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On-board two-position optical system of classification and determination of trajectory coordinates of objects in video stream

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ABSTRACT

The article discusses the possibility of using a two-position onboard optical-location system for detecting, classifying and determining the coordinates of the trajectory of objects in the video stream installed on the small aircraft. Every year the requirements for new monitoring systems are becoming more stringent. The data obtained from a single, albeit high-quality, optical sensor can no longer meet the assigned tasks, such as performing search and rescue operations in remote areas, as well as solving problems of finding people in disaster zones. and environmental disasters in a complex noise environment. The system considered in the article includes optical-location sensors, each of which is capable of forming a high-resolution image and classifying the observed objects, as well as, when used together using stereo vision methods, to obtain estimates of the coordinates of the object's trajectory. observed objects. It is shown that combining information in an optical location system allows detecting, classifying and determining the parameters of motion of objects, including people and animals. The article presents the operating modes of the system, and the corresponding restrictions on the conditions for its effective operation.

Keywords: small aircraft, two-position location system, monitoring systems, classification.

1. INTRODUCTION

Every year, the results of human activity, as well as various natural phenomena, such as storms, floods, forest fires, earthquakes, etc., cause environmental, man-made, economic and human disasters [1].

Currently, the urgent task is to develop new on-board operational monitoring systems for the analysis of the above incidents. In recent years, to solve this kind of problems, optical monitoring systems are actively used, implemented on the basis of small aircraft (SA) and using various methods of observing and analyzing the earth's surface [2, 3]. In the recent past, the use of such solutions was limited by high weight and size characteristics, the complexity of the implementation of such monitoring systems, as well as their high price, however, over the past decades, significant changes have occurred in this area. The miniaturization and increased performance of computing systems now allow to implement a monitoring system based on small aircrafts (SA), whose weight and size parameters, and the value of an order of magnitude less than the counterparts of past generations considered monitoring systems. The use of small-sized SA has many advantages, including the speed of deployment, the efficiency of preparation for launch and the ability to fly at a fairly low altitude, as well as in hard-to-reach places and places that pose a danger to human life. In addition, high resolution optical sensors, modern stabilization systems, focusing, etc. will allow you to observe the details of the relief and small-sized objects from the sides of the SA. However, every year the requirements for new systems for monitoring the earth's surface are becoming more stringent. Data obtained from a single, albeit high-quality, optical sensor can no longer satisfy the tasks set, such as the implementation of search and rescue operations in remote hard-to-reach areas, as well as when solving problems of searching for people in disaster zones and environmental disasters, especially under the influence of destructive influences.

In this regard, the transition to multi-position spatially distributed on-board optical-location systems, in particular, two-position systems, is expedient. The use of two-position optical location systems (OLS) makes it possible to form a combined image of the observed surfaces, to solve the problems of classifying objects and zones, and also through the use of spatially distributed two or more optical location sensors to obtain estimates of the trajectory coordinates of the observed objects through the use of stereo vision methods, namely range, angular coordinates, speed, acceleration, etc.

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This paper shows the feasibility of using a two-position OLS for solving problems of operational monitoring, in particular: detection, classification and determination of coordinates of objects.

The two-position on-board monitoring system proposed in the work is implemented on the basis of the following means: methodology for constructing spatially distributed location systems; methods of the theory of data transmission; methods of the theory of high-resolution image processing, using specialized masking and compression algorithms without significant loss of useful information for transmitting data to a joint information processing point; theory of geometric design of a stereo pair; classification methods based on the use of neural networks; methods of semantic segmentation and building a database of observed surfaces and objects.

2. FEATURES OF THE IMPLEMENTATION OF ON-BOARD TWO-POSITION OPTICAL-LOCATION SYSTEMS

If two or more high-resolution optical sensors are used in a computer vision application, then they should be as identical as possible to avoid unnecessary complications [4]. Then the calibration will make it possible to obtain two practically identical copies of the same optical sensor. When using the same optical sensors of the location system and correct calibration, the probability of errors when switching to a single coordinate system is reduced. Therefore, knowing the distance of the base length between the centers of the projections of two optical sensors, it is possible to determine the coordinates of the observed objects.

The structure of the software and algorithmic support of a two-position airborne OLS is shown in Figure 1.

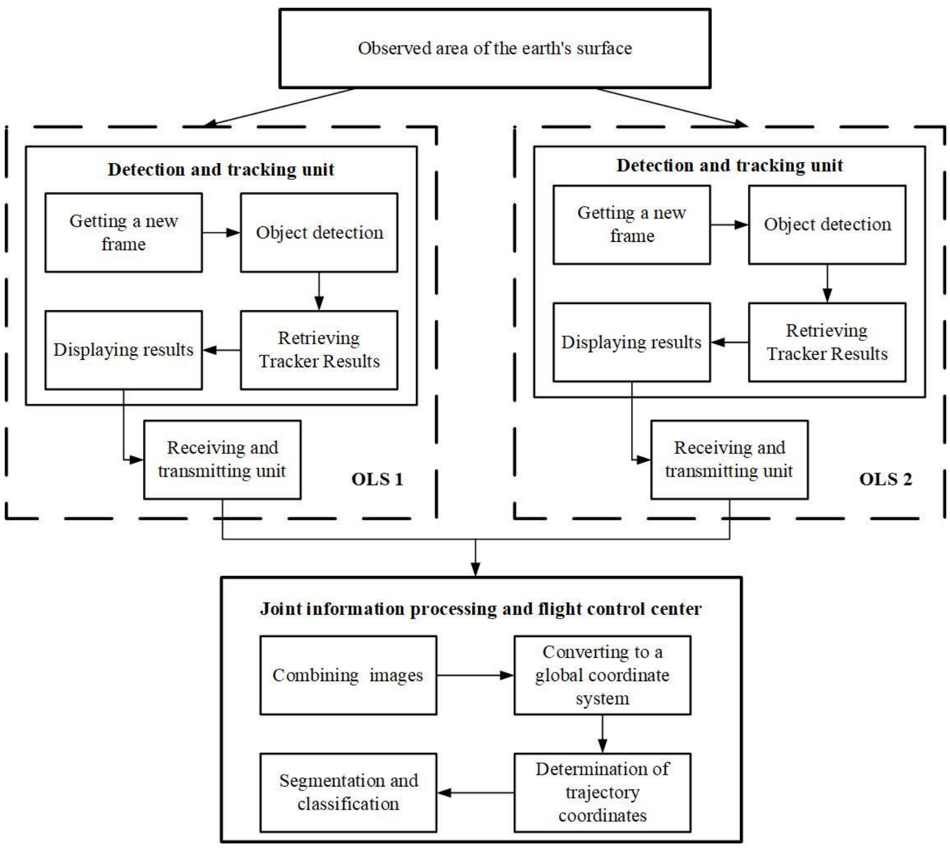


Figure 1. The structure of the software and algorithmic support of the on-board two-position OLS

The operation process of the two-position on-board OLS is as follows - on the basis of each carrier of the on-board equipment, a preprocessing unit is installed, in which the elements of the two-position system of small-sized location systems at the first stage detect and determine the coordinates of the object using an infrared sensor. It should be noted that the use of such a sensor contributes to the fulfillment of the detection task even in unfavorable weather conditions. Further, in the process of selecting a fragment of the image, algorithms for detecting and measuring the coordinates of objects are performed. In addition, a decision is made to detect new objects, and parameters for optical focusing on the detected object are transmitted by infrared sensors [5-8].

Then the two-position OLS receives image frames with the performed operation of subtracting the background, on which the object to be classified is located. Object classification is carried out using a neural network, which is trained on a series of images of the corresponding pre-formed database. Namely, a database of marine vehicles, a database of underlying surfaces, a database of man-made objects and a database of land vehicles. After deciding on the belonging of the detected object, information is issued about its classification to the next stage of processing.

The work of the classifier is implemented in the center for joint information processing and flight control, which can be located either on-board one of the equipment carriers, or on the ground. Before transmitting information, it must be compressed and masked, that is, protected from unauthorized access, in the case of transmission over open channels [9-16], while the choice of the strategy for generating an orthogonal or quasi-orthogonal matrix affects the quality of the procedure [17]. The final decision on the classification of objects is made taking into account the weight processing of the input data, based on quantitative parameters, noise environment, the proximity of the carrier to the classified surface, etc.

3. IMPLEMENTATION OF THE CLASSIFIER

In order to implement the classifier based on the generated database, it is required to organize the collection of information, for example, on the underlying surfaces.

In the case when it comes to obtaining data about the terrain directly from one or several SA, the question arises of a structured presentation of all information received during the flight and reconnaissance of the terrain in real time in order to further transfer it to the center for joint information processing and flight control for implementation of the classifier based on the generated database [18, 19].

In the scientific community, multiple methods of image classification have already been researched [19-23]. The classifier plays an important role in extracting and interpreting useful information from the data set obtained from the aircraft. The classifier is required to perform the following tasks: intellectual analysis of spatial data; effective decision making; creating thematic maps; field research; disaster management; determining the types of observed areas from the aircraft, etc. Methods for classifying objects in high-resolution images can be divided into three main categories: automated; manual; hybrid.

All three categories of classification methods have their own advantages and disadvantages. Most of the methods for classifying objects in images are automated methods. The classification of high-resolution images requires the selection of an appropriate method based on the requirements of the task at hand.

Controlled classification methods based on neural networks are used to classify underlying surfaces and objects such as vehicles, houses, animals, etc. [19, 21].

A classifier based on neural networks is a promising method. The work of this classifier is based on the work of a convolutional neural network, which involves its construction and training. This neural network is a multilayer perceptron (figure 2), which makes it possible to obtain an appropriate response using several input parameters.

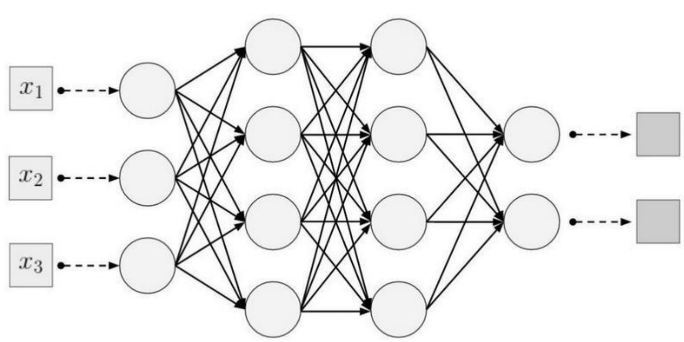


Figure 2. An example of a multilayer perceptron

The errors of such a classifier are determined by running all available observations and comparing the actual identification responses obtained during the experiments with the reference values set at the training stage. The process of training the network is carried out by sequentially minimizing the error of falsely classified zones.

To solve the classification problem using the neural network described above, the search for the value of its weights and thresholds, which are unknown parameters, is performed. This process is the tuning of a model of a multilayer structure, implemented by a neural network, to training data with a known identifier (car, boat, train, or other object of interest) [4, 19, 21].

Thus, the neural network distinguishes features of images, from such as the sea and land surfaces, and ending with smaller objects - land and sea transport.

The following parameters were chosen for assessing the quality of the classifier's work: the proportion of correctly classified images (accuracy) and the area under the error curve (AUC ROC). The share of correctly classified objects in the image is about 87.3%.

4. CLASSIFICATION BASED ON IMAGE SEGMENTATION

In addition, methods are known based on cluster analysis, with the help of which the space of spectral features was divided into distinguishable groups, and the classification of image elements made it possible to simultaneously segment the scene into spectrally homogeneous regions.

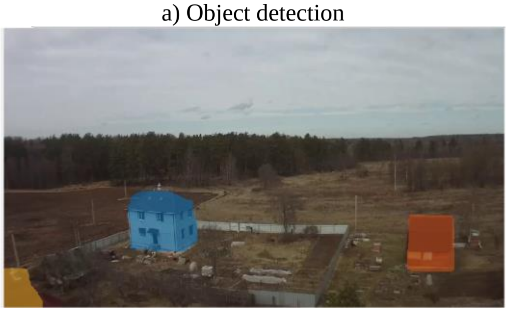
Processing frames of a video stream using semantic segmentation allows you to divide the processed scene of the earth's surface into classes. The expediency of such an interpretation of the frame lies in the fact that an increasing number of applications converts computer data into a graphical form that is more understandable to humans [4, 9].

Semantic segmentation of video frames obtained from SA for the classification of various attributes is a rather difficult task, since the differences are large, one cannot expect that the earth's surface will be homogeneous. Segmentation of these images for use in different applications is challenging, and the process never ends. Thus, there is a need to automate a system that performs this process using a convolutional neural network.

Semantic segmentation allows you to highlight objects. For example, houses will be marked with one color and, accordingly, one "Building" label. Figure 3 demonstrates house detection and selection.

a) Object detection

b) Semantic segmentation



c) Instance segmentation

d) Classification

Figure 3. An example of different types of segmentation

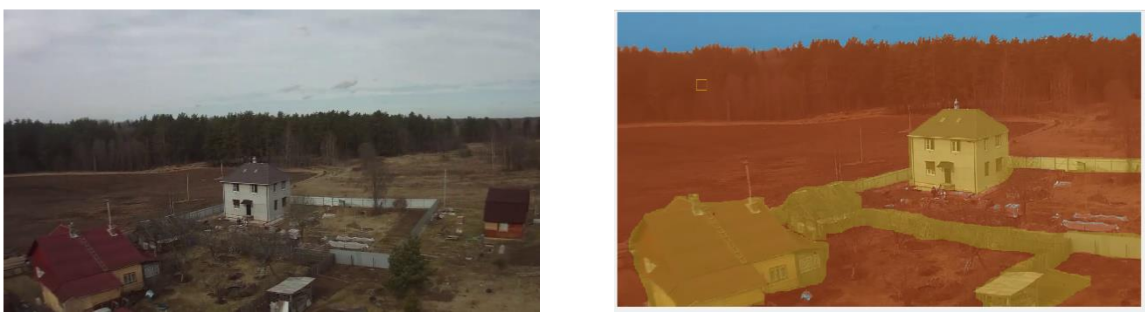
Thus, we can highlight the features of this method, namely: efficiency and simplicity of obtaining the result, high accuracy, ease of implementation.

Figure 4 shows a frame of a video stream and the same frame, after it has been segmented and two classes are selected on it. Namely: sky and earth. The classification of this frame was implemented in the MATLAB environment using a neural network. Figure 4 (b) there is a clear division into the respective classes: sky and vegetation.

(a) Original (b) Segmented

Figure 4. Video stream frame with two classes: sky and vegetation

Segmentation of frames of the video stream (figures 5 and 6) has also been performed, where there is a more saturated landscape of the earth's surface. So in figure 4, two classes were allocated: in figures 5 and 6, three classes.



(a) Original (b) Segmented

Figure 5. Video stream frame with three classes: sky, vegetation and buildings

(a) Original (b) Segmented

Figure 6. Video stream frame with three classes: sky, vegetation and buildings

Thus, experiments were carried out on the segmentation of frames of the video stream with the subsequent classification of the selected zones. The sky is highlighted in blue, trees and vegetation are highlighted in orange, and various buildings are highlighted in yellow.

As a result of this research, the method of semantic segmentation was implemented and considered, followed by classification of the zones of the earth's surface allocated into separate classes based on the captured video stream frames formed by the SA equipment.

In this experiment, we used real video data obtained from the SA equipment. Thus, it was shown that it is possible to classify frame zones based on the use of semantic segmentation and a neural network.

5. CONCLUSION

In the conditions of annually intensifying requirements for new systems for monitoring the earth's surface, the use of two-position optical-location monitoring systems based on small aircraft is expedient for solving problems of detection, classification of observed surfaces and objects, as well as determining the trajectory coordinates of observed objects. The use of such systems increases the overall reliability of the system in the event of failure of one of the carriers of the optical-location system, which is important when performing search and rescue operations in remote areas, as well as when solving problems of searching for people in disaster zones.

Although the use of neural networks for solving segmentation and classification problems is not something fundamentally new, their use in two-position optical-location systems is difficult. Within the framework of this experiment, real video data obtained from the SA equipment were used and the possibility of their combination, semantic segmentation and subsequent classification was shown.

As a result of this study, the method of semantic segmentation was implemented and considered with the subsequent classification of the observed zones of the earth's surface allocated into separate classes from the captured video stream frames, formed by the equipment of small aircraft and combined into one single image.

Such monitoring systems allow for a short period of time to cover vast areas of the observed space; inform the operator about the presence of observed objects in the coverage area in real time; have high efficiency of work in hard-to-reach places and dangerous places for human life, as well as the ability to work at any time of the day.

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