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Digitalization of UAV transport and technological cycles in smart agriculture

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Abstract. The transport and technological cycles of unmanned aerial vehicles used in various options for the implementation of agricultural technologies in smart farming are discussed. The analysis of UAV function was carried out, starting with regular and detailed aerial photography and ending with the spraying of chemicals and spraying fields. It is shown that the digitalization of UAV transport and technological cycles based on GERT-network models makes it possible to provide effective information and analytical support for decision-making processes in logistics monitoring and flow control systems in agricultural production. An analysis of the fundamental principles of GERT-network modeling led to the conclusion that this method is applicable for solving a number of systemic problems in optimizing UAV transport and technological cycles in precision farming, including their planning, modeling and development, as well as quality control of their implementation.

1 Introduction

Smart farming as a methodology is the processing of individual parts of the same field in different ways [1, 2]. This allows farmers to use every square meter strategically and intelligently. Smart agriculture is different from traditional mechanized agriculture. The classical methods of applying fertilizers and pesticides are considered obsolete in many countries, due to low accuracy and inability to take into account the conditions in individual areas of the fields. As a rule, the average characteristics of the entire area were used for processing, which often does not correspond to the real situation and is quite wasteful in terms of financial and labor costs. Now that it is possible to obtain high-precision measurements in individual areas, including using sensors on unmanned aerial vehicles (UAVs), a new era of smart farming has begun. Farmers can intelligently apply the necessary

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fertilizers based on the data obtained, resulting in increased yields and increased agricultural productivity, while significantly reducing costs. However, an urgent problem arises related to the optimization of transport and technological cycles (TTC) of UAVs used in smart farming [3, 4].

2 Materials and methods

There are many uses for drones in smart agriculture, with UAV capable of performing several different functions, from regular and detailed aerial photography to the careful spraying of chemicals.

2.1 Accurate aerial photography for precision farming

Agricultural UAVs are a useful tool primarily for mapping and visualization, as they provide higher accuracy than other potential technologies for this work, such as satellite imagery. A satellite image, regardless of the quality of the camera, still comes from orbit. UAV is able to fly directly over the fields, therefore providing a much higher image resolution. In addition, satellite images may be out of date, and the drone provides up-to-date information in real time, which allows you to correctly determine which fertilizers and pesticides are needed at the moment.

UAVs equipped with modern sensors help to obtain multispectral images with more detailed information about the state of a particular crop. In this way, more important data can be obtained compared to images from a standard camera, including in the near infrared range. This enables farmers to create more informative drought maps and pay due attention to crops.

Multispectral maps are far from the only type of aerial photography that can be taken with a drone. Standard maps in red-green-blue (RGB) format can show farmers how certain plants grow. For smart farming, it is important that these photos are taken from UAVs and not from satellites. Higher resolution gives a more accurate and detailed picture of the condition of crops, which allows the use of individualized smart farming strategies.

2.2 Spraying and seeding with UAV

UAVs can not only be the “eyes” for farmers, but they can also be directly involved in smart farming. The ability to follow a flight map allows UAV to also perform seeding or spraying functions. Some versatile platforms can perform multiple functions at the same time: apply seed, re-seed individual areas, or spray crop protection products in precisely selected areas.

2.3 UAV sprayers

Modern UAVs are versatile and efficient in terms of power. For example, a UAV sprayer with high-capacity batteries is fully charged in just a few minutes, allowing farmers to work productively for a long time. The ability to spray and seed 24/7 helps increase productive hours while keeping labor costs to a minimum.

The use of UAVs for the precise application of chemicals is an important step for the future of agriculture. Using fewer products and only in the most necessary places makes it possible to significantly reduce the amount of toxic substances in the environment.

2.4 UAVs for field spraying

Modern UAVs for field spraying use information collected from the air to accurately apply chemicals to fields in an automated manner. Especially for agriculture, the Agras T30 UAV was developed, capable of performing autonomous flights in various agricultural conditions. In addition to efficient software and a robust design, this model is equipped with optimized spraying and spraying systems for precise application of plant protection products or seed.

3 Results and discussion

Digitalization of UAV TTC based on GERT-network models [3, 4] provides information and analytical support for decision-making processes in logistics systems for monitoring and managing flows in agricultural production, which reduces the risk of non-execution of TTC operations and affects the overall efficiency of agricultural production. Providing up-to-date analytical information on all necessary parameters of the TTC is required for informed decision-making in real time.

The execution time for monitoring or transporting plant protection products, including spraying operations and spraying plants, is estimated by the decision maker (DM), based on the calculation of the GERT network. Real-time calculation operations make it possible to use actual analytical information coming from all objects of the agricultural complex in modeling. Thus, for the implementation of GERT-network modeling, there is all the necessary information about the necessary parameters of the TTC for making timely management decisions that are optimal both in terms of time and resource costs.

To describe the nodal logic of the GERT network model of the TTC, information is needed on the operations performed when planning agrotechnical measures, monitoring the state of crops, monitoring and analyzing the use of agricultural machinery, including both controlled ground vehicles and ground unmanned vehicles and UAVs.

The fundamental principles of the graphical and analytical method for evaluating and reviewing plans (GERT-analysis) are presented in research of Pritsker A.A.B. [5-7]. It should be noted that since the late 1950s network analysis has been widely used for planning and managing projects [8]. PERT and CPM, the most well-known network modeling techniques, have been applied to a variety of projects for planning and management purposes. However, PERT and CPM have limited capabilities that do not allow modeling many complex network forms of processes that include cycles. A more flexible generalized network tool, which has received increased attention from a lot of scientists, is GERT (Graphic Evaluation and Review Technique) [9]. GERT includes such features as probabilistic branching (stochastic node models), network looping (feedback loops), multiple sink nodes (multiple outputs), and multiple node implementation (repeated events) not available in PERT/CPM. These functions of the GERT-network model provide the user with the ability to model and analyze transport and technological processes and systems of a very general type (regardless of the type of transport system and transport infrastructure objects). Since many real problems in transport and technological systems are associated with probabilistic events, false starts, repetition of actions (transport cycles) and multiple results, the GERT network in this case is an ideal tool for modeling and analysis.

It should be pointed out that the conceptual basis for building PERT/CPM networks is simple and widely known. GERT networks are similar in design to PERT/CPM networks. However, PERT and CPM differ in that in CPM, activities are assumed to have only one time for duration, while in PERT, the duration of activities is probabilistic and is usually described by a beta distribution with three estimates. A more detailed explanation of PERT and CPM can be found in [9].

Existing GERT network modeling packages allow using different probability distributions for node activation times, such as constant, normal, uniform, Erlang, lognormal, Poisson, beta, gamma, etc. The GERT model also has the ability to assign fixed and variable costs to network transport and technological activities.

Thus, GERT modeling can be effectively used to solve a number of systemic problems in the optimization of transport and technological cycles, including their planning, modeling and development, as well as quality control of TTC [10, 11].

4 Conclusion

The results of GERT modeling can be used by the decision maker (DM) in several ways to facilitate and improve transport and technological cycles. The main difference between the results of GERT and the results obtained from the PERT or CPM network (apart from the fact that the results of GERT reflect the stochastic structure of the TTC) is the statistics of the costs of implementing cycles. These cost statistics make a significant contribution to determining whether TTC implementation should be initiated and/or how that implementation (or TTC pool) can best be controlled.

Moreover, the output of the GERT analysis can also be used to determine the requirements for transport units, loading and unloading equipment and transportable resources for the analyzed shopping center. Typically, cost statistics are used as budget data for a TTC project, taking these factors into account. For example, if statistics on TTC lead times show an excessive cycle time, then additional resources (vehicle units), equipment can be added to reduce the overall TTC lead time. Such additions can also be made to reduce the likelihood of project transport activities not being completed in the later stages of the project, when associated costs will be highest. The effect of the increase in these resources will subsequently be reflected in the statistics of the cost of implementing the transport and technological structure.

In general, the GERT network model is not as sensitive to changes in the activation time of network nodes as it is to changes in the branch probability in these nodes. Of course, if TTC lead time is extremely cost sensitive, then a slight change in node activation time can affect TTC delivery even if the overall cycle time does not change significantly. However, one of the unique features available in GERT network modeling is the ability to use any of the nine probability distributions for node activation time. Since the set of TTC integrated into a transport network is usually unique, the choice of probability distribution for network events is subject to significant uncertainty. In such cases, it may be useful to experiment with alternative distributions to observe the overall effect on network statistics. Such experiments may lead the decision maker to conduct a much more in-depth study of the nature of the distribution of the TTC implementation time, and not simply adopt a subjective beta distribution, as is often done in PERT. This can lead to a deeper understanding of the logic of nodes operation of the transport network and the analysis of the entire transport and technological infrastructure as a whole.

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