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WAYS FOR GREATER EFFICIENCY AERIAL RECONNAISSANCE SYSTEM WITH USING ON-BOARD COMPLEX OF UNMANNED AERIAL VEHICLE

The analysis of receiving images processes by using the aerial reconnaissance's on-board opto-electronic equipments. Substantiates the direction of reducing the time for the delivering of video from unmanned aircraft to ground complex, which is about reducing the volume of image data transmitted through the use of image processing techniques. Substantiates the improvement of the quality of a predetermined image processing save information to enhance the effectiveness of aerial reconnaissance systems.

Keywords*: on-board complex, video information, imagery reconnaissance, aerial photograph, resolution, information intensity, interpretation, efficiency, accuracy of information received.*

Introduction

Analysis of preparation and conducting of operations, local wars and also a characteristic feature of modern and future conflicts, shows the new character of warfare. The increasing dynamics and speed of military operations, increasing of destructive means of warfare and maneuver capabilities of troops resulted in the expansion of the scale of operations, and also the transformation of the sea, air, space and land into a single global theater of war. This growing trend is the use of intelligence information in order to prevent sudden conflicts, and also a control over the military, political and economic activities of neighboring and foreign countries [1–2]. One of their components of receiving the intelligence for the security forces control system is aerial reconnaissance. The circulation of information between the control structure should take place in real time. Which means, the effectiveness of the security forces control system depends on the efficiency of the information provision's process. However, reducing the efficiency of information processing, and also increasing time delays due to communication processes lead to late transmition of information in the command and intelligence center. Therefore, there is a need to ensure the timely delivery of information to specify the quality of its air reconnaissance system.

Therefore, the aim of the article is to analyze the delivery quality of video control in the system of air reconnaissance in real time.

1. Analysis of receiving specific images' processes with using the on-board opto-electronic means of aerial reconnaissance

One of the informative types of aerial reconnaissance, with the using on-board optoelectronic means, in the visible range of electromagnetic waves, is aerial reconnaissance. Thus, as a result of conducting aerial reconnaissance on board an unmanned aerial vehicle, species information is formed, often aerial photographs.

One of the effective ways to obtain intelligence in the interests is aerial photography. This is because:

– firstly, the enemy, with relatively low costs, may commit partial or complete counteraction to radio electronic reconnaissance;

– secondly, the use of photographic optoelectronic systems will allow us to obtain the most complete and reliable data about the enemy, to obtain photo documents necessary for providing combat operations, compiling and correcting topographic maps and plans, and also provides the highest accuracy of determining coordinates. A distinctive feature of photographic systems over other means of species reconnaissance is: in obtaining aerial photographs having high resolution on the terrain (detail); in increasing the completeness of information about the enemy; in obtaining photo documents necessary for the effective management of units in the course of combat operations; in the exact definition of the coordinates of objects [3].

The process of processing and transmitting the species information from the on-board unmanned aerial vehicle complex to the ground complex includes the following steps:

1. At the first stage, there is the setting a task for air reconnaissance.

2. At the second stage, there is a launch of on-board air reconnaissance means and also the approaching of unmanned aerial vehicle to the designated reconnaissance area.

3. At the third stage, is monitoring of reconnaissance area. In the functioning process of the airborne

complex, formation, collection and transmission of species information is carried out.

4. In the fourth stage, the receiving and collection of information by ground complex. The processing center receives the specific information in the form of a video sequence and aerial imagery from the UAV, tied to the cartographic background, video information models of the areas the image of the current situation on the cartographic background.

5. The fifth step is about the processing of imagery, aerial photo interpretation and analysis, and also drawing up reports on the results of air reconnaissance and decision-making. Here, time of deciphering aerial images depends on the task level, information content of the image, the size of the photographed area, nature of the terrain, conditions and qualifications interpreter of its work. It is important that photo reading held at the time close to real. At the same time, the efficiency of decoding depends on the resolution of the aerial photographs and the degree of preservation of information about key features of the decryption (brightness and contour information).

Analysis of airborne communication channels, which are using for a video transmition to a ground control station, characterized by limited bandwidth. As a result, there are disadvantages associated with:

– limited capabilities of transmission channels and providing of specific information transfer on communication channels in real time, with the required volume, at a predetermined speed and at a certain distance without distortion under artificial and natural jamming;

– limitations on weight-and-size and insufficient energy resource of the BC, which will not allow to use powerful equipment for information processing;

– wrong choice of optical-electronic means of recording specific information to the UAV flight in the air monitoring area, which leads to poor-quality aerial imagery.

Knowing the requirements for the resolution of aerial view $R_{rv}^{(req)}$, we can detect the digital volume of the original W_{orig} airphoto, generated by cameras on Board the UAV according to the formula:

$$W_{orig} = \sum_{i=1}^{N} \left(Z_r(R_{rv}^{(req)}) \times Z_c(R_{rv}^{(req)}) \times \ell og_2 Y_i^{(sq)} \right), \quad (1)$$

where N_{cp} – number of color planes involved in the formation of a digital aerialphoto; $\ell og_2 Y_i^{(sq)}$ – the number of digits when forming the element CCDs; $Z_r(R_{rv}^{(req)}), Z_c(R_{rv}^{(req)})$ – accordingly, the number of rows and columns in the image frame subject to the requirements of the resolution of aerial view;

W_{orig} – the volume of the original aerial view.

An analysis of the characteristics of digital cameras on-board aerial reconnaissance systems shows that the generated aerial on board unmanned aircraft reach significant volumes of information. So, board equipment for collecting, processing, and data channels on existing on-board complexes do not provide a complete record and transmit video information stream. As a result there is a rise of time delays and data processing, as well as distortions in the images (loss of resolution aerial photograph) during the information transmission. This reduces the effectiveness of aerial reconnaissance system, using the on-board systems. However, depending on the operations' conditions of an on-board complex there are different requirements for imagery intelligence.

The main requirements for specific intelligence are information delivery efficiency, reliability and completeness of the received aerial imagery.

One of the key components in airborne reconnaissance system with the on-board systems aerial reconnaissance is the efficiency of information delivery. The speed of delivery of intelligence information will depend on the time T_{it} of informing taking into account of interpretation of aerial photographs. The corresponding expression is represented by the formula:

$$T_{it} = T_{deliv} + T_{dec} = T_{proc}^{(BK)} + T_{tran}^{(BK-AK)} + T_{proc}^{(AK)} + T_{dec}, \quad (2)$$

where T_{it} – the time taken to pass information relevant to the interpretation of aerial photographs; $T_{proc}^{(BK)}$ – the processing time of the aerial photograph on board the UAV; $T_{tran}^{(BK-AK)}$ –- transmission time aerial view of BK at AK; $T_{proc}^{(AK)}$ – the processing time of the aerial photo on AK; T_{dec} – time decryption of aerialphoto.

Reducing the delivery efficiency of the information results in its aging and decreasing reliability of the information.

The validity of the aerial photographs is considered in two directions. On the one hand, due to the accuracy of the information processing processes and data with on-board complex, the ground control station, on the other hand, the accuracy of the information is determined by the degree of false information (the real situation).

In the first case, the validity of the aerial images due to processing and transmission processes, the degree of correspondence is regarded as the received information, and may not reflect the initial information due to the following factors:

– low-bandwidth data channel;

– data transmission channel noise that distort the received information;

– applying the image processing techniques that can result in partial loss of information in the image.

The degree of compliance with the original aerial photograph restored, as a result of processing and transmission of information can be judged similarity metric. The main quality indicators are:

– peak signal-to-noise ratio h of picture (PSNR-peak signal to noise ratio). This value characterizes visual distortion that are made in the image and is determined based on the following formula:

$$h = 20\lg(255/\sigma_{img}) \text{ (dB)}, \qquad (3)$$

where σ_{img} – the standard deviation of the pixel values of the restored image relative to the source and is determined on the basis of the following formula:

$$\sigma_{img} = \sqrt{\sum_{i=1}^{Z_r} \sum_{j=1}^{Z_c} (y_{ij} - y'_{ij})^2 / Z_r \times Z_c} . \qquad (4)$$

Here y_{ij}, y'_{ij} – the elements of respectively the original and the reconstructed images at the receiving side, $Z_r \times Z_c$ – accordingly, the number of rows and columns in the image frame.

Formula (3–4) that, the smaller the degree of distortion of the reconstructed image after processing, the greater will be the degree of conservation of decoding characteristics (brightness contrast, the contour information) that will increase the efficiency of decoding.

In the second case, the validity of the degree of aerial photographs is considered as untrue information. However, the information may partially or completely be true in cases where:

– types of images, obtained with the help of photographic systems, tampered by the enemy;

– the opponent has taken measures for masking objects;

– reconnaissance area and objects on it can be partially or completely not correspond to the actual situation in the area;

– late delivery of data to the ground complex, which leads to aging information.

Completeness obtained aerial photographs due to the process of its formation, and is based on the requirements to the level of resolution of the aerial photograph. On the basis of the objectives for conducting aerial reconnaissance, and put forward requirements to the characteristics of CCD-matrixes of optical-electronic equipment. Violation resolution aerial imagery leads to loss of interpretive signs objects and recognize them on the wrong areas.

Thus, the efficiency of delivery of information, completeness and reliability of the aerial imagery affects the promptness and correct solving of necessary tasks in the control system with the using on-board systems of aerial reconnaissance. The final stage is a specific intelligence information processing, which includes an aerial photo interpretation and compilation of all the intelligence reports for decision-making.

2. Substantiation of the direction for the modernization of methods for reducing the initial volume of images in on-board unmanned aerial reconnaissance systems

To reduce the time of delivery of aerial photographs, technologies are used to reduce the information intensity or compression. Existing technologies and methods of image processing have a number of features. Some methods are characterized by high computational complexity, others, in the process of processing, loss of information in the aerial photo blocks. This leads to the complexity of meeting the requirements for preserving the resolution of an aerial photograph and increasing the component of the delivery time of aerial photographs. Therefore, it is necessary to analyze the main approaches used in image processing [4–6].

The main approach embodied in these methods is based on the preliminary transformation of aerial photographs. In the image after their transformation, there is a reduction in both psychovisual redundancy and statistical. Psycho-visual redundancy is predetermined by the peculiarities of the human vision in the perception of the individual components of the image. Statistical redundancy is associated with the correlation and predictability of the data. Compression is mainly due to the inclusion of psychovisual redundancy (due to the peculiarities of visual perception of individual components of the image). Thus, it becomes possible to reduce the original image volume without significantly distorting the information, and also to obtain a complete restored image after processing. Studies have been conducted evaluating parameters of the compression methods that implement the main approaches to reduce redundancy, namely: arithmetic coding (AC), run length encoding (RLE), method vocabulary encoding (LZW), methods used in formats JPEG, JPEG2000 and JPEG-ls.

According to the results of the research, the following conclusions can be drawn:

– comparative analysis of processing systems in different quality preservation regimes shows that the largest reduction factors of the initial volume are achieved for image processing methods with quality level control (JPEG and JPEG2000);

– for compression methods without quality preservation (there is no processing stage associated with eliminating psychovisual redundancy), such as AK, RLE, LZW are inherent: insufficient values of the degree of reduction of the initial volume (on average, at 2-3 times);

– for a good image restoration quality (PSNR values of at least 35 dB), the reduction factor of the initial volume is 2.5 times on average;

– for a satisfactory image restoration quality (PSNR values of not less than 30 dB), the reduction factor of the initial volume is on average 9.5 times;

– the degree of reduction of the initial image volume by 10 times for the medium-saturated image is achieved with a signal-to-noise ratio below 25 dB.

A comparative analysis of the existing image processing technologies revealed the following:

–- on the one hand, the application of image processing techniques without preserving quality provides a reduction in time spent processing and transferring images due to a significant reduction in the original volume. However, the use of such methods leads to a decrease in the resolution of images, as well as distortion and destruction of the original semantic structure. At the same time, the required level of luminance and contour information is not maintained due to high values of the reduction factor of the initial volume;

– on the other hand, the use of image processing methods with preservation of quality does not provide sufficient reduction of the initial volume of information and the possibility of its transmission within the established time periods. As a result, there is a decrease in the speed of delivery of information, which entails an increase in decryption time.

Based on the above, it can be argued that a significant amount of species information generated on board an unmanned aerial vehicle leads both to an increase in the time delays in the delivery of information to the ground control station and to an increase in the time for deciphering aerial photographs for the promptness of the decision. The consequence of this are both the limited characteristics of the airborne complex and the shortcomings associated with the transmission and processing of information in onboard unmanned aerial reconnaissance systems. Existing methods of reducing the information intensity do not provide the requirement for preserving the resolution of the image images for a given quality of interpretation. This is due to the fact that existing methods do not fully provide the necessary degree of reduction of the initial volume without introducing distortion.

Thus, this direction can be implemented using existing image processing technologies, namely, methods to reduce the initial volume of images, which in turn will lead to an increase in the speed of decision-making for the management system.

Conclusions

1. It has been substantiated the importance of aerial reconnaissance with the using of unmanned aerial vehicle in the process of managing the system for collecting, processing and transmitting aerial photographs.

2. It has been analyzed the processes of obtaining specific images with the using of on-board airborne reconnaissance means and has been justified that with the increasing of the flight height of the unmanned aerial vehicle the requirements with respect to the characteristics of the CCD matrix increase, which leads to an increasing in the initial volume, which in turn is determined by the class of solved problems On deciphering objects.

3. Evaluation of the influence of information intensity growth on the increase in time delays in the delivery of information from the airborne complex showed that the time for the delivery of data from the aircraft to the ground complex is mainly determined by the time of preparation and transmission of data over a communication channel that has capacity limitations.

4. The actual direction of reducing the total time for processing and transferring information is to use image-processing methods with the required level of preservation of key features of interpretation.

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НАПРЯМОК ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ СИСТЕМИ ПОВІТРЯНОЇ РОЗВІДКИ З ВИКОРИСТАННЯМ БОРТОВОГО КОМПЛЕКСУ БЕЗПІЛОТНОГО ЛІТАЛЬНОГО АПАРАТУ

А.М. Алімпієв

Проводиться аналіз процесів отримання видових зображень за допомогою бортових оптико-електронних засобів повітряної розвідки. Обґрунтовується напрямок зменшення часу на доставку відеоінформації з борта безпілотного літального апарату на наземний комплекс, яка полягає в зменшенні обсягів переданих відеоданих на основі використання методів обробки зображень. Обґрунтовується вдосконалення методів обробки зображень із заданою якістю збереження інформації для підвищення ефективності функціонування систем повітряної розвідки.

Ключові слова: *бортовий комплекс, відеоінформація, видова розвідка, аерофотознімок, роздільна здатність, інформаційна інтенсивність, дешифрування, оперативність, достовірність одержуваної інформації.*

НАПРАВЛЕНИЕ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ СИСТЕМЫ ВОЗДУШНОЙ РАЗВЕДКИ С ИСПОЛЬЗОВАНИЕМ БОРТОВОГО КОМПЛЕКСА БЕСПИЛОТНОГО ЛЕТАТЕЛЬНОГО АППАРАТА

А.Н. Алимпиев

Проводится анализ процессов получения видовых изображений с помощью бортовых оптико-электронных средств воздушной разведки. Обосновывается направление уменьшения времени на доставку видеоинформации с борта беспилотного летательного аппарата на наземный комплекс, которое заключается в уменьшении объемов передаваемых видеоданных на основе использования методов обработки изображений. Обосновывается совершенствование методов обработки изображений с заданным качеством сохранения информации для повышения эффективности функционирования систем воздушной разведки.

Ключевые слова: *бортовой комплекс, видеоинформация, видовая разведка, аэрофотоснимок, разрешающая способность, информационная интенсивность, дешифрирование, оперативность, достоверность получаемой информации.*