ANALYSIS OF EFFICIENCY OF THE UNMANNED AERIAL VEHICLES USE IN CONTEMPORARY AGROTECHNOLOGIES

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Abstract: This paper investigates the problems associated with the economical efficiency of aerial photography for the application in unmanned aerial vehicles (UAV) with low-class photography systems. The aim is to analyse the efficiency of employing unmanned aerial vehicles for specialized search and transforming the capabilities of UAVs for high efficiency applications in the agriculture. The structure and efficiency of the UAV operation when used in modern agricultural technologies for improving the functions such as search, recognition, monitoring of mobile milking systems and the manipulative-robotic actions of UAVs are shown. The range of applications could be significantly broadened by supplying the UAVs with special devices to directly carry out technological operations such as spraying of chemicals, planting plants, pasture monitoring, etc.

Key words: unmanned aerial vehicles, precision farming, exact search, detection, video robotics.

1. INTRODUCTION

The effective monitoring of the environment, the localization of objects on earth surface or beneath it, plays a major role in a wide spectrum of humankind activities. However, the monitoring is usually complicated by such unfavourable factors as high levels of radiation, the presence of harmful substances as well as natural disasters. In these cases, it is greatly advantageous to exploit the capabilities of the unmanned aerial vehicles. Defining the specific parameters of UAVs at the design stage is based on the application of special methodology and evaluation functions which set the criteria for the tactical and technical requirements which should be met by the UAVs [1].

By monitoring the airspace, the earth and water surface, depending on the particular mission of the UAVs, it can supply aerial images, it can monitor the climate and atmospheric conditions, supply hydrology and meteorology data, evaluate radiation levels and contamination in case of nuclear incidents. Additionally, UAVs could be used for surveilling glaciers and ice caps, studying oceans, including the tracking of marine species, geophysical observations, aerial photography aerial cartography. In agrotechnology [2], UAVs could be extensively employed to the monitoring of the landscape and the crops, farmlands and grazing grounds, the spraying of chemicals for agricultural purposes.

The technological regulation of agricultural processes (growing plants, livestock breeding, nature management) require the execution of large number of operations in different moments in time at different points of the farmland. Thus, the practical applications of the UAVs of the helicopter type (agrocopter), which are supplied with special equipment for local operative interventions on agriculture production bio-objects (APB), could be substantially expanded. The implementation of energy efficient and ecological agricultural technologies through the use of UAVs is one perspective field for developments [3].

The aim of research presented in this paper is to **analyse the efficiency of employing unmanned aerial vehicles** for specialized search and transforming the capabilities of UAVs for high efficiency applications in the agriculture.

2. PROBLEM DEFINITION AND RELATED WORK

Constant and comprehensive monitoring of the conditions for implementation of agro-technological processes, the dynamics of changes in the conditions of agricultural land, characteristics of technological processes through the use of technical means for real-time monitoring is an important prerequisite for the implementation of highly productive and efficient agricultural technologies. The information on the conditions of the agricultural lands is used to generate digital soil distribution and other maps, for the control of the dynamics of the changes in the condition and the characteristics of APB and for fast operative correction of the performed technological processes [4]. In arable agricultural land are defined in priority technological zones: seed production, seedlings, planting in the soil, growing APB. Air monitoring complexes with UAV are used to update and clarify geospatial information.

UAVs are efficient and invaluable way for obtaining high quality data. The principle means for data acquisition is through the imaging channel (digital camera), thermovision channel (infrared camera), geolocation channel (GPS transceiver), devices for remote monitoring (gas analyser, laser rangefinder, etc.).The priority areas are interconnected and in parallel a complex of technological processes of agricultural production is carried out, such as: control the livestock health, monitoring on grazing grounds, veterinary care (using UAVs, allow for remote application of tranquillizers, vaccines, antibiotics, etc.); forensic examination (assessment of damage caused by animals); safety and protection of animals during grazing; cattle herding; monitoring of animal nutrition and water balance [5]. The priority zones in the agricultural production are related to the inventory of the agricultural lands; creation of digital flight maps; assessment of the workload and control of the implementation; monitoring of the condition of the crops; assessment of crop germination; protection of agricultural lands; treatment of crops with pesticides to eliminate pests and crop diseases. By scanning the crops, UAVs evaluate the parameters of agro-technological processes in on-line mode and can spray with the required amount of chemicals through regulating the altitude and volume of the liquid in real time, consequently providing uniform coverage of the entire area [6].

Real technical solutions are provided through remote participation of operators in making intelligent decisions. The peculiarities of modern complexes with UAVs are that these are automated complexes that have a built-in intelligent control system that must independently solve basic tasks, so that the possibility of control and management with the participation of an operator, remote control and monitoring from remote terminals, to be carried out by ground stations. The information for the operator must be provided by the on-board sensors of the UAVs in real time and the human-machine interface creates the feeling of presence on board and at the same time the real physical and psychophysiological strain is greatly diminished. The degree of autonomy and the conditions for the transfer of authority and responsibilities to the “On-board management system to the operator” are determined by the specific conditions of the conducted activity, as well as the achieved level of machine learning of the on-board UAVs management system. In this case, the UAV functions autonomously, while the participation of the operator, includes monitoring and control of the level of change of the flight path, recognition and confirmation of the anatomical and morphological parameters of the APB [7,8,9].

Using video analysis to detect the appearance of disease- or pest-infected areas, UAVs are able to detect those classified as airborne targets. Often the joint use of image and infrared channels allows to effectively solve the problems of detection and identification of objects, and the joint use of remote instruments for gas analysis with geolocation tools solve problems for localization of air pollution [10, 11].

UAVs can be used to search, find and determine the coordinates of objects. New robotic technical means are needed to carry out localized operations on agriculture, especially in the conditions of geographically scattered agricultural sites and in the absence of sufficient human resources. In animal husbandry, UAV-based “video shepherd” is used to manage the herd and deliver individual care for the animals. In crop production, when the technology of differentiated agriculture is applied, which takes into account the condition of the separate APBs, a “video technologist on agricultural land” is used, through a multifunctional technological module of UAV. When monitoring the environment, in particular in the activities of forestry, hunting farms, fish farming uses a "video inspector of territories" based on a multifunctional device for search and detection [12].

The UAVs are equipped with guidance systems, on-board radar systems, sensors and video cameras. New technologies enable the UAVs to successfully perform functions that in the past were incompatible with them or performed by other means. The UAVs are the "all-seeing eye in the sky", allowing the ground operator in real time to monitor and control the development of the situation in a given area or route. They can work in areas with radiation and chemical pollution. Based on the analysis of the experience of economically developed countries, we can talk about the formation of two trends: first, increasing the functionality of UAV systems, including increasing the range of flight and time spent in the air; second, minimize the size of the UAV.

Engaging UAVs in the agriculture sector is an optimal solution in terms of ergonomic, economic and technical indicators for most of the tasks related to the rapid collection and analysis of information [13].

2. METHOD FOR ANALYZING THE EFFECTIVENESS OF USING UAVS.

Searching and finding objects could be presented as process that progresses in the course of time, which sequence of actions might lead to various results. The task of the object search theory is to elaborate methods for defining the best search plan that ensures such way of acting out of the many alternatives, which would lead to finding the object within minimal time and with minimum funds. The elaborated consequence of actions responds to the optimal plan and is a searching algorithm. Elaborating such an algorithm in connection with solving various searching tasks is one of the present work's goals.

The quick and reliable finding of objects depends on many factors, the major are as follows:

- Method of searching (flight route, flight profile, sequence of terrain or space observation, etc.);
- The equipment used for objects finding;
- Type of the objects;
- Undertaken measures for resisting the finding.

Finding objects is influenced by a number of random factors, and as a result it is impossible to state in advance the object would be or wouldn't be found at these circumstances and searching methods. In other words, finding certain object during the time for its searching is a random event and hence, the proper methods of the probability theory should be used. The main criterion for the used searching air complex efficiency is the relative efficiency:

$$U = \frac{W_p}{W} \quad (1)$$

where W_p, W are the relative probability for fulfilling the set task with and without data from the air search. Practically, defining these values is often a very hard task as far as it requires hard work for defining the efficiency of forces and the funds for both ways of application. To define the efficiency of the actual searching tools, criteria are used, including:

- The probability for solving the task by the searching UAV;
- The expenditures for solving the tasks;
- The expenditures for the received information from a unit of earth surface.

The probability for executing the flight task (FT) by the searching UAV is defined

$$P_r = P_i \cdot P_o \cdot P_{pnv} \cdot P_{ot} \cdot P_d \cdot P_{inf}, \quad (2)$$

where P_r, P_i are the probabilities for flawless work; P_o the probability that the UAV would go to the searching area; P_{pnv}– the probability for overcoming unfavorable influences in the area of observation and at its approaching. For civil UAV this is the probability to overcome such factors as bad weather conditions as well as factors acting on the UAV, if used in natural disasters, fires, volcano eruptions, failures in a nuclear power plant, etc. For UAV that are used for military purposes, this is the probability to overcome enemy's anti-aircraft defense. This probability could be defined according to the following equation:

$$P_{pnv} = e^{-\sum_{i=1}^{N} \lambda_i t_{ni}} \quad (3)$$

Where λ_i is the intensity of effective influence of the i-th unfavourable factor; t_{ni} - the time UAV is in the area of direct influence of the i-th unfavourable factor; P_{ot} is the probability for finding the object; P_d - the probability for giving information to the user; P_{inf} - the probability the information given to the user not to lose its significance at the moment it passes from the receiving by the UAV to its giving to the user,

$$P_{inf} = e^{\frac{-T_{ot}}{T_g}} \quad (4)$$

where T_{ot} is the time for finding and passing data, which is sum of the time, when the object is found by the operator on the screen, the time, when the object is identified by the operator, and the time for defining the object's coordinates; T_g – average time of UAV being in certain status or place.

The definition of each of these parameters could be made through the algorithms, described in [14].

The expenditures for the FT execution are defined as sum of the expenditures for one FT execution:

$$C_{1P} = \frac{C_{LA}}{n_{pr}} + C_D + C_T, \quad (5)$$

where C_{LA} is the expenditures for new aircraft; n_{pr} – predicted number of applications of UAV; C_D – the expenditures for additional consumables for ensuring one flight; C_T – the expenditures for fuel and consumables.

The price for unloading information from one unit of earth surface is universal specific criterion as far as it gives opportunity to evaluate the efficiency of each searching of UAV, considering its survival and the productivity of its purposeful loading:

$$\overline{C_I} = \frac{C_{1P}}{P_p F_\Sigma^1}, \quad (6)$$

where F_Σ^1 is the sum of the observed area of the earth's surface within one flight.

We can review an example for searching object with the help of UAV. Three different UAV are reviewed, which execute one and the same task (the search of group of people on an area of $S_p = 80km^2$) with the same board equipment. The difference is only in the speed of the UAV flight, which influences the time for finding the desired object. The task is to compare the efficiency of these UAVs for two possibilities for their use – random (Fig. 1) and regular (Fig. 2) search methods [12,15].

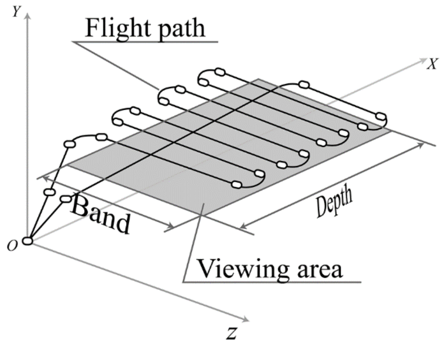

Fig. 1. Arbitrary search method with UAVs

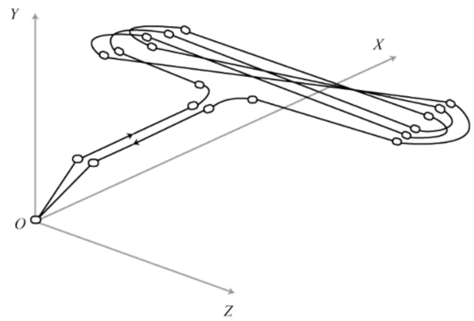

Fig. 2. A regular method for searching with UAVs

The results from applying the described above method show that the efficiency of overcoming the unfavorable circumstances by the UAV depends on the speed and the height of the flight. By increasing the speed, the probability for overcoming the unfavorable influences increases significantly. They also show that the speed might influence negatively the FT execution in the process of finding an object. But defining the probability the information received during the searching to have not lost its accuracy shows that increasing UAV flight's speed has favorable effect on this parameter. After defining all factors that are part (2), the probability for executing the task while searching an object is defined [13, 16]

3. EVALUATION OF EFFICIENCY

Evaluation of efficiency: In modern world, alongside with the traditional piloted planes more and more often UAV are used for getting air-photo images [12, 17]. UAV equipped with optic tools could be used for solving many tasks, which execution with piloted aircrafts (A) is inexpedient because of number of economical, technical and other reasons. They are compact, mobile and easy for maintenance. However, UAV have number of disadvantages. Their sensibility towards wind and the low capacity for carrying useful load are among the significant disadvantages. Getting highly quality images and their subsequent rendering, which is aimed at deriving and quality evaluation of the parameters and characteristics of the observed objects, is of paramount significance.

This article would define the threshold size of the zone for getting air-photo images, where UAV loses its efficiency compared to the traditional equipment of air-photo as well as it would review the reasons for the economical efficiency drop. In order to define the economical efficiency of the used UAV, one needs to calculate the financial expenses that are defined as the sum of all expenses for the completed work:

1 Expenses for creating plan-height base;
2 Expenses for photographic work;
3 Expenses for transportation of equipment;
4 Officers' remuneration.

Density of markers' distribution is necessary to be defined before calculating the expenses:

$$L_x = L_y = R.\sqrt{M_{pix}.1000} \quad (7)$$

where L_x and L_y are the linear dimensions of the area shown on image at a resolution R ; M_{pix} – number of megapixels in the image. Also, in order to define the markers' density, one should know the base of photographing of B_x and the distance between the routes B_y [12,18]. The size of the longitudinal p_x and the transverse overlapping p_y is usually set 60 or 30% respectively:

$$\mathrm{B_x} = \frac{\mathrm{L_x}\cdot(100\text{-}\mathrm{p_x})}{100\%}; \quad (8)$$

$$\mathrm{B_y} = \frac{\mathrm{L_y}\cdot(100-\mathrm{p_y})}{100\%} \quad (9)$$

The number of bases n_b between the markers of the same height depends on the accuracy of constructing the stereo model by height m_z and the set relief height h_s.

$$n_b = \sqrt{\frac{4h_s^2}{m_z^2} - 45 - 1} \quad (10)$$

where $m_z = \frac{L_x\sqrt{2}}{2tg\frac{2\beta}{2}}.\frac{0{,}5}{1000\sqrt{M_{pix}}}.6$; 2β is the visual field of the lens.

Using (8), (9) and (10), the density of putting the signs per square kilometer from the zone of photo taking *n* is calculated as follows

$$\mathrm{n} = \frac{10^6}{\mathrm{n_b}\cdot\mathrm{B_x}\cdot\mathrm{B_y}} \quad (11)$$

The elemental natural fires that include fires in forests, steppes, peat-bogs and other natural sites are dangerous and dynamic processes that cause great damages on nature and infrastructure, often lead to human casualties, which threatens national security. Very often, we have to fight against natural fires, gathering great number of fire-fighting forces and funds. And here the task for rational planning and management of these forces and funds arises.

In the recent years, in regard to creating space systems for monitoring forest fires as well as the fast progress of the technology for UAV use, it is possible to evaluate the parameters of forest fires in real time, which opens the road to operative control systems with feedback.

4. CONCLUSION

Within the important scientific and practical problem of increasing labour productivity and productivity in agriculture, it is necessary to purposefully adapt the UAVs to the real conditions of application, to provide reliable real-time information on the course of changes in technological processes: registration of agricultural technological parameters (temperature, humidity, fertility), field inspection, soil sampling (water, air), correction of electronic maps of the real spatially differentiated yield, etc. When deviations of the process parameters from the set ones are detected (detection of depressed zones (pests, diseases), etc.), the UAV immediately performs laser-optical and biochemical operations on APB (selective or by area). Conditions for use in agricultural technology with self-organizing APB led to the need to change the flight operations of the UAV, possibility to use robotic technological monitoring, reception, processing, image recognition, self-organization and management, algorithms for detection, targeting and monitoring of agricultural sites of interest, using a machine vision system, as well as the impact on APB. The original and unique capabilities of the UAVs are determined by the system for recognizing the anatomical, morphological and ethological characteristics of developing biological objects with timely detection of locally defined areas of origin (development) of infections and occurrence (spread) of pests, interested, foreign or missing biological objects.

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