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ANALYSIS AND PROSPECTS AERIAL IMAGERY OF UNMANNED AERIAL VEHICLE

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Statement of the problem

The main purpose of using UAVs is getting the images of required areas with specified characteristics. It is well known that aerial imagery as a kind of remote sensing is the most economically and technically justified way to collect spatial information, the basis for the creation of topographic maps, plans and three-dimensional models of the terrain. For the past century aerial imagery is an effective tool to perform search operations in geodesy, geophysical investigations and in conducting various types of monitoring.

Nowadays, the use of UAVs in aerial imagery is rapidly increasing. This is due to many reasons and primarily cost of aerial imagery which is several orders of magnitude (!) less than the use of manned aircraft. In addition to high economic efficiency, UAVs have the additional advantage over traditional aerial imagery and space removal. In particular, we note the possibility of [4]:

- Conduct low altitude imagery to obtain high resolution image of areas;
- Shooting at an angle to the horizon (perspective imagery), which is impossible with space imagery and quite difficult in traditional aerial imagery;
- Creating panoramic images (satellite and traditional aerial imagery do not have this capability);
- Thorough imagery of small objects (planar and linear areas of industrial development, power lines, transport infrastructure, flooding areas, mountain derivable and dumps, etc.), as well as mapping and preparation of cadastral plans of urban and rural settlements;
- Mobile and operational imagery of the territory, including the areas of emergency situations in real-time monitoring: the whole cycle from the departure till the results obtaining can take several hours;
- Avoiding complex preparatory procedures and organizational operations.

However, for efficient execution of these tasks it is necessary to solve technological problems in the use of UAVs for aerial imagery.

Connection to important scientific and practical problems

UAVs every year take up a growing sector, both in the military and in the civilian sector. At the beginning of the XXI century UAVs are produced in 52 countries. Dozens of large and small companies competing in this market, developed and tested more than 150 types of UAVs. Given the promising developments, today there are nearly 300 current projects of unmanned systems, both in the military and in business activity [5]. The range of applications of UAVs is constantly expanding and we can expect this trend to continue in the future. For example, UAVs can be used in the following areas:

- Remote sensing, digital 2-D and 3-D mapping;
- Monitoring hazardous to human objects (exclusion zone around Chernobyl, forests fires, hazardous industries, arms depots, etc.);
- Monitoring of pipelines to prevent unauthorized selection of products, as well as leaks, breaks, etc.;
- Control of the state border of Ukraine;
- Information support of MOE operations in the area of environmental and man-made disasters (such as the Chernobyl zone, fires in hazardous industries, etc.);
- Information support of the State Border Services for the protection of benthic marine economic zone of Ukraine from poaching fishing;
- Search and rescue operations;
- Relaying signals;
- Chemical and biological treatment of linear and planar objects in agriculture;
- meteorological reconnaissance;
- Inventory of human settlements and agricultural grounds;
- Monitoring the state and illegality crops, tracking of the quality and timeliness of various agricultural activities;

Analysis of recent research and publications devoted to the solution of the problem

The number of publications that advertised capabilities of UAVs having different structural types is increasing. Given that the list of models, their advantages and disadvantages would have taken a lot of space, the curious reader is referred to the references on the web by keyword UAVs. In some studies [5, 6, 7] system analysis is given using different types of models for the purpose of UAVs aerial imagery of areas for mapping. However, we note that the trend of the UAVs is directed primarily to the use of aircraft and helicopter types in comparison with other models (Fig. 1). In addition, development of digital photogrammetric processing methods have led to applications and software systems that can work out not quite condense aerial imagery in automatic mode that allows the use of digital nonmetric shooting system and refuse from gyrostabilized devices and GPS receivers [8].

Remaining part of the overall problem

When using UAV to process topographic aero picturing, we need to solve a number of problems, such as:

- An analysis of the research in order to identify shortcomings in the use of UAVs aerofoto;

- Perspectives for the development of UAV remote sensing.

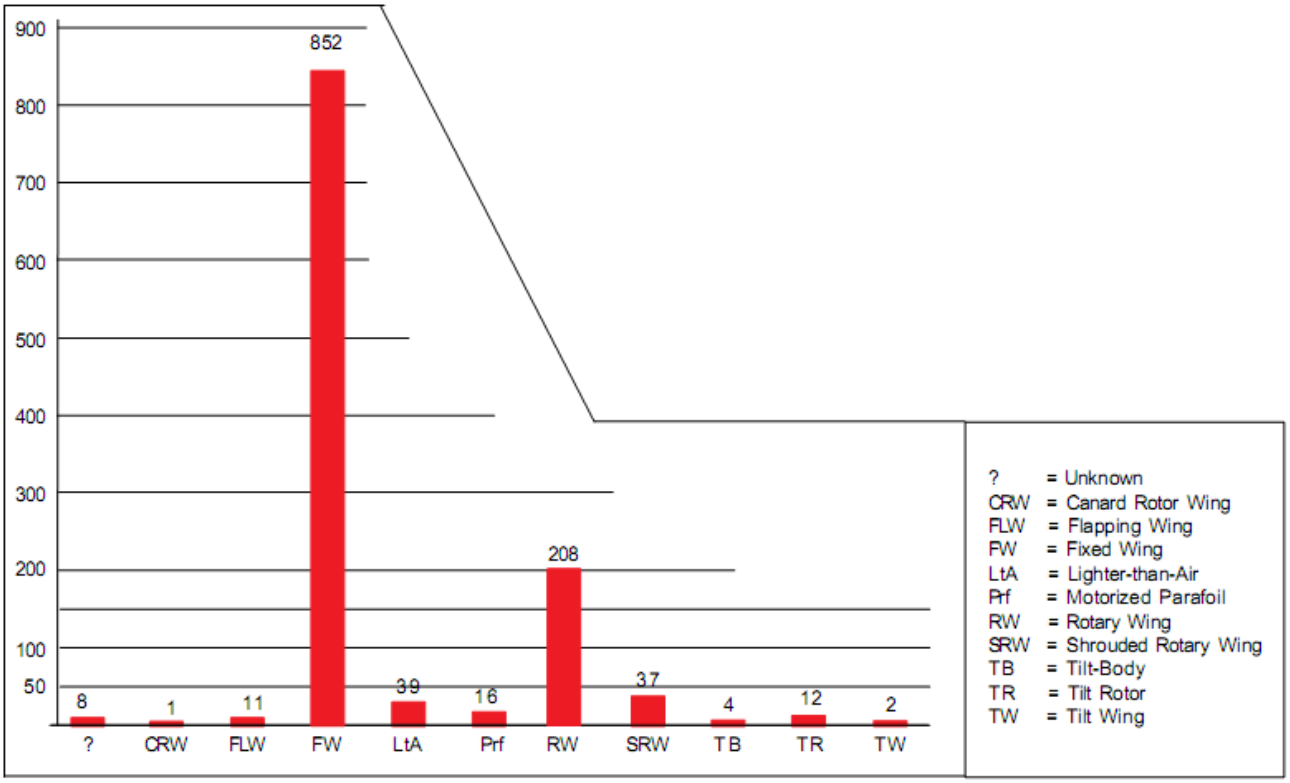

Fig..1. Chart ratio of UAV aircraft and helicopter types to each other
(according to UVS International-a leading international association of unmanned systems)
www.uvs-international.org

Tasks identification

For four years, the authors of this publication conduct experimental - research work on the implementation of the UAV in aero picturing process [1,2,3,4]. The results of these studies showed that there are many difficult problems to solve that require not only financial support, but also to solve technical issues of design, navigation, speed processing of materials received, etc. Therefore, the authors are directly involved in the actual testing of these devices. T some inexplicable euphoria that arose in geodesic environment that seems to be all the issues resolved and we can implement any UAV that are advertised are not specialized companies.

It should, however, be emphasized that advertising always sells dreams for reality, and real professionals should not have this delusion!

Therefore, the important is the task of analyzing their own experience of development and use of UAVs in identifying ways to improve its use for quality materials aero picturing mapping purposes.

The core material description

For definition of the problem, we will make a small review of the experiments and based on the results we will analyze the possibility and prospects of UAV during aero picturing process.

Let proceed directly to consideration of the experiments' results:

During the first phase of the work, different routes of the aero picturing have been done in the rural areas Kolonschyna Kyiv region on the board of the UAV "Bird" design FAX - NTU "KPI" (Figure 2) [3]. Analysis of the results revealed a number of shortcomings of the proposed technology, for example:

- Not exact observance of speed and altitude due to lack of pilot operational telemetry data;

Instability of remote control airplane at a distance of over 700 meters and low stability of the system to electromagnetic interference;

- Lack of protection when moving the camera on the ground ;

- Inconvenient quick access to the camera, which made it difficult to change settings ;

- High level of vibration that led to the unclear image;

- A relatively high speed on the route

On the other hand, despite the disadvantages of the results of processing the material has been concluded that the prospects of continuing this work . To this end, the authors designed and made as an example the

specialized small unmanned aircraft model "Pegasus" with the electrical engine.

This model is special because it allows a short distance take-off and landing, combined with low speed flight (Fig. 3) [1,4]. Particular attention in the design of the aircraft has been focused on the protection of on-board equipment during takeoff and landing. The aircraft is equipped with a new remote control system with high-range modern integrated system definition, recording and remote monitoring of flight parameters .

To perform the first experiment on the board of the aircraft there was a camera Canon EOS 450D coupled to intervalometrom [2]. Remote discovery and inclusion was carried out by a separate remote control.

Take-off weight of 65 kg Wingspan 5m Length 2.5m Airspeed 80-150 km / h Weight 25 kg payload Flight time with a load of 25 kg 4 h Airframe weight 32 kg Weight 10 kg Fuel 5 ... Engine 15 hp two-cylinder Take-off speed of 60 km / h Landing speed 50 km / h Runway 50 ... 70 m The maximum climb rate of 6.5 m / s Aerodynamic efficiency, 95 km / h 15 The radius of the bend 40…60 m	

Fig..2. Specifications and appearance of the UAV *«**ФАКС-4 ПТАХ**»*

Take-off weight of 12 kg Wingspan 2,4 m Length 1.7 m Airspeed 50-110 km / h Mass of payload 5/7, 5 kg Flight time with a load of 1.5 kg 0.5 / 4 hours Weight of the glider 8/8, 5 kg Electric motors 2/3, 5 kW Take-off speed of 40 km / h Landing speed 40 km / h Runway 25 m The maximum climb rate of 4 m / s Aerodynamic efficiency, 80 km / h 11 Bend radius of 30 m	

Fig..3. Specifications and appearance of the UAV *«**ФАКС-5 ПЕГАС-Е та -G**»*

The second phase of the experimental work consisted of two parts. In December 2011 was performed aero picturing of the same area in Kolonschyna villages of Kiev region. The main objective of the experiment was to study the accuracy of piloting during their parallel route length of 1000 meters in altitude 300 meters relative to the starting point (Fig. 4). Routes were built by landmark guidelines and the control was carried out by the operator of the aircraft from the ground visually. Straightness and accuracy of the route from the first attempt had been achieved.There was satisfactory compliance with the altitude and airspeed .

The second part of the work held in April 2012 in the village of Mines Mykolaivskoho district, Lviv region. The purpose of this part of the experimental work was the technology of the aero picturing work in rural areas and obtain photographs conditioned areas of rural development. Work performed under

favorable weather conditions - no cloud cover and wind force of up to 5 m / s. During one day there were 5 flights from unprepared sites. Some takeoff and landing took place just off the streets of the village. During the 30-minute flight from a height of 300 m the picturing of the routes with a total length of about 6 km (although some of them more than once to improve the technology of navigation and removal) was made.

The third stage of the experiment was to conduct block removal of the village Vivnya Stryisky district, Lviv region . Its surroundings: gardens and fields are leveled flat surface. To control the accuracy of the coordinates of object points of this town, which has already created topographical plan in the scale of 1:2000 . That is actually one clear path could serve as a reference or benchmark.

Aero picturing had been performed via using UAV "Pegasus" in May, when the growing season has not started yet.

The project was implemented by the orthophotos , with the removal and fixing on the ground end of the route . Aero picturing main parameters are as follows: height - 300 m, ground speed - 60 km / h., Scale removal - 1: 17000 , focal distance shooting digital camera Canon EOS-450D - 18 mm. Floors were designed accordingly : LC = 80 %, Ry = 40% , the number of tracks - 8, photographing interval - 2.5 sec.

Technology of the direct aero picturing was carried out with the navigation equipment and manual control of the aircraft: the creation of the beginning of the reversal of the route and destination of the end of the route, where the crew is located. [2]

Analyzing the quality of the tracks, it should be noted that single-mindedness, consideration of drift angle and longitudinal overlap of images stays within tolerance (Fig.4). However, there remains the problem of relatively large angles of pitch and roll , due to insufficient stabilization system.

For quantification resulting images processed stereo sample different routes (9 anchor points Moreover, the processing was carried out without distortion and with the exception of the aberration. Results of precision guidance presented in the table.

Analyzing the presented results, we see that, firstly, consideration aberrational distortions definitely need to do. Second, the accuracy of the orientation of images allows you to create large-scale plans actually in scale 1:2000. In addition, as a result of the orientation, the images' angles are calculated, in this case the angles of pitch and roll were in the range of 3 - 10 degrees, and the angles of wear did not exceed 3 - 4 degrees. This is because although the stabilization of the aircraft works, but it is not enough to reach the level to 5 degrees, while the drift angle, which can be adjusted in the air gives larger than the minimum result..

Since the main objective of the experimental work was to carry out the removal and block further on this basis of the process fototriangulation then let's discuss this in more details. So, as a result of the aeropicturing the eight trips was made.

Fig. 4. One of the routes of the block removal

Table 1

Value UPC spatial coordinates resulting from the orientation with and without taking into account the distortion

RMS (м)	M_X	M_Y	M_Z
With aberration	0.430	0.187	0.623
Without aberration	0.155	0.080	0.314

Analysis of parallel routes indicates that only 3 of practically all are within acceptable norms, while the rest disperse and form a "pants", although the lateral overlap stays and actually 50 % of the kept materials can be processed. Why has this negative phenomenon appeared? There is one explanation: the plane was sent incorrectly at the beginning of the route, but then in the second half of the route, which was close to the pilot managed to adjust the output is projected route.

So, as a result of the processing unit, which consists of the above three routes following results : m_X = 0,39 m , m_Y = 0,46 m , m_Z = 0,94 m , indicating a lack of accuracy of the coordinates for the 1:2000 scale .

This is due to the fact that the edges of the block and routes (Fig. 4) images have quite large angle of turn, pitch and roll , and this in turn causes errors in the measurement: the importance of cross- parallax leads to additional errors .

In order to avoid the above defects a new modification of the UAV (Figure 5) has been designed and created. In the present time, the model is under the experimental and production test. Additionally, it should be noted that the airplane is equipped with radiobeacon, parachute and it is planned to install GPS-receiver to determine the linear elements of external orientation. The aircraft is equipped with the special navigation equipment that performs aero picturing automatically.

General analysis of research materials

Analyzing Experimental work, first of all, we should note trend of UAV for aero picturing work. In our view, in can be divided in two directions. The first area is characterized by the following features:

1. Directly the UAV design is simplified as much as possible (no stabilizers and aero equipmnet for

shooting camera , GPS- receiver to determine the linear elements of external orientation , etc.).

2. To reduce in maximum the size and weight of the UAV , and reduced payload.

3. Stability achieved by increasing airspeed .

4. Avoiding of the gaps in aero picturing achieved by increasing the overlap of images both in longitudinal and transverse overlap (90%) .

5. Processing of the Images when creating orthophotos is performed automatically, this is possible via the powerful modern softwear.

Take-off weight of 7/ 8 kg Wingspan 2,3 m Length 1 m Airspeed 40-150 km / h Mass of payload 3/ 4 kg Flight time with a load of 1.5 kg 0.6 / 1.5 hrs Airframe weight 4 kg Electric Motor 1/ 2 kW Take-off speed of 35 km / h Landing speed 35 km / h Runway 15 m Climb speed of 5 m / s Aerodynamic efficiency , 60 km / h 14 The radius of the bend 15 м	

*Fig.5. Specifications and appearance UAV «**FAX-8 SkyBow-E and-G**»*

In another direction, we may note the following:

1. Existence of the more powerful digital film systems that are able to automatically take into account the angle of flight wear, establishment of geodetic GPS- receivers, which determine the accuracy of the corresponding elements of external orientation .

2.GPS equipment (video camera) that lets to pilot a plane as in the manual and in the automatically.

3. The device to stabilize the aircraft, which will reduce the angles of pitch and roll, and thus the possibility of reducing speed.

4. Keeping of the aero picturing parameters in the performance process (straightness routes specified longitudinal (60-80%) and transverse (30-40%) overlap).

5. It is necessary to conduct field work for PVP at performing fototrianhulyatsiyi.

Both the first and the second line have their advantages. In the first version of the attractive features is that the dimensions of the aircraft are small and can be transported without unnecessary restrictions on object to any form of transport. In addition, the removal is carried out fully automatically , and this in turn requires the presence of experts – aero picturing operators. However, at first glance such attractive benefits are not always compensated. Even with a projected maximum ceiling of photos ithe gaps are possible. Also do not forget that in the presence of large angles in the process of transforming values increased uncertainties that may affect the accuracy of the coordinates of the points of the object. Another fairly significant negative leverage is high speed . Indeed, at high speed and low altitude there is the presence of the resolution image. For example , we calculate this value for the following parameters survey: neutrophils = 300 m , f = 18 mm , t = 0,01 mm , W = 100 km / h, then σ = 0,02 mm, which will be on the ground - 32 cm . As in the first and second directions do not forget about the latch for the film cameras : they must be central, otherwise, it leads to disruption ortoskopiyi [9].

To confirm this, we calculate the error in measuring the coordinates of the digital image of the camera, which is mounted on the UAV above - Canon EOS-450D. All options assume from previous calculations. The result is : Δh = 0.06 mm, which again will be on the ground - 1 m! Of course, these errors can be reduced primarily due to the exposure time. This means that you must spend aero picturing in sunny weather when there is a maximum illumination of the object. However, this raises the second obstacle , namely the presence of dense shadows that can cause deterioration of quality assurance. Thus, elimination of this problem requires the use of film cameras with central latch.

Let consider the displacement of points on the image, which is caused by the change in angular orientation of the external elements of the image, during its formation. Offset coordinates Δx and Δy points depending on the change of angular elements of external orientation $\Delta\omega$, $\Delta\alpha$, and $\Delta\kappa$ can be determined by formulas approximate transformation. The result is that the displacement Δx = 0,005 mm is caused by the rotation angles of the camera according to $\Delta\omega$ = 5 ', $\Delta\alpha$ = 0,7' and roll angle at $\Delta\kappa$ = 2,5 '. These changes in the values of the angular elements of external orientation may occur when the angular velocity evolutions aircraft roll at 8 ° per second for pitch 1 ° per second and yawing 4 ° per second. The displacement Δy is corresponding angles $\Delta\omega$ = 0,8 ' and $\Delta\alpha$ = 5' and turn through an angle $\Delta\kappa$ = 1,7 ',

corresponding to the angular velocity evolutions for roll 1,3 ° per second, with pitch 8,3 ° per second yawing 2,8 ° per second. Presented calculations reaffirmed that under aero picturing flight should be possible to stabilize the aircraft, or determine with sufficient accuracy the angular orientation elements of images.

Conclusions

So after spending a generalized analysis regarding the use of UAVs for the purpose aero picturing, we need to make the following conclusions:

1. Certainly, the use of UAVs for aero picturing work is a matter of perspective : it is proved great interest , and only in the production and implementation of these tools .

2. From our point of view the general requirements for the UAV should be as follows:

a) The first flight of providing maximum stability through appropriate gyro stabilization equipment;

b) the presence on board of geodetic GPS- receiver , with which in kinematic mode with sufficient precision (10-20cm) are determined by linear exterior orientation of images ;

c) the presence aero equipment equipped by the inkrymentation miniature rotary optical sensors , with which it is possible to determine the angular exterior orientation with an accuracy of a few seconds;

d) The navigation equipment by means of which might implement a manual, semi-automatic and automatic control device ;

e) in respect of the safety features of the UAV and airborne equipment (parachute system , beacon , etc.);

f) the availability of sufficiently powerful digital camera with a telephoto lens , in terms of distinguished ability (at least 20-60 megapixels);

g) The mandatory metrology research digital cameras in terms of the definition of distortion and interior orientation elements ;

h) the possibility of UAV be in flight at least one hour ;

i) compact UAV : the ability to transport it without a special means ;

j) restricting the runway (sales mode " off from his hands " and glideslope in point) ;

k) determining the time of flight drift angle and its automatic using of the aero picturing.

3. In the future, the authors plan to implement the requirements listed above reality (most of them in the information presented above , already implemented) and to carry out testing and production testing flowsheet aero picturing works to create ortofoto - and topographical plans for material removal.

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ANALYSIS AND PROSPECTS AERIAL IMAGERY OF UNMANNED AERIAL VEHICLE

Glotov V., Tserklevich A., Zbruckij O., Kolisnichenko V., Prokhorchuk A., Karnaushenko R., Galecky V.

The results and analysis of block aero shooting from UAV rural village are presented. Attention is focused on a number of issues that arise during the aero shooting process and on their possible solutions.