ABOUT THE ISSUE OF JOINT PROCESSING OF IMAGES OF THE EARTH'S SURFACE, OBTAINED FROM DIFFERENT TYPES OF MEDIA

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***Abstract**: The problem of joint processing of images of the Earth's surface obtained from spacecraft and unmanned aerial vehicles, which is associated with the need to combine frames of Earth sections during image preprocessing, is considered. A procedure has been developed for processing images of the Earth's surface to monitor the area in order to identify long-term changes, and a procedure has been developed for processing images of the earth's surface to monitor the area in order to identify long-term changes/*

***Keywords**: spacecraft, unmanned aerial vehicles, Earth's surface, images.*

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Introduction

The procedure for remote sensing of the Earth (ERS) from a spacecraft is widely used to assess the state of the terrain, for example, to detect the state of vegetation [1] or, very importantly, the consequences of destruction after technological and environmental or military events. But these methods do not provide detailed information about the state of the infrastructure. In this case, there is a need to support technologies for space survey of territories with additional methods of photographing a given surface of a land plot from heights from 10 m to 200 m using telephoto equipment placed on board unmanned aerial vehicles (UAVs).

Thus, the problem arises of joint processing of video and photographic materials obtained by UAV and spacecraft (SC) equipment. Joint processing of photographs or video materials from the spacecraft and UAV boards provides the most comprehensive information about the state of the studied territory of the Earth (Fig.1)

Improvement of scientific approaches to the creation of software and hardware tools for the use of unmanned aerial vehicles (UAVs) and spacecraft for remote monitoring from the air of territories is a modern urgent problem. This is due to the problem of searching, detecting and identifying objects in a given area, with determining the coordinates of these objects. It is also important to track changes in the state of objects over time with the subsequent transmission of photo or video information in real time [1, 2, 3, 4]. A comprehensive assessment of damage from damage and destruction as a result of technical and environmental disasters is extremely important, because only after that it is possible to plan the restoration of the infrastructure of the territory. As for precision farming, the development of this direction requires accurate and promptly updated information about the state of vegetation and soil. Obtaining such information is possible only when using remote sensing of agricultural fields due to the large size of their areas. The ability to quickly identify diseased areas of vegetation is essential. This allows at the early stages of development with minimal costs and quickly localize and "cure the disease." [1, 5].

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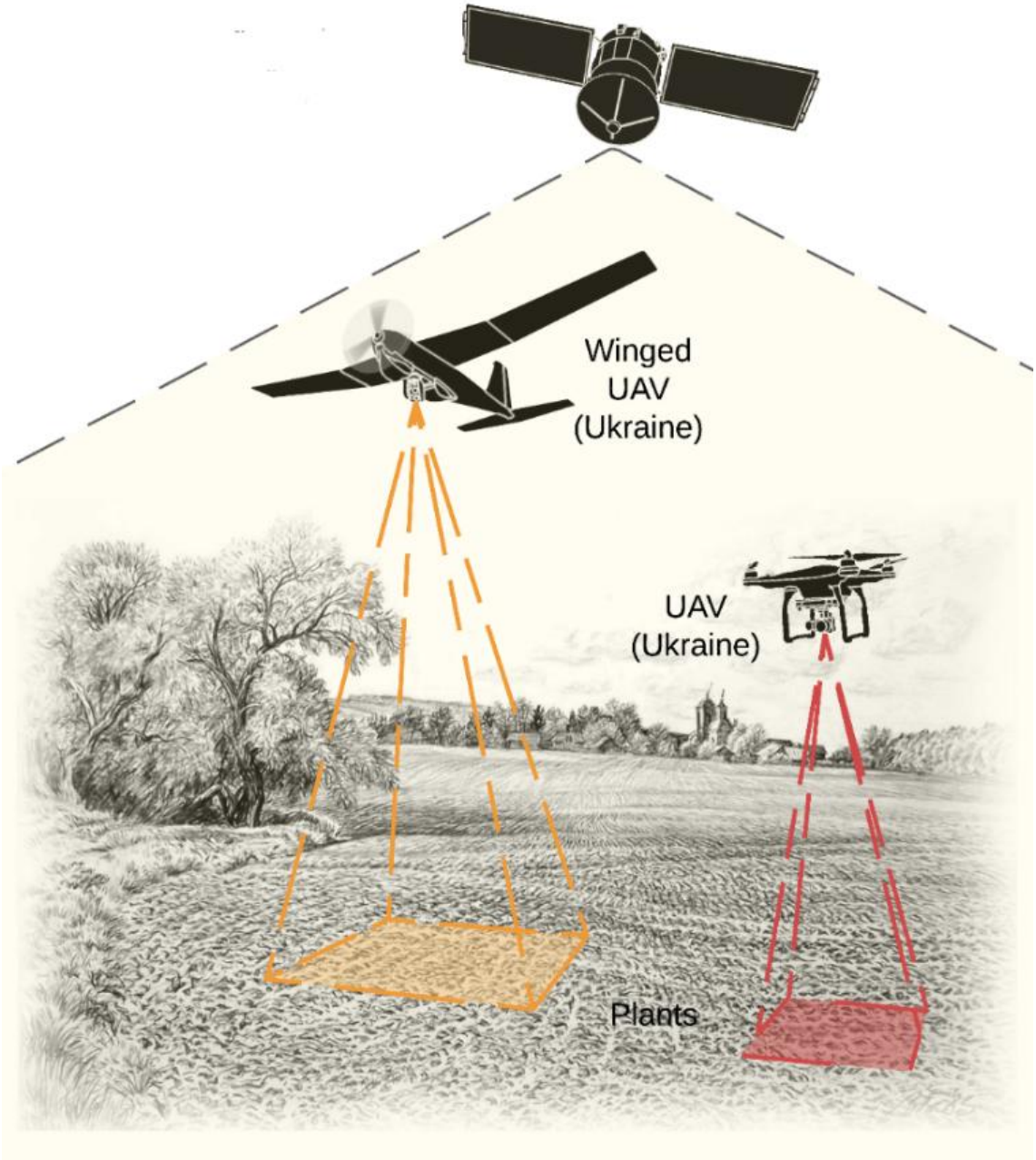

Fig.1 Illustration for the procedure of remote sensing of the earth's surface from various types of media

II. Formulation of the problem

The task of the authors' research was to improve the quality of environmental monitoring using neural network identification and classification of objects on multi-zone satellite images and multi-zone images obtained from UAVs.

The research reported on included both theoretical research and the solution of applied problems. The mathematical basis of image processing is the computational apparatus for pattern recognition. Practical research is based on experiments, software implementation and testing of algorithms and technology.

Thus, the task of the authors' research is to increase the accuracy of recognition of objects on the earth's surface (infrastructure objects or the vegetation state of agricultural lands). The authors have experience in this area. In particular, one of the topical research areas of Department 265 of the V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine (NASU) is the creation of technologies and intelligence systems after technical and environmental events, which are most often accompanied by the destruction of infrastructure. The team of authors has long been working on improving unmanned aerial vehicles and adapting their capabilities to perform many important and relevant tasks for the industry and agriculture of Ukraine. For example, in 2017, an employee of the 265th department Prokopchuk V.V. took part in the manufacture and testing of these UAV models, and on August 25, 2017 presented a cargo drone that set a Ukrainian record - lifted a weight of 16 kg into the air.

This article discusses the use of a scientific idea, which consists in developing a method for joint computer processing of digital and analog images obtained from UAVs, as well as quasi-simultaneous and reusable multi-zone space images. Currently, this direction is being developed by Department 265 of the Institute of Cybernetics of the National Academy of Sciences of Ukraine

III Problems in the collaborative image processing

Below is a list of the most typical problems and tasks that arise in the development of methods for such joint processing of images of the earth's

surface, including multi-temporal ones (which is sometimes necessary to identify the dynamics of changes in individual parts of the earth's surface). The solution of these problems occurs during the so-called pre-processing of images, after which it becomes possible to further process the prepared images according to the adopted program:

- The problem of compensating for the mismatch of different-time frames of remote sensing images.
- The problem of combining images obtained from different aircraft.
- The problem of the impact of atmospheric phenomena.
- The problem of filtering noise in the image.
- The problem of joint processing of images of the earth's surface with different resolutions.

Below is an overview of the current state of research on these problems of joint image processing.

1. The problem of compensating for misalignment of different-time frames of remote sensing images.

Images obtained from an unmanned aerial vehicle (UAV) are misaligned relative to each other at different times. This problem also arises when processing images from spacecraft is required, namely, an automated search for changes in space images of different times. Then it becomes necessary at the pre-processing stage to use methods for eliminating the misalignment of different-time frames of remote sensing images. Among the methods for eliminating such an obstacle in the processing of remote sensing image frames, there are methods based on the search for key points and phase correlation. The algorithm for compensating the misalignment of multi-temporal image frames using key points is based on a preliminary search for an image of key (special) points. Such procedures include, for example, methods: Speeded Up Robust Features (SURF), Scale-Invariant Feature Transform (SIFT), as well as such more modern approaches as Oriented FAST and Rotated BRIEF (ORB)

and KAZE/AKAZE. [2]. Such methods (in general, the SIFT method and their modifications) are often used to solve the problems of processing images obtained from both air and space carriers. In the case when monitoring requires long-term observations (for example, for mapping and monitoring glacier velocities, in the practice of searching for changes in terrain using satellite images or using aviation), images obtained by different systems, under different conditions (different angle and direction of sighting) are often used, different times of the day, etc.). For the correlation of multi-temporal images, the algorithms FFT (Fast Fourier Transform), NCC (Normalized Cross-Spatial Correlation), Cross-corre - cross-correlation on orientation images or the joint registration and correlation algorithm can then be used. (CO-Registration of Optically Sensed Images and Correlation - COSI-Corr) [3]

2. The problem of combining images obtained from different aircraft.

This implies an exact comparison of the pixels of two images corresponding to the same points on the earth's surface. This gives rise to data on the spatial resolution of images. Distortions can occur when gluing microframes and diverging axes of devices, shooting angles that form multispectral images.

A common practice for assessing the quality of combined images is visual analysis. It is obviously subjective and poorly suited for mass image processing. Combining images with different spatial resolutions and in different spectral ranges also causes difficulties [4].

It happens that the spatial resolution of images differs by several times, and for a number of tasks one-to-one correspondence of pixels of different spectral channels is required with the highest possible accuracy of the spatial resolution of the panchromatic channel. That is, at the stage of imaging, there should be a

one-to-one correspondence of pixels corresponding to the same piece of terrain and belonging to different spectral channels. Devices that form the image are often not coaxial, which makes the task of combining their images relevant. In addition, already building an image from a set of microframes is a complex procedure that requires the use of high-precision technologies. Therefore, at the first stage of image processing, it is necessary to strictly control the spatial correspondence of images. Some of the algorithms are described in the publication [6].

3. The problem of the influence of atmospheric phenomena

Unfavorable weather events, such as rain, fog, snow, can lead to inaccurate performance of object identification tasks using video frames. Many scientific studies are devoted to the use of improved vision systems that reduce the impact of precipitation on the quality of video information [7].

Some well-known algorithms for eliminating the effect of precipitation on the quality of photographs are used: the spatial median filtering algorithm, algorithms based on photometric and dynamic rain models, a two-stage algorithm for improving the quality of video images. Each of these approaches has its own advantages and disadvantages; therefore, the task of developing an algorithm that compensates for the effect of precipitation on the images obtained during remote sensing is relevant. Often the elimination of the described shortcomings is carried out in two stages: the procedure for detecting and eliminating particles of precipitation and the procedure for increasing the contrast are performed separately in order to reduce the foggy effect on the distant plan [7].

4. The problem of filtering noise in the image

In the process of obtaining remote sensing data, there are images that have been distorted by noise generated during the generation or transmission stage. The reasons that influenced the appearance of noise in the image may be a malfunction in the communication channels, errors in the operation of the signal recording device, and others. Satellite imagery and UAV imagery are an effective way to obtain data, but the quality of data depends not only on the hardware component of the remote sensing process. Ultimately, this leads to a deterioration in the quality of visual perception and a decrease in the likelihood of decisions that will be made based on the analysis of such images. To successfully solve the problems of searching and identifying objects, determining various kinds of quantitative characteristics, it is necessary that the primary images be characterized by a high indicator of visual quality, which is lost due to unsatisfactory conditions for obtaining images, imperfection of information transmission systems and their display.

5. The problem of joint processing of images of the earth's surface with different resolutions.

The problem of comparing two images over the past two decades has been an active research topic in the field of processing remote sensing images of the earth's surface. Most existing methods consider images of the same area, where viewpoints differ by small shifts in position, orientation, and viewing parameters such as focal length. Image elements associated with different shots have a comparatively close resolution. For this reason, elements of the scene that appear in different images will be approximately the same scale. When images from spacecraft and UAVs of the same area are compared, new problems arise in comparing two images with different spatial resolutions. This issue has received little attention in the past [7].

Obviously, the resolution with which a 3D object is observed in an image mainly depends on two factors: the distance d from the camera to the object and the focal length f associated with the camera lens. Image resolution increases as f increases and decreases as d increases. Therefore, r = f/d is a first order approximation of the image resolution measurement. Therefore, there is a need to develop methods for matching a pair of images with completely different resolutions.

At the same time, we have input image data for processing with low resolution (image from the spacecraft) and images with high resolution (image from the UAV).

In the research on the topic of the report, the development of an algorithm for pre-processing images was provided and carried out, taking into account the features of digital images from a spacecraft and UAVs.

The images received from the spacecraft have a mismatch in colors, which further complicates their joint processing. At the pre-processing stage, it is proposed to use an algorithm for eliminating the mismatch of color channels of Earth remote sensing (ERS) images, based on the search for key points and differing by their additional check for each channel.

IV Complex processing of multi-temporal images of the Earth's surface.

Development of a procedure for complex neural network processing of multi-temporal images of the earth's surface obtained by remote sensing equipment located on spacecraft and UAVs.

Consider the procedure for processing images of the earth's surface for the following task: monitoring of the area should be carried out in order to determine long-term changes in the earth's surface. A typical task is the assessment of deforestation areas with the possibility of assessment and spontaneous deforestation. This is necessary to calculate the damage caused by

unauthorized logging, to calculate the funds that should be provided for the restoration of natural resources.

At the same time, it is necessary to conduct video monitoring of the study area periodically in the long term, in fact, every time to map the area in automatic mode. The idea is to obtain multi-temporal images of some areas of the tested forest massifs, bordering each other, with a clear spatial reference. In this case, changes in the brightness of the earth's surface must correspond to real changes in the earth's surface. To do this, it is better to use pictures taken with one sensor. Then the same shooting technology will be used, so the differences in brightness in the images will be guaranteed to be associated with changes in the earth's surface. In addition, if you need to compare the state of the area for different years, then it is desirable that the pictures were taken approximately in the same months and at the same time of day. This ensures that long-term changes are detected, rather than seasonal dynamics of the area. After selecting images for comparison, it is necessary to perform their radiometric calibration and atmospheric correction, since it is important that the difference in the state of the atmosphere does not interfere with the detection of real changes on the ground.

Image processing will consist of the following steps:

1) The array under study (the area from which images have already been taken) with the coordinates (two-dimensional) of each “frame” is considered a template.

2) Selection of geometric spatial references, key points that are used to define the boundaries of each frame. And when the UAV passes the next time after a certain time, a picture of the same area is obtained. The time interval between successive studies of the territory is determined from the characteristics and objectives of the task.

3) The operation of combining the boundaries of these multi-temporal images is carried out (determining the "common" frame for two snapshots). (Images

received from an unmanned aerial vehicle (UAV) in different periods of time have discrepancies relative to each other. The same problem arises when processing images from spacecraft is required, namely an automated search for changes in satellite images at different times. Then it becomes necessary at the stage pre-processing, use methods for eliminating the discrepancy between frames of remote sensing images at different times).

4) Mathematical processing to detect the correlation of these two images is possible after the following preparatory work:

a) elimination of errors due to scale mismatch for different terrain images;

b) elimination of errors due to differences in the spatial resolution of images of the same area of the surface;

c) elimination of the influence of differences in the angles of inclination of the shooting cameras. Distortions arise when gluing microframes and divergent axes of devices, shooting angles that form multispectral images;

d) elimination of the influence of atmospheric changes [2];

e) creation of a panchromatic image (black and white) of a specific area using multi-zone imaging, if it is decided to use the methods of correlation analysis of panchomatic images. Otherwise, methods of applying the correlation processing of multispectral images can be applied;

f) orthorectification (orthocorrection) of images if necessary, mathematical rigorous transformation of the original image (image) into an orthogonal projection and elimination of distortions caused by terrain, shooting conditions and camera type.

Note: not all of the above preparatory work may be needed, it all depends on the specific requirements for monitoring land masses.

Below in fig.2-4 one of the operations of preliminary processing of images of the earth's surface - image alignment - is illustrated for the purpose of the next step of the technique: comparison of images at different times. Various satellite images of one of the areas were processed using OpenCV, an open source computer vision library.

Fig. 2,3 - satellite images of one area of the territory, made with an interval of several days.

Fig. 2

Fig. 3

Fig. 4 Photo from the UAV superimposed on a satellite the area photo as an example of the program operation for combining two photos using OpenCV (an open source computer vision library available for free use for scientific, academic and commercial purposes).

After combining the images, it becomes possible to separate 2 frames of images at different times for processing them by the methods of correlation analysis [3] using computer processing programs and identify changes in the state of the terrain [4,5].

Conclusion

1.The article analyzes the current state of scientific research on the problem of joint processing of images from different media or multi-temporal images of the same area of the earth's surface, which carry information about the state of land use areas.

2. A procedure has been developed for processing images of the earth's surface to monitor the area in order to identify long-term changes. At the same time, it is necessary to conduct video monitoring of the study area periodically in the long term, in fact, every time to map the area in automatic mode. The idea is to obtain multi-temporal images of some areas of the test territories bordering each other with a clear spatial reference and subsequent compensation in the general case for the placement of multi-temporal frames of remote sensing images, combining images obtained from various aircraft of atmospheric phenomena and noise filtering in image.

3. A procedure has been developed for processing images of the earth's surface to monitor the area in order to identify long-term changes After combining images, it becomes possible to select 2 frames of images at different times for their processing by methods of correlation analysis using computer processing programs and detecting changes in the state of the terrain [6,7].

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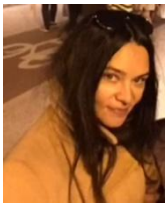

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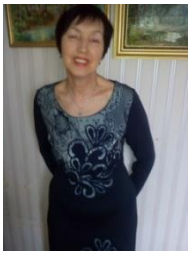

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