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DESCRIPTION OF THE SHAPE OF THE IMAGE OBJECT

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Abstract. When performing many tasks of industrial control, detection, search, recognition, medical diagnostics and fast transmission of images by unmanned aerial vehicles, the problems of efficient description of the objects of interest occur. The spatial data may have high dimensionality. The paper discusses the methods of compact presentation of the object contour on the basis of successive application of the spatial or spectral encoding of two-dimensional signals. The comparative assessment of the efficiency of compression of the method under consideration and that of the entropy encoding method is presented.

Введение

Efficiency can be obtained by using, for example, the Hadamard transform to represent spatial data defined on a digital grid. Efficiency can be obtained by using, for example, the Hadamard transform [1] to represent spatial data defined on a digital grid. Efficiency can be achieved by using, for example, a Freeman code [2] to represent spatial data defined on a digital grid. The distinctive statistical property of a typical image of a contour is a property of high linear dependence – high correlation of the values of discrete samples. The existence of this property makes it possible to perform the efficient data compression with a zero value of the image restoration error.

Теоретические принципы

The case of processing, where the a priory information is used, is under consideration. The availability of such information opens the opportunities for reducing the computational complexity of the processing, shortening the time of transmission of the necessary data, etc.

Method 1 is spectral. Let us to present the contour image in the form of a random two-dimensional sequence

$$g(x,y) = ((x_0, y_0),...,(x_{M-1}, y_{N-1})), \quad (1)$$

where (x_i, y_i) are the spatial variables and N is the number of pixels of the contour.

The symbol sequence we will write the code sequence as a two-dimensional image

$$\mathbf{C} = (c_{ij}),\ \{i,\ j)\} \in \square^{+}, \quad (2)$$

consisting of implementations of random vectors.

It is known that a certain efficiency of the description of contours is achieved by applying coordinate transformations to the (1). The best minimisation result is achieved when a set of eigenvectors of the covariance matrix $\mathrm{cov}(c_{ij})$ of the two-dimensional Matrix $\mathbf{C}$ is considered as a basis of expansion [3]. The computation of eigenvalues and eigenvectors is a rather laborious task. To random vectors $\mathbf{c} = (c(0),\ c(0),\ ...,\ c(N-1)^T$, of the matrix (2) of size $N \times N$, an orthogonal Hadamard transform can be applied to minimise the data to be used for describing the contour. The computational gain is ensured at the cost of encoding the integer pixel values with Hadamard functions. The Hadamard transform is performed with of Hadamard fast transform. The discrete decomposition of matrix C in a coordinate system, the base space of which is formed by the vectors of the Hadamard matrix, may be written in the form [4]

$$\hat{\mathbf{C}} = \frac{1}{N^2}(\mathbf{HCH}), \quad (3)$$

where $\hat{\mathbf{C}}$ – is the matrix of the transform coefficients by the size $N \times N$,

$\mathbf{H}$ – is the matrix of the Hadamard by the size $N \times N$.

The components of the vectorsof the matrix $\hat{\mathbf{C}}$ are uncorrelated random values and considered as attributes presenting the two-dimensional image. To implement the efficient description of the contour, it is sufficient to use the coefficients of the vectors $\hat{\mathbf{C}} = (\hat{c}_{ij})$ corresponding to maximum dispersions of the set $\{\hat{\sigma}_{ij}^2\},\ \{i,\ j\} \in \square^{+}$. In the field of transforms, the dispersions have the sense of the eigenvalues $\Lambda = (\hat{\lambda}_{ij}),\ \hat{\lambda}_{ij} \in \square$ of the covariance matrix $\mathrm{cov}(\hat{\mathbf{C}})$ [5]. Then the following equation is valid for the two-dimensional:

$$\sum_i \sum_j \hat{\sigma}_{ij}^2 = \sum_i \sum_j \hat{\lambda}_{ij}^2 .$$

In accordance with the distribution of the $\{\hat{\sigma}_{ij}^2\}$ then the volume of input of processing the data describing the contour is reduced. The matrix $\hat{\mathbf{C}}$ are reduced to the dimensions ensuring the restoration of the contour image with a zero mean-square error $\varepsilon = 0$.

Method 2 is entropic. The matrix $\mathbf{C}$ reflects the source C with the probabilities p_{ij} of the appearance of elements of two-dimensional space. The sequence $g(x, y)$ may be considered as an output of a source without memory with the known entropy value. The knowledge of the distribution (p_{ij}) makes it possible to obtain the entropy value, assess the maximum possible efficiency of description by the optimum entropy encoding method. Since the entropy value does not depend on the symbol sequence order, we will write the code sequence (1) as a two-dimensional image (2) $\mathbf{C}$.

It is assumed that the elements of boundaries of the objects form a connected set with the connectivity component S. In this case, it is possible to achieve the high efficiency of describing the boundaries using the Freeman code. In general, the accuracy of the border description is determined by the size of the grid step and the number of image elements in S [6].

The theoretical principles of the method 2 are illustrated by the example of processing of the segmented image of the contour.

Example of the efficient description of kontour

An image of an object for an effective description of its shape is shown in Fig.1.

The object контура description is implemented by means of the Freeman code with the connectivity component $S = 4$ [7]. The sequence of the code is shown below (lexicographic entry in the form of a table).

Fig. 1. Image of the object of interest

The characteristic of the source is the entropy *H*. The value *H* determines the upper value of the average length *l* of the prefix code, with the use of which you can compress the source. As a result of the entropy encoding of the source *H* by the Huffman code, the resulting value of the code length approaches the value

$$l \Rightarrow H = 0{,}9097.$$

The average length of a Huffman code word is 1.6 bits.

Table 1. Freeman Code Sequence Characters

0	0	0	0	0	0	0	1	1	1	0	3	3	3	0	1
1	1	1	0	0	3	3	3	3	0	1	1	1	0	0	0
0	0	0	3	2	2	2	3	2	2	2	2	3	3	3	3
0	0	3	2	2	2	3	2	1	2	2	2	1	0	0	0
1	1	1	1	2	2	1	2	0	0	0	0	0	0	0	1
1	1	0	3	3	3	0	1	1	1	1	0	0	3	3	3
3	0	1	1	1	0	0	0	0	0	0	3	2	2	2	3
2	2	2	2	3	3	3	3	0	0	3	2	2	2	3	2
1	2	2	2	1	0	0	0	1	1	1	1	2	2	1	2
2	1	2	2	2	2	2	2	2	1	0	0	0	0	0	0

Table 2 presents the data on the efficiency of compression of the at the intermediate and final stages of the image processing. The efficiency was evaluated by the compression ratio

$$\eta = V \,/\, V_{\text{cod}},$$

where V – are the costs of description without encoding;
V_{cod} – are the costs of storing (transmitting) the data after efficient encoding: encoding Freeman ⇒ Huffman encoding.

Table 2. Contour Data Compression Efficiency for Method 1 and Method 2

Coding Method	Data Type	Data sitze, bit	Data sitze, bit	Lossless Compresson ratio
Hadamard Transform	4-bit	640	426	≈ 1,5
Freeman Code	2-bit	320		640/320 = 2
Freeman Code ⇒ ⇒ Huffman Code	1,6	256		640/256 = 2,5

Results and their discussion

Experimental studies have shown that the considered methods make it possible to reduce the size of the initial contour data by 1.5 -2.5 times. The effectiveness of the description depends on the geometric characteristics of the contour under study, the magnitude of the correlation between the adjacent pixels of the Freeman sequence.

Coordinate transformations (method 1) are inferior in efficiency to method 2. In addition, they have computational cost (3).

Conclusion

1. The features of the algorithm for the point numerical encoding of images of contour make it possible to use relatively simple encoding algorithms based on the Freeman code and entropy approach for the purposes of compression.

2.The considered method, based on the combination of segmentation, transformation and filtering algorithms, accelerates the process of transmission, processing and signal energy saves.

3. Besides, the shortening of the time required for the information transmission improves the reliability of the system from the information security standpoint and reduce the probability of the information capturing by a hacker.

4. The method 2 can be used not only to describe the shape of objects, but also to solve the problems of segmentation and classification of objects.

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