm{P}2,i}$ – 1st, 2nd,…, i-th control signals for the second propulsor; $U_{\mathrm{P}k,1}$, $U_{\mathrm{P}k,2}$,…, $U_{\mathrm{P}k,i}$ – 1st, 2nd,…, i-th control signals for the k-th propulsor;

– vector of control signals of manipulators UM

$$\mathbf{U}_{\mathrm{M}}=\{U_{\mathrm{M}1,1},U_{\mathrm{M}1,2},...,U_{\mathrm{M}1,j}\ U_{\mathrm{M}2,1},U_{\mathrm{M}2,2},...,$$
$$...,U_{\mathrm{M}2,j}\ ...\ U_{\mathrm{M}l,1},U_{\mathrm{M}l,2},...,U_{\mathrm{M}l,j}\},$$

where $U_{\mathrm{M}1,1}$, $U_{\mathrm{M}1,2}$,…, $U_{\mathrm{M}1,j}$ – 1st, 2nd,…, j-th control signals for the first manipulator; $U_{\mathrm{M}2,1}$, $U_{\mathrm{M}2,2}$,…, $U_{\mathrm{M}2,j}$ – 1st, 2nd,…, j-th control signals for the second manipulator; $U_{\mathrm{M}l,1}$, $U_{\mathrm{M}l,2}$,…, $U_{\mathrm{M}l,j}$ – 1st, 2nd,…, j-th control signals for the l-th manipulator;

– vector of control signals of gripping devices $\mathbf{U}_{\mathrm{GD}}$

$$\mathbf{U}_{\mathrm{GD}}=\{U_{\mathrm{GD}1,1},U_{\mathrm{GD}1,2},...,U_{\mathrm{GD}1,n}\ U_{\mathrm{GD}2,1},U_{\mathrm{GD}2,2},...,$$
$$...,U_{\mathrm{GD}2,n}\ ...\ U_{\mathrm{GD}m,1},U_{\mathrm{GD}m,2},...,U_{\mathrm{GD}m,n}\},$$

where $U_{\mathrm{GD}1,1}$, $U_{\mathrm{GD}1,2}$,…, $U_{\mathrm{GD}1,n}$ – 1st, 2nd,…, n-th control signals for the first gripping device; $U_{\mathrm{GD}2,1}$, $U_{\mathrm{GD}2,2}$,…, $U_{\mathrm{GD}2,n}$ – 1st, 2nd,…, n-th control signals for the second gripping device; $U_{\mathrm{GD}m,1}$, $U_{\mathrm{GD}m,2}$,…, $U_{\mathrm{GD}m,n}$ – 1st, 2nd,…, n-th control signals for the m-th gripping device;

– vector of control signals of technological equipment $\mathbf{U}_{\mathrm{TO}}$

$$\mathbf{U}_{\mathrm{TO}}=\{U_{\mathrm{TO}1,1},U_{\mathrm{TO}1,2},...,U_{\mathrm{TO}1,c}\ U_{\mathrm{TO}2,1},U_{\mathrm{TO}2,2},$$
$$...,U_{\mathrm{TO}2,c}\ ...\ U_{\mathrm{TO}v,1},U_{\mathrm{TO}v,2},...,U_{\mathrm{TO}v,c}\},$$

where $U_{\mathrm{TO}1,1}$, $U_{\mathrm{TO}1,2}$,…, $U_{\mathrm{TO}1,c}$ – 1st, 2nd,…, c-th control signals for the first technological operation; $U_{\mathrm{TO}2,1}$, $U_{\mathrm{TO}2,2}$,…, $U_{\mathrm{TO}2,c}$ – 1st, 2nd,…, c-th control signals for the second technological operation; $U_{\mathrm{TO}v,1}$, $U_{\mathrm{TO}v,2}$,…, $U_{\mathrm{TO}v,c}$ – 1st, 2nd,…, c-th control signals for the v-th technological operation.

Besides, the functional structure in Fig. 3 takes into account the following perturbing effects acting on individual components of the generalized MR:

– vector of disturbing influences acting on the robot's body, $\mathbf{P}_{\mathrm{B}}$

$$\mathbf{P}_{\mathrm{B}}=\{P_{\mathrm{B}1},P_{\mathrm{B}2},...,P_{\mathrm{B}b}\},$$

where $P_{\mathrm{B}1}$, $P_{\mathrm{B}2}$,…, $P_{\mathrm{B}b}$ – 1st, 2nd,…, b-th disturbing effects for the body;

– vector of disturbing influences acting on the propulsors, $\mathbf{P}_{\mathrm{P}}$

$$\mathbf{P}_{\mathrm{P}}=\{P_{\mathrm{P}1,1},P_{\mathrm{P}1,2},...,P_{\mathrm{P}1,i}\ P_{\mathrm{P}2,1},P_{\mathrm{P}2,2},...,$$
$$...,P_{\mathrm{P}2,i}\ ...\ P_{\mathrm{P}k,1},P_{\mathrm{P}k,2},...,P_{\mathrm{P}k,i}\},$$

where $P_{\mathrm{P}1,1}$, $P_{\mathrm{P}1,2}$,…, $P_{\mathrm{P}1,i}$ – 1st, 2nd,…, i-th perturbing effects for the first propulsor; $P_{\mathrm{P}2,1}$, $P_{\mathrm{P}2,2}$,…, $P_{\mathrm{P}2,i}$ – 1st, 2nd,…, i-th perturbing effects for the second propulsor; $P_{\mathrm{P}k,1}$, $P_{\mathrm{P}k,2}$,…, $P_{\mathrm{P}k,i}$ – 1st, 2nd,…, i-th perturbing effects for the k-th propulsor;

– vector of perturbing influences acting on manipulators, $\mathbf{P}_{\mathrm{M}}$

$$\mathbf{P}_{\mathrm{M}}=\{P_{\mathrm{M}1,1},P_{\mathrm{M}1,2},...,P_{\mathrm{M}1,j}\ P_{\mathrm{M}2,1},P_{\mathrm{M}2,2},...,$$
$$...,P_{\mathrm{M}2,j}\ ...\ P_{\mathrm{M}l,1},P_{\mathrm{M}l,2},...,P_{\mathrm{M}l,j}\},$$

where $P_{\mathrm{M}1,1}$, $P_{\mathrm{M}1,2}$,…, $P_{\mathrm{M}1,j}$ – 1st, 2nd,…, j-th perturbing effects for the first manipulator; $P_{\mathrm{M}2,1}$, $P_{\mathrm{M}2,2}$,…, $P_{\mathrm{M}2,j}$ – 1st, 2nd,…, j-th perturbing effects for the second manipulator; $P_{\mathrm{M}l,1}$, $P_{\mathrm{M}l,2}$,…, $P_{\mathrm{M}l,j}$ – 1st, 2nd,…, j-th perturbing effects for the l-th manipulator;

– vector of perturbing influences acting on gripping devices, $\mathbf{P}_{\mathrm{GD}}$

$$\mathbf{P}_{\mathrm{GD}}=\{P_{\mathrm{GD}1,1},P_{\mathrm{GD}1,2},...,P_{\mathrm{GD}1,n}\ P_{\mathrm{GD}2,1},P_{\mathrm{GD}2,2},...,$$
$$...,P_{\mathrm{GD}2,n}\ ...\ P_{\mathrm{GD}m,1},P_{\mathrm{GD}m,2},...,P_{\mathrm{GD}m,n}\},$$

where $P_{\mathrm{GD}1,1}$, $P_{\mathrm{GD}1,2}$,…, $P_{\mathrm{GD}1,n}$ – 1st, 2nd,…, n-th perturbations for the first gripping device; $P_{\mathrm{GD}2,1}$, $P_{\mathrm{GD}2,2}$,…, $P_{\mathrm{GD}2,n}$ – 1st, 2nd,…, n-th perturbations for the second gripping device; $P_{\mathrm{GD}m,1}$, $P_{\mathrm{GD}m,2}$,…, $P_{\mathrm{GD}m,n}$ – 1st, 2nd,…, n-th perturbations for the m-th gripping device;

– vector of disturbing influences acting on technological equipment, $\mathbf{P}_{\mathrm{TO}}$

$$\mathbf{P}_{\text{TO}} = \{P_{\text{TO}1,1}, P_{\text{TO}1,2}, ..., P_{\text{TO}1,c}\ P_{\text{TO}2,1}, P_{\text{TO}2,2}, ...,$$
$$..., P_{\text{TO}2,c}\ ...\ P_{\text{TO}v,1}, P_{\text{TO}v,2}, ..., P_{\text{TO}v,c}\},$$

where $P_{\text{TO}1,1}$, $P_{\text{TO}1,2}$,…, $P_{\text{TO}1,c}$ – 1st, 2nd,…, c-th perturbations for the first technological operation; $P_{\text{TO}2,1}$, $P_{\text{TO}2,2}$,…, $P_{\text{TO}2,c}$ – 1st, 2nd,…, c-th perturbations for the second technological operation; $P_{\text{TO}v,1}$, $P_{\text{TO}v,2}$,…, $P_{\text{TO}v,c}$ – 1st, 2nd,…, c-th perturbations for the v-th technological operation.

Thus, the MR for agricultural works is a complex multi-coordinate control object, and it is necessary to have a distributed multi-coordinate monitoring and automatic control system for its effective functioning. Therefore, as can be seen from the functional structure of MR, shown in Fig. 3, the agrarian MR should contain multi-coordinate systems for monitoring and automatic control of engines, manipulators, gripping devices and technological equipment [19; 20]. It is possible to increase the efficiency of these systems by applying adequate mathematical models [21], intelligent technologies at the stage of the development of their functional structures, control algorithms and control devices [16].

Conclusions

As a result of the analysis of the properties of the generalized agricultural MR as a multi-coordinate control object, the main tasks of its monitoring and control are formalized. It is determined that the most important controlled coordinates of agrarian MR are vectors of spatial motion, working parameters of technical equipment of individual propulsors, manipulators, gripping devices, as well as parameters of given agricultural works and operations.

Further research should be conducted in the field of synthesis of mathematical and experimental models of agricultural MRs, functional structures of automatic control systems for movement and execution of specified operations using various methods, development of special algorithms for situation analysis, accumulation of databases on environmental influences for automatic decision making using intelligent approaches.

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АНАЛІЗ ЗАДАЧ МОНІТОРИНГУ Й АВТОМАТИЧНОГО КОНТРОЛЮ СІЛЬСЬКОГОСПОДАРСЬКОГО МОБІЛЬНОГО РОБОТА

Анотація. *Робота присвячена розгляду й аналізу комплексу завдань моніторингу та автоматичного управління сучасними мобільними роботами, призначеними для автоматизації різних видів технологічних операцій у сільському господарстві. Дослідження свідчать про високу активність компаній-виробників і вчених у розробці конструкцій і систем дистанційного керування різними типами сільськогосподарських роботів через загальне зростання попиту на продукти харчування в умовах обмежених запасів прісної води, високих цін на мінеральні добрива та заробітної плати населення. персонал. У роботі представлено класифікацію сучасних сільськогосподарських роботів за ступенем мобільності, типом системи керування, робочим середовищем, галузевим і функціональним призначенням. Визначено, що такі роботи оснащені вбудованими платами з мікроконтролерами або мікропроцесорами. Їх має кожен робот, незалежно від конструкції та типу системи керування. Крім того, для автоматизації сільськогосподарських робіт найчастіше використовуються методи і засоби дистанційного керування, але автоматичні та автономні мобільні роботи самостійно виконують значно ширший перелік завдань, оскільки працюють на основі адаптивно-інтелектуальних методів керування. Авторами сформульовано основні завдання моніторингу й автоматичного керування узагальненим сільськогосподарським мобільним роботом, зокрема моніторинг і автоматичний контроль векторних параметрів просторового руху, робочих параметрів технічного оснащення рушіїв, маніпуляторів, захватних пристроїв, а також параметрів заданих сільськогосподарських робіт та операцій. Функціональна структура узагальненого сільськогосподарського мобільного робота, як багатокоординатного об'єкта керування, враховує взаємодію керованих координат векторів, сигналів керування двигунами, маніпуляторами, захватами та технологічним обладнанням, а також впливи на окремі його компоненти (кузов, рушії, маніпулятори, захоплювальні пристрої та технологічне обладнання).*

Ключові слова: сільськогосподарський мобільний робот; система управління; сільське господарство; автоматизація; контрольовані координати

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