A Method for Digital Processing of Bitmap Images

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Abstract—A method for processing of graphical information is proposed. The method makes it possible to code contour images with the use of complex numbers unambiguously defined by the image shape. Mapping of a noise bitmap image onto the complex plane is studied. The possibility of solving such recognition problems as object identification and determination of the orientation of a figure in a plane is demonstrated.

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INTRODUCTION

Investigation of efficient digital methods for transmission, processing, and storage of graphical information in radar, telecommunications systems, and computer networks is a topical problem. Since digital transmission (or storage) of graphical information involves algorithmic coding and subsequent decoding, these operations are used in image recognition and reconstruction procedures, which are implemented via comparison of the coded image with some reference image. Digital processing methods are applied to discrete signals, which, as a rule, are the result of optimum spectral processing of analog information with digitization according to Kotelnikov [1].

Recognition of any objects or scenes requires the development of special algorithms. In this case, there are no universal recognition algorithms. All recognition methods can be divided (with some degree of conditionality) into two large groups. Historically, methods based on the application of geometric and topological features of considered objects were developed first.

Later, the second group of methods appeared, in which the concept of the feature space is used and processing of object images (including recognition) is performed in this space. This group comprises methods based on the fractal approach [2] and methods involving Fourier expansion [3], wavelet representations [4], and holographic image representation [5].

The problem of recognition of images and scenes is solved via various complex methods. In correlation analysis, the object characteristics are compared with preprepared characteristics of reference images. Simultaneously, the problem of the influence of the object distortions on the invariance of the output correlation peak with respect to different variations of the recognized object is solved.

One of the developed methods for solution of this problem is based on the correlation analysis of images with the help of specially selected invariant correlation filters with linear phase coefficients. This approach consists in the following: The 3D image of the reference object is replaced with a synthesized effective reference object that contains information on possible states of the recognized object. This synthesized object is formed for the reference object via replacement of its 3D image with the Fourier spectrum along the spatial coordinates. This replacement is performed for several measurements of the initial reference object: for its small rotations or scale variations. For each measurement, an individual Fourier spectrum along spatial coordinates is formed. Then, a composite filter is formed from the set of images weighted by the set of coefficients of the Fourier spectrum along the spatial coordinates as a linear combination of the linear phase coefficients for all initial reference images [3]. Another possible approach to recognition of the graphical image of an object is the use of wavelet analysis.

A new direction related to the second group of methods is the application of fractal analysis methods; the use of these methods in solution of recognition problems was first considered in [2]. Algorithms of fractal image recognition are based on the application of the paradigm “topology of an object—fractal dimension of an object.” The methodological basis of these algorithms is the rejection of topological constants and the description of the object classes in terms of different fractal dimensions (for example, Hausdorff dimension $D$ or the signatures of dimensions). The a priori space of deterministic or probabilistic features is determined through a dynamic test. The choice and preparation of the test material for experimental studies of the recognition process considerably affect the validity of the results.

The approach based on the theory of iterative transformations is efficient. This method of coding the fractal blocks is based on the assumption that the image redundancy can be efficiently used by means of self-
transformation of blocks. The processing algorithm is based on coding of any given original (initial) image by a special transformation that creates the sequence of images converging to the fractal approximation of the initial image upon iteration of any initial image. The requirements for this transformation are as follows: It should be contracting in the metric image space with metrics $L_2$, it should preserve the original (initial) image nearly invariantly, and the complexity of this image should be smaller than the complexity of the initial image [6].

Fractal coding algorithms are more efficient. However, known algorithms of fractal representation have long coding times. More complex processing methods related to the object-recognition problems (for example, separation into classes, recognition of scaled and rotated objects) and to separation of objects in the presence of an underlying surface, noise, and different types of interference may be proposed in the future on the basis of the methods of digital coding of graphical information.

1. METHOD FOR CODING OF GRAPHICAL INFORMATION

A method of representation of (bitmap) contour images that is based on coding of the position of neighboring pixels in the sliding measurement window is proposed for efficient processing of graphical information. This 2D coding allows representation of any contour image in the form of a complex number, a feature that allows application of the corresponding mathematical tools.

This method can be considered a variant of the fractal approach based on the creation of a character set from the complete set of primitive elements (square or rectangular matrices of given dimensions). In this method, the complete field of an image is scanned and the distribution function with respect to the complete set of matrices is established for the studied image. Then, the analysis based on the comparison of the results and the preliminary data for special test (template) images is performed.

In earlier approaches using the measurement window, the overlapping of nonintersecting matrices in the image field is used. This approach is equivalent to the displacement of the applied matrix at each step by the length of its row. After reaching the end of the image row, whose width is equal to the height of the column of the applied matrix, the matrix is displaced downward by the complete height of the matrix column to the next row of the image. In this case, the motion (displacement) of the measurement window (matrix) is continued from the same edge of the image as that in the previous row. Thus, it is as if the graphical object is transformed into one long row.

In the considered approach, for a given square (or rectangular) image field, the measurement window with the dimensions of the matrix slides successively along the row of the bitmap image, being shifted each time by one cell of the matrix along the row of the image.

After reaching the right edge of the image field, the window-matrix is again displaced to the left edge of the image field and is shifted downward by one cell (a row of pixels). At each step of this operation, the type (number) of the matrix coinciding with the image in the window is registered. After the above operation is performed, the distribution of the image representation over all types of matrices used in the scanning procedure can be constructed.

For performing the coding operation and subsequent processing of the object’s features, it is necessary to perform preliminary preparatory operations. The set of reference objects is determined; these objects are considered during the image recognition procedure. Then, for the complete set of matrices with the chosen dimensions, the distribution function is determined for each template element according to the described image-scanning method. This function shows how many times a particular matrix is found upon successive scanning of the images of each reference object.

Twenty-four figures of different complexity, which were taken from the well-known Tangram Chinese puzzle (Fig. 1) [2], were used as the reference images. The Tangram set includes a square cut into five triangles (two large, one intermediate, and two small triangles), a square with an area equal to the combined area of the two small triangles, and a parallelogram with an area equal to that of the square. These geometric figures can be used to make several hundred primitive silhouettes of different complexity: humans, animals, household articles, toys, numbers, letters, etc. All figures have the same area; therefore, they are the ideal test objects for investigation of the efficiency of different methods for processing of graphical information and for image recognition.

The coding operation is performed in the simplest way for the measurement window comprising a matrix with dimensions of $2 \times 2$ pixels. The coding procedure for obtaining the corresponding complex number is as follows: The entire image is mapped onto a window with dimensions of $2 \times 2$ pixels. In this case, each two successive windows have two common (overlapping) vertical cells. Then, the number of times each matrix is found upon scanning of the entire image is calculated and the corresponding distribution over all reference matrices is constructed.

In the considered case, for the matrices with dimensions of $2 \times 2$, 16 different variants of filling the measurement window (or coding (reference) matrices) are possible; the coding matrices consisting of only 0 or 1