ANALYSIS AND EVALUATION OF EFFECTIVENESS OF THE USE OF UNMANNED AIRCRAFTS FOR ENVIRONMENT MONITORING

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Abstract

The present article reviews the problems of economic effectiveness of air photography by unmanned aircrafts equipped with photographic systems of low class. The structure and effectiveness of work is shown.

Keywords: unmanned aircrafts, economic effectiveness, monitoring, air-photo images.

1. INTRODUCTION

Effective monitoring of environment, searching and finding various objects on the Earth's surface or in its depths is of significance for a wide range of human activities' fields and often, and often the solution is complicated by the influence of various unfavourable factors such as increased radiation, availability of harmful substances, disasters and averages. This task is of even greater significance at solving military problems, fight against terrorist's groups, drug-dealing business and conducting operations on state border control for protection of the sea economic area of Bulgaria from poaching of precious species. In these cases, the use of unmanned aircrafts (UA) for such purposes becomes especially effective. Defining their rational parameters in the course of the general engineering /design/ requires the use of a special methodological apparatus as well as of criteria functions that allow making informed forming of tactical and technical requirements for UA (Petrova, 2019a-b).

Scientific-technical sources' analysis showed that 80-90% of the operations conducted using UA, are in the overlapping military and civil field. The issue of establishing multifunctional complexes with unmanned aircrafts (CUA) with double use (DU) that are meant for solving national economic and special tasks is up-to-date.

2. ANALYSIS OF EFFECTIVENESS OF THE UA USE

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 effectiveness is the relative effectiveness:

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

where are relatively the 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 effectiveness of forces and the funds for both ways of application. To define the effectiveness of the actual searching tools, criteria are used, including: The probability for solving the task by the searching UA; 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 UA is defined:

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

where is the probability for flawless work; – the probability that the UA would go to the searching area; – the probability for overcoming unfavorable influences in the area of observation and at its approaching. For civil UA this is the probability to overcome such factors as bad weather conditions as well as factors acting on the UA, if used in natural disasters, fire, volcano eruption, failure in a nuclear power plant, etc. For UA that are used for military uses, this is the probability to overcome enemy's anti-aircraft defence. This probability could be defined according to the following formula:

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

where λ_i is the intensity of effective influence of the *i*-th unfavourable factor; t_{ni} - the time UA 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 UA 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 should be found by the operator in the field of 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 UA being in certain status or place.

The definition of each of these parameters could be made through the algorithms, described in (Antipov, 2011; Petrov, 2013; Smolyakov, Fedorovich, 2006).

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

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

where C_{LA} is the expenditures for new A; n_{pr} – prognosticated number of applications of UA; 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 effectiveness of each searching of UA, considering its survival and the productivity of its purposeful loading:

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

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 UA. Three different UA 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 UA flight, which influences the time for finding the desired object. The task is to compare the effectiveness of these UA use at two possibilities for their use – random (Figure 1) and regular (Figure 2) search methods (Petrov, 2010b; Rakov, Nikitin, 2012a).

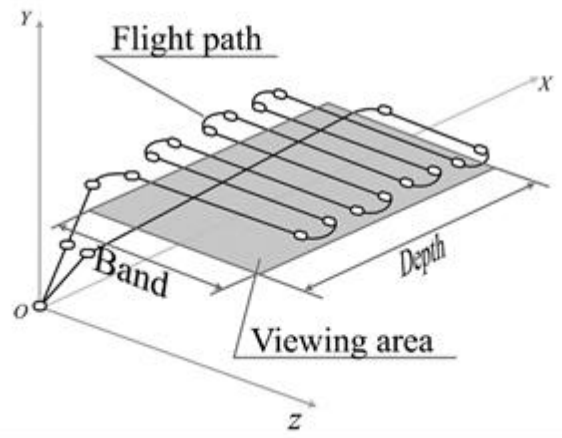

Figure 1. Random search methods.

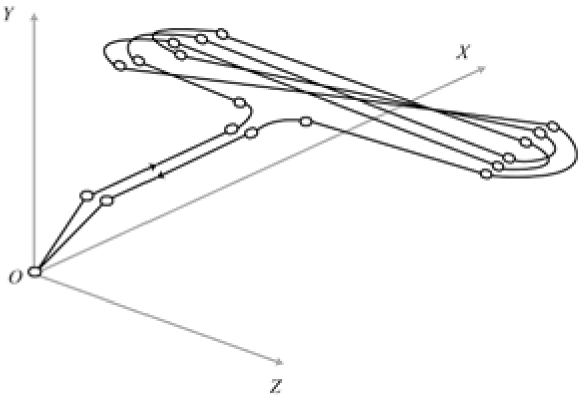

Figure 2. Regular search methods.

The results from applying the described above method show that the effectiveness of overcoming the unfavourable circumstances by the UA depends on the speed and the height of the flight. By increasing the speed, the probability for overcoming the unfavourable 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 actuality shows that increasing UA flight's speed has favourable effect on this parameter. After defining all factors that are part (2), the probability for executing the task while searching an object is defined (Nikitin, Rakov, 2012; Petrov, Miron, 2019).

3. EVALUATION OF EFFECTIVENESS

In modern world, alongside with the traditional piloted planes more and more often UA are used for getting air-photo images (Antipov, 2011; Antonov, Hristozov, 2018). UA 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 (Antonov, 2017; Petrov, 2013; Shrayner, Makarov, 2012b). However, UA have number of disadvantages. Their sensibility towards wind and the low quantity of useful load are among the significant disadvantages. Getting highly informative images, their effective procession aiming deriving and quality evaluation of the parameters and characteristics of the observed objects is of quite significance.

This article would define the threshold size of the zone for getting air-photo images, where UA loses its effectiveness compared to the traditional equipment of air-photo as well as it would review the reasons for the economical effectiveness drop. In order to define the economical effectiveness of the used UA, one needs to calculate the financial expenses that are defined as the sum of all expenses for the completed work: Expenses for creating plan-height base; Expenses for photographic work; Expenses for transportation equipment; Officers' remuneration.

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

$$L_x = L_y = R \cdot \sqrt{Mpix} \cdot 1000 \quad (1)$$

where L_x and L_y are the size of the area, which is shown on the momentary image at image's resolution R; $Mpix$ – 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 (Kostyuk, 2010; Petrov, Mugleva, 2017a). The size of the longitudinal p_x and the transverse overlapping p_y is usually set 60 or 30% respectively (Petrov, 2010a):

$$B_x = \frac{L_x \cdot (100 - p_x)}{100\%} \quad (2)$$

$$B_y = \frac{L_y \cdot (100 - p_y)}{100\%}. \quad (3)$$

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

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

where $m_Z = \frac{L_x \cdot \sqrt{2}}{2tg\frac{2\beta}{2}} \cdot \frac{0.5}{1000 \cdot \sqrt{Mpix}} \cdot 6$; 2β is the visual field of the lens.

Using the formulae (2), (3) and (5), the density of putting the signs per square kilometer from the zone of photo taking *n* is calculated as follows:

$$n = \frac{10^6}{n_b \cdot B_x \cdot B_y} \quad (5)$$

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 (Enimanev, 2019c; Novakova, Enimanev, Andonov, 2007; Enimanev, 2007a-b; Enimanev, 2016).

In the recent years, in regard to creating space systems for monitoring forest fires as well as the fast progress of the technology for UA 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

In conclusion, we can say that the speed of the UA flight influences significantly the effectiveness of execution of the task: the higher this speed is, the higher the UA effectiveness is. But designing and subsequent use of high-speed unmanned aircrafts is connected with solving complicated number of problems that require the use of science-grounded methods for projects' management. Because of the high complexity and the lack of reliability of the theoretic studies' results, their experimental testing is still imperative. And the effectiveness of UA meant for long-term observation requires separate study.

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