The model of increasing the efficiency of agricultural robotic system

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Abstract. The expenses recoupment of agricultural companies is given considerable attention in many countries. Global food security risks require the development of a new generation of intelligent technologies that combine agrobots, highly sensitive sensors with artificial intelligence technologies, which will increase agricultural productivity while reducing the negative impact on the environment. The article describes a model of an intellectual agricultural robotic system, which, based on the data received from sensors installed in the fields, allows robotic agricultural equipment to form tasks to process fields. A conceptual model of an autonomous agricultural system that implements the ideas is proposed in the article.

1. Introduction
The emergence and implementation of agricultural robotic systems (agrobots) and the development of autonomous agricultural systems based on them required the development of models for their effective use [1]. Since these systems are still expensive enough to increase their competitiveness compared to manual and mechanized labor, they should be used with maximum efficiency [2-4].

As indicators of the effectiveness of the agro economic robotic system can be considered, for example, the efficiency of the expenditure of resources, the effectiveness of the movement of the robotic system, the effectiveness of the processing of fields. The following criterion can be used as a generalized efficiency indicator:

Efficiency = grown crop / the predicted value of the maximum possible harvest.

2. Conceptual model of an autonomous agricultural system
An ideal autonomous agricultural system is a fully autonomous system where artificial intelligence makes a decision to perform agricultural work (figure 1).

Since such a system, in fact, is controlled by artificial intelligence, the following control levels can be distinguished in it: strategic, tactical, and physical [5].

3. Strategic level of autonomous farming management
At the strategic level the need for agro technical processing of a particular field is determined on the basis of information from sensors. Sensors’ data is entered into the database, which also stores information such as the type of agro technical field, the predicted yield (tables 1 and 2).
Figure 1. A conceptual model of the considered agricultural robotic system.

The algorithm for generating a task for an agrobot for sequential agricultural fields processing is shown in figure 2.

Intelligent decision-making systems «assessment of the probability of losses from lack of irrigation», «assessment of the probability of loss due to lack of field processing», «assessment of the probability of losses due to the late harvest» can be implemented as a fuzzy inference system, an artificial neural network or a classical production system [5].

Based on the processed information from the sensors, an operator or intelligent system creates a route for the agrobot – a list of fields to process. In this list, the fields that require processing should be arranged in descending order of losses risk due to lack of processing. This amount of risk is estimated as the product of the probability of risk occurrence (table 2) and the maximum possible amount of loss – estimated crop cost (table 1).

Table 1. The structure of the autonomous farming database (information about cultivated fields).

| Field ID | Field type         | Field area (m²) | Average yield per square meter of field, kg / m² | The cost of one kilogram of crop (rubles) | Estimated crop cost (rubles) |
|----------|--------------------|-----------------|-----------------------------------------------|------------------------------------------|-------------------------------|
| 01       | Potato field       | 60000           | 3.5                                           | 10.3                                     | 2 163 000                     |
| 02       | Carrot field       | 90000           | 3.9                                           | 7.3                                      | 2 562 300                     |
| 03       | Cabbage field      | 100000          | 3.2                                           | 6.2                                      | 1 984 000                     |
| 04       | Beetroot field     | 100000          | 3.3                                           | 6.7                                      | 2 211 000                     |

Table 2. The structure of the autonomous farming database (sensors' data).

| Field ID | Average daily soil temperature (°C) | Relative soil moisture (%) | Pest density (pcs / m²) | Weed density (pcs / m²) | Probability of loss due to lack of watering | Probability of loss due to lack of field processing | Probability of losses due to the late harvest |
|----------|-------------------------------------|----------------------------|------------------------|------------------------|---------------------------------------------|--------------------------------------------------|-----------------------------------------------|
| 01       | 16.2                                | 70.3                       | 7.2                    | 12.3                   | 0.23                                        | 0.47                                             | 0.4                                           |
| 02       | 15.3                                | 72.3                       | 5.4                    | 14.4                   | 0.46                                        | 0.15                                             | 0.33                                          |
| 03       | 16.5                                | 64.7                       | 6.9                    | 15.2                   | 0.56                                        | 0.13                                             | 0.73                                          |
| 04       | 16.7                                | 58.6                       | 13.3                   | 12.4                   | 0.24                                        | 0.3                                               | 0.82                                          |

4. Tactical and physical level of autonomous farming management
At the tactical level the system searches for the sequence of processing agricultural fields that is most effective. To search for a sequence, you can use one of the algorithms used to solve the problem of finding the shortest path in a graph between two vertices (figure 3), namely the algorithms Dijkstra, Bellman-Ford, Floyd-Worshell, Johnson, Lee (wave algorithm), algorithm A* [6-8].
Figure 2. Algorithm for the tasks formation of agrobot on the agricultural fields processing.

The physical level of control is used directly during the agricultural fields processing in the sequence specified at the tactical level and is not considered in this article. This level implies a whole range of technologies related to the direct interaction of agrobots with the cultivated soil and crops. These are, for example, algorithms for positioning an agrobot, recognizing weeds, and high-precision processing of crops. These technologies are being improved using the latest advances in data mining.

Figure 3. Agricultural fields and access routes to them, presented in the form of an undirected graph.
5. Conclusions
The modern level of technology allows the introduction of robotic systems for agricultural purposes, implement the ideas proposed in this article. Autonomous agricultural robots are being developed in many countries. As an example, the following agrobot models can be cited: «Case IH Magnum» (USA, Netherlands), «New Holland T8 Blue Power» (USA, Netherlands), «Kubota» (Japan), «Autonomous Tractor» (USA), «Mahindra» (India), «Avrorarobotics» (Russia) (figure 4). Modern agrobots can perform the following operations: agricultural pests monitoring, plants irrigating, fertilizers applying and crops hilling.

Measurement of temperature and humidity of agro-technical fields has not been a problem for a long time. More complex and expensive are methods for measuring the amount of agricultural pests and weeds. But in this area there is a certain success, for example, the French commercial agrotechnical system «Sencrop», allows in addition to measuring soil temperature and humidity to detect pests in it (figure 5).

The using of the proposed model should allow increasing the efficiency of agricultural companies by minimizing the risks caused by the possible influence of destabilizing factors.

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