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Information technology for processing digital textures in aerospace monitoring systems

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Abstract. In this article, we developed and described a method for segmentation of informative textured regions of an image that are close in color and structure, consisting of the stages of primary and secondary segmentation that provide the solution to the problem of localization of image areas. Step-by-step processing of the image by the proposed method ensures maximum elimination of localization errors in false regions. In addition, the transition from one processing step to the next decreases the analyzed amount of information, namely the area of segmented image areas. In order to reduce the time during the practical implementation of the method, it becomes possible to parallelize the processing and solving problems in a time scale close to the real one. The input parameters are an aerial photograph, a priori information about the areas to be segmented, and meteorological and navigation-technical conditions for aerial photography. Output parameters are images with localized informative areas.

Key words: image, texture, pixel, aerial image, digital matrix, texture models, information system, method of segmentation, digital image correction

INTRODUCTION

Currently aerospace monitoring with the usage of aerospace pictures is widely applied in the study of natural-territorial systems. The modern term "monitoring" refers to the systematic observation, analysis and assessment of the state of environment, its change under the natural evolution and human economic activity influence, as well as the forecasting of these changes for management and control purposes. Automated image processing of the Earth's surface allows effective solving of scientific and applied problems in the field of cartography, research of the natural environment, oceanology, search and development of minerals, agriculture, forestry and many other areas [1-3].

by certain properties and connected by a certain bond, the parameters of which are constant and determine the nature of the given texture [4,5].

One of the most complex and relevant problems of computer images processing is solving the task of segmentation of such textural areas of image processing

Aerospace images obtained as a result of aerospace monitoring are overwhelmingly a combination of textural areas of natural origin and artificial objects. In the theory of image processing texture is a structure characterized by the presence of a repeating "pattern" consisting of some homogeneous areas of approximately the same size (Fig. 1).

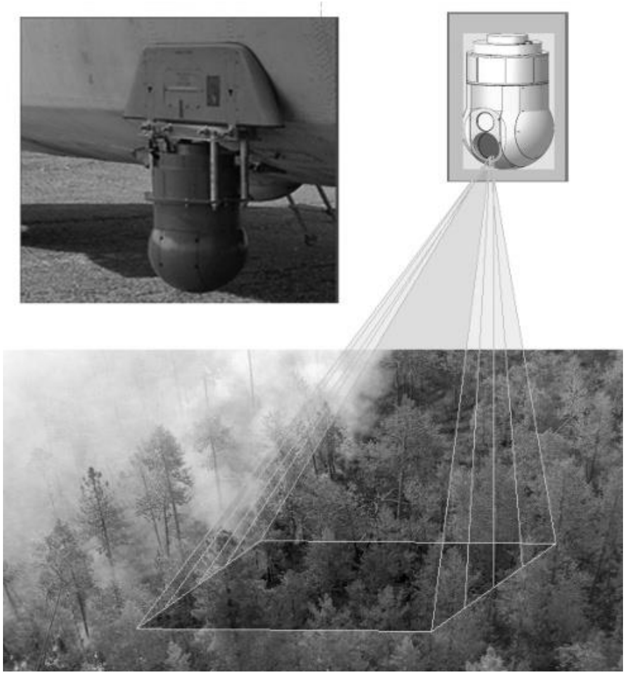

Fig. 1. Optoelectronic system of aerospace monitoring

A photograph of a brick wall, an aerial photograph of city blocks and a cosmic image of a summer tundra site with numerous round lakes are examples of a textural image. In other words, the texture (in Latin texture - fabric, structure) is a kind of organized surface area consisting of elementary areas characterized as natural objects, in particular areas of vegetation, which often occupy a significant part of the aerial photo (Fig. 2).

The information provided above proves the relevance of the operational processing and operational analysis of the aerospace monitoring data problem.

Fig. 2. Images of aerospace monitoring which contain natural objects

OBJECTIVES

The purpose of the research is the development effective methods of automated processing of the earth's surface images.

This paper is devoted to the actual problem of computer image processing: the development of methods for segmentation of textured image areas. The solution of this problem can be used in cartography, mineral exploration and many other areas.

FORMULATION OF THE RESEARCH PROBLEM

By a digital aerial image we mean a two-dimensional digital photographic image that displays data that the user needs. Digital aerial images are formed during registration upon scanning systems with air carriers [6-9].

For each unit of the analog image area, the average density of the shading and a numerical value corresponding to this density are calculated. The result of such an operation is a digital matrix. Then, the digital matrix on the display is converted into visible image elements - pixels. Thus, the visible image is composed of individual pixels, colored in tones of the color scale according to the numerical values given to them.

The pixel of the digital image is optically homogeneous and there are no separate elements inside it. The geometric dimensions of the digital image are limited by the characteristics of the forming system and the parameters of the photo-recording system. Analysis of the literature [10-16] has shown that from the mathematical representation point of view the digital image is a two-dimensional function f(x,y), where x and y are spatial coordinates, and f is the brightness for each pair of coordinates, also called the intensity or color of the image at the point with these coordinates [17].

The digital image f(x,y) can be represented in the form of a matrix with dimensions MxN. Values (x,y) are discrete quantities. For convenience and clarity, the coordinate values are taken as integer values. The origin is the upper left corner of the image, which coordinates are $(x, y) = (0,0)$. The next point in the first line of the image has coordinates:

$$(x, y) = (0,1) \text{, and } x \subset [0, N-1], y \subset [0, M-1],$$

as shown in Fig.3.

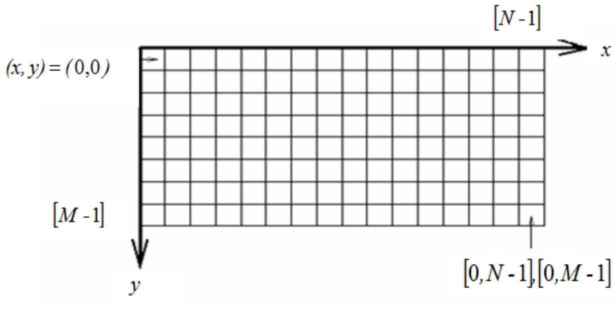

Fig.3. Representation of aerial images in the coordinate system

DEVELOPMENT OF THE STRUCTURE OF SOFTWARE AND HARDWARE TOOLS FOR IMAGE PROCESSING

Let's consider the basic information limitations of the system in question:

- input data are aerial photographs, a priori information on the areas to be segmented, and meteorological and navigation-technical conditions for aerial photography;
- output parameters are images with localized informative areas.

It is believed that the system in which aerial photographs obtained as a result of monitoring the Earth's surface are processed can be represented by three subsystems:

- image pre-processing subsystem;
- a subsystem for setting and adjusting the parameters of the information system;
- final image processing subsystem.

Let's highlight the main components of the image handling process [18]. At the preliminary stage, the operator analyzes the navigational, technical and meteorological conditions of the survey and selects algorithms for image preprocessing. The input image (aerial photography) enters the image preprocessing system.

The image preprocessing subsystem is designed to implement algorithms for improving the quality of the input image. It includes image filtering software modules using median filtering masks, averaging filter, intensity control and other image parameters. In parallel to the preprocessing operation, the parameters of the survey conditions are entered into the parameter setting subsystem.

In the parameter setting subsystem, a set of characteristics of informative areas is formed, taking specified classes and shooting conditions into account. The database for setting parameters contains reference descriptions of classes of textures (as vector sets of features). The parameter adjustment subsystem performs image processing and analysis to obtain a feature vector, taking image acquisition conditions and shooting conditions into consideration. As a result of complex processing, an image with localized (marked with lines) informative areas is created.

For further analysis of the images characteristics, a set of operations is used to improve the perception of the image by the observer, or (if such a task arises) to convert it into another image more convenient for machine processing [19].

Aerial images of the same terrain object can differ by such criteria as shooting conditions, illumination, noise, etc. In case the processing system input receives images which do not meet the requirements, the result of the algorithmic operations may not be correct.

Let’s consider the most significant factors of the flight of an object performing the aerial photography, affecting the resulting image quality.

The height of aerial survey. The spatial resolution of the image depends on the height. The larger it is, the less resolution, which makes it difficult to recognize.

Influence of the atmosphere. When aerial photography is made from high altitudes, optical radiation carrying information about reconnaissance objects passes through the atmosphere. The smaller the size of objects the more the atmosphere reduces the contrast between them. If, under the influence of the atmosphere, the contrast of informative areas decreases so much that it becomes less than the threshold contrast of the optic-electronic aerospace monitoring system, such areas will not be displayed on aerial photographs.

Change in the magnitude of the illumination of the Earth. The illumination of the earth's surface depends on the height of the sun above the horizon.

Linear and angular movements of the aircraft, as well as the vibration of the aircraft, lead to the image shifts in the plane of the aerial photograph, which leads to a deterioration in the sharpness of the image.

Let us outline the main methods of preliminary image processing used to eliminate or correct flight factors for digital aerial photographs. Digital image correction: elimination of the non-linearity of tone transfer function, image sharpness enhancement, and geometric correction. Brightness transformations of the image: change of contrast, elimination of noise, and underlining of borders.

Depending on the tasks of preliminary processing, appropriate image processing methods are used to solve them. To increase the contrast of the image, the histogram of the brightness values is modified for its best display; filtering, quantization of the image by brightness, etc. Weak contrast is the most common property of remote sensing images due to observation conditions, limitation of the reproduced luminosity range, etc. The contrast task is also associated with improving the coordination of the dynamic range of the image and the screen on which the visualization is performed. The noise is caused by various factors: thermal effects, detector failure, interactions between electronic components of the imaging system, sampling errors, transmission errors, etc. Noise in the image appears in a variety of forms and is often difficult to simulate, so many methods of noise reduction are special which makes it convenient to divide the types of noise by category and generalize the descriptive noise models.

As most types of noise occur in the detectors themselves or in the electronic components of the imaging system, their characteristics are determined in individual image pixels or within scanning lines. Therefore, trying to eliminate the noise before any oversampling of the image is better, as oversampling will "smudge" noise into neighboring pixels and lines, which will only make the filtering more complicated in the future. It is assumed that the input images can be distorted by three kinds of noise: normally distributed noise, impulse noise of the form "salt-pepper" and multiplicative noise.

In a normal noise distribution a random variable $N(0,q)$ with a mathematical expectation equal to 0 and a variance q characterizing the noise amplitude is added to each pixel of the original (noiseless) image.

Fig. 4 portrays the results of adaptive median filtering application for removing the "salt-pepper" noise of high intensity. Fig 4a shows us the input aero photography noisy with gauss noise. Fig 4b shows us the picture distorted by the noise of the "salt-pepper" type. Fig 4c shows us the picture noisy with multiplicative noise. Fig 4d shows us the picture after applying Gaussian filtering to it in order to remove the noise.

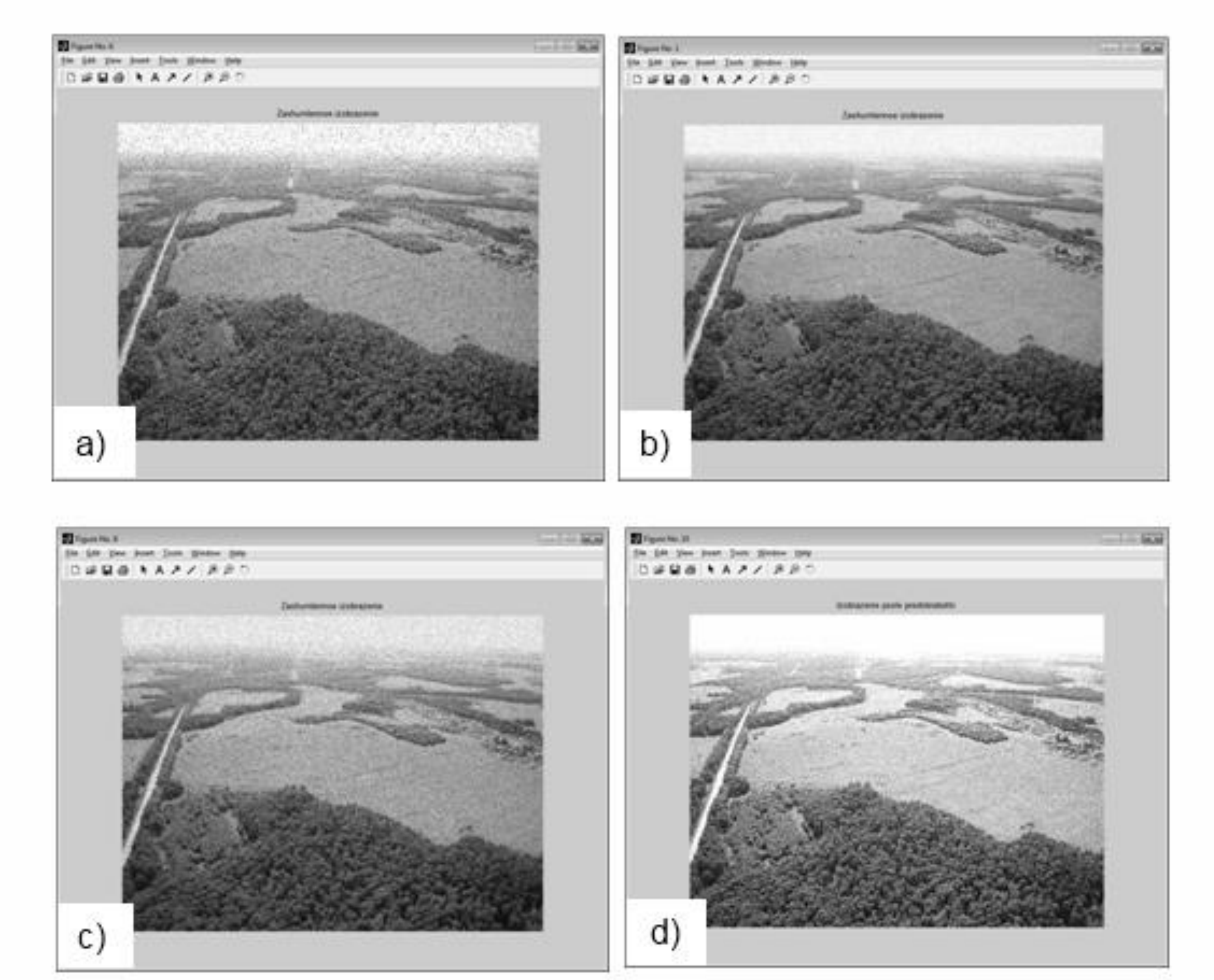

Fig. 4. Images before and after preprocessing in order to remove the noise: a) – image noisy with Gaussian noise; b) – image noisy with the "salt-pepper" type noise; c) – noisy with the multiplicative noise; d) – image after preprocessing

Impulse noise, referred to as a "salt-pepper" noise in the English literature, occurs when the elements of the photo or video camera matrix are not functioning correctly (failing). Multiplicative noise (speckle noise) is formed as a result of coherent superposition from spatially random sources of scattering. Scattered waves are superimposed on each other, thus causing speckle noise in the image. Methods and algorithms for preliminary processing, depending on the source data, are selected by the operator. Thus, as a result of preprocessing, we obtain an image prepared for the segmentation of texture areas, which increases the method efficiency.

Among the conditions of photography, the most significant factors are: the time of the year (summer is the best one), the time of the day (the best one for the atmosphere state is the time before dinner), the humidity of the objects and the air haze, the angle of the picture and the slopes of the terrain. Under the influence of the inclination angle of the aerial photograph, linear and angular distortions of the image appear in the picture. The terrain also causes the displacement of the aerial photo pixels. Linear displacements of pixels on aerial photos, caused by the effect of the inclination angle and terrain, lead to distortions in the segments length that limit the areas of the image sections. Among the physical properties of the photo image, the original image resolving power and contrast and the degree of contrast of the resulting image are the ones which predetermine the physical possibilities of its interpretation and have a decisive overall impact on its decipherment [20].

OVERVIEW OF SOFTWARE AND HARDWARE IMAGE PROCESSING DURING THE AEROSPACE MONITORING

Currently, when designing and developing systems for complex analysis of aerospace monitoring images, it is advisable to use modern matrix processors, which significantly enhance the efficiency of image processing in solving such problems as data compression, image segmentation, encoding and decoding, and image identification and deciphering.

Analysis of the existing software and hardware systems has shown that the NeuroMatrix family processors are the representatives of a new class of vector-pipeline DSPs and they can be effectively used in image processing tasks. They are distinguished by the high processing capacity of large data streams with relatively small hardware costs and low power consumption, as well as the prospects for further increasing the processing power of the family processors due to the deepening of the pipeline and implementation on other technologies having smaller topological design standards [21,22].

Thanks to the hardware support of matrix-vector operations and the opportunity for productivity increase, the NeuroMatrix processors can be applied for a wide range of problems in such areas as video processing, pattern recognition, radiolocation, telecommunications, navigation and plenty of others. Thanks to the built-in tools for multiprocessor systems construction they can be used as basic blocks for creating parallel computing systems. So, using modern software development tools oriented at the NeuroMatrix family processors usage allows us to create highly efficient systems of aerospace monitoring images processing.

Based on the conducted studies, a method for segmentation of aerial photographs texture areas, schematically shown in Figures 5 and 6, can be proposed. As shown in Fig. 5, segmentation according to statistical characteristics leads to the intersection of texture areas belonging to different classes [23]. This indicates the presence of areas close in color and structure or otherwise, areas of intersection in the image.

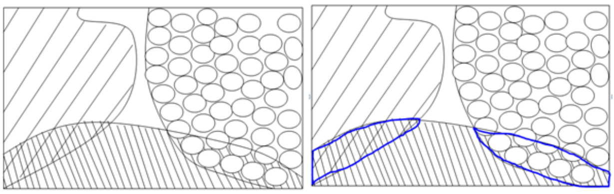

Fig. 5. Schematic result of primary segmentation

In this regard, to refine the boundaries of texture areas, the secondary segmentation stage is implemented based on the root-mean-square deviation values of the image matrices of the texture regions before and after applying the discrete cosine transformation. At the secondary segmentation stage only the intersection areas are processed. Schematically, the result of the secondary segmentation is shown in Fig. 6.

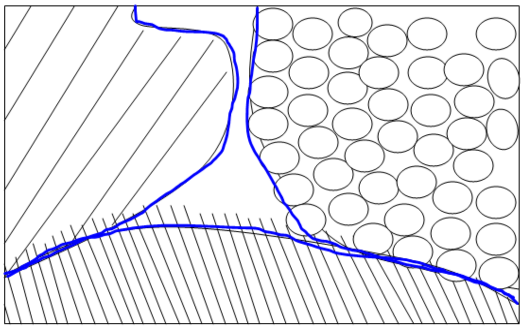

Fig. 6. Schematic result of secondary segmentation

After performing the secondary segmentation stage, the operator decides whether to perform the next step - either refinement of parameters for more accurate segmentation of areas, or transition to the localization stage of the selected areas. The result of the method is an image with localized texture areas.

CONCLUSIONS

In this article, we developed and described a method for segmentation of informative textured regions of an image that are close in color and structure, consisting of the stages of primary and secondary segmentation that provide the solution to the problem of image areas localization. Step-by-step processing of the image using the proposed method ensures maximum elimination of localization errors in false areas. In addition, the transition from one processing step to the next decreases the analyzed amount of information, namely the area of segmented image areas. The result of the method is the localized areas of the sought-for informative textural regions.

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