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Digital processing of video information of objects by the method of contour-structured lines

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Abstract - *This article describes the developed video compression codec based on the application of the contour-structured lines method, and also presents the results of experiments to identify its practical advantages in digital processing. To assess the reliability of the research results, frames of video sequences of various plots and genres with different redundancy, texture, and mobility of video objects were tested. In this case, both a visual assessment of the image quality and objective metrics of the standard deviation and the peak signal-to-noise ratio (PSNR) were used.*

The proposed complex use of the methods of contour-structured lines and algorithms for segmentation of image processing and the allocation of contours in a monochrome image makes it possible to improve methods of encoding a video stream and compressing video information, which is expressed in an increase in the efficiency of video information transmission, an increase in channel capacity due to the use of hardware and software modules of processing transmission devices data, compression of the video stream, codecs, and improvement of the video surveillance system of various objects.

Key Words: video data, codec, algorithm, image compression, pixel, quantization, information processing, matrix, image contours, filter.

1.INTRODUCTION

In the world, special attention is paid to the development of methods and the improvement of systems for processing information resources. At the current level of development of information and communication systems, the issues of digital processing of video information of categorized objects that are of great strategic importance are becoming especially relevant. In this aspect, if the total amount of data was 0.16 Zettabytes (Zb) in 2006, and reached 1 Zb in 2016, then by 2025 this figure will reach 163 Zb. A fifth of all data by 2025 will be considered critical, that is, this information will affect the life and safety of people, the international situation, and peace on the planet.

All over the world, research is being carried out aimed at increasing the degree of information compression, the development of mathematical models of compression and decompression of information, the creation of computer programs to reduce the volume of video data. In this area, there is a justified need to develop new, more promising compression methods based on modern algorithms for processing video data, the development of computer programs to improve the storage system for video surveillance data. The implementation of these tasks, including the creation of methods and tools for operational processing of information from video surveillance of categorized objects, focused on reducing the occurrence of criminogenic situations, is one of the important problems.

Along with the intensive development of information and communication technologies, close attention is paid to the protection of important facilities and the widespread use of modern video surveillance equipment, drones, technical means, and devices for collecting, processing, compressing, storing information. In this regard, tangible results have been achieved in detecting and preventing threats, incidents, riots, thefts, theft, criminal acts, etc. To ensure the stability of the activities of categorized objects, the development of a system for operational digital processing of information resources of video

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surveillance, the creation of technical means of visual observation, and computer processing systems for making operational decisions and responding to emerging situations was started. Along with this, it becomes necessary to improve video surveillance tools and methods of their digital processing based on computer systems.

2. RELATED WORKS

Researches by V.P. Dvorkovich, Yu.B. Zubarev, A.A.Gogol, V.N. Bezrukov, M.I.Krivosheev, I.N. Krasnosel'skiy, Yu. Semenova, L. Richardson (USA), R. Gonsales (USA), R. Woods (USA), K. Blatter (Germany), S. Winkler (Holland), M. Adler (UK), P. Gubanov (USA).

3. METHOD

The video surveillance system is an integral part of the security complex. The presence of this type of device assists dispatching services. With the help of video equipment, you can exercise control over strategically important areas in the protected area, timely identify the occurrence of an emergency.

The main goals of video surveillance at protected facilities are:

- ✓ control over checkpoints (entry, as well as entry and exit of vehicles);
- ✓ monitoring the events taking place on the protected perimeter as a whole, as well as in separate internal rooms;
- ✓ conducting situational supervision over the state of the object;
- ✓ round-the-clock monitoring of all movements of employees around the perimeter of the facility;
- ✓ overseeing the work of employees and ongoing production processes;
- ✓ archiving the received video information and storing it on media for a specified time

The execution of the last specified task requires a fairly large amount of memory, often in units or even tens of terabytes.

So, for example, a video stream without compression from a FullHD camera at a rate of 25 frames per second has a frame with a resolution of 1920x1080 and a total number of pixels of 2073600.

Imagine one pixel in the simplest form of color coding - RGB24, where 8 bits are allocated for the components Red, Green and Blue. That is, 1 pixel will occupy 24 bits of information space. Therefore, one 1080p frame would require 49766400 bits or 47.5 Mbps. I would like to have 25 such frames per second. Hence, the uncompressed bitrate is 47.5 x 25 = 1187.5 Mbps = 1.16 Gbps, that is, to store an hourly video fragment from a 2 Mpix IP video camera, you will need 500 GB of disk space, and the bandwidth of the gigabit network will not be enough to transmit the stream [1].

The idea of digital processing of video information of objects by the method of contour-structured lines consists of image segmentation based on the extraction of structural lines of a simplified image and further compression of data segments using traditional methods. The block diagram of the codec was developed, in which the following actions were carried out (Fig. 1.): quantization of the original signal; highlighting contours in the image; transfer of compressed images; receiving a compressed image; filling the inner space of the contours with the corresponding colors; smoothing outlines to improve the quality of the recovered images.

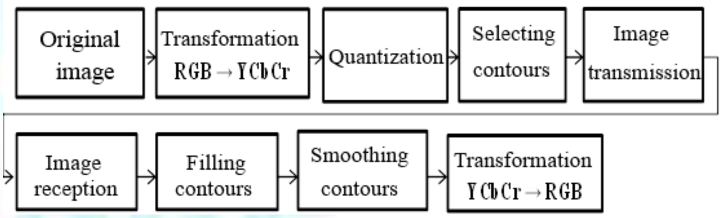

Fig.1. Structural diagram of the video data compression codec based on contour - structured lines

In the process of quantizing the pixels of the brightness plane of the palette by 5-7 bits (in order to obtain a large number of areas with the same image brightness) - this stage is necessary, since in the next step, the contours are selected, and the contours can be selected only for areas that have the same brightness.

In the edge selection unit, the process of edge selection on the image is carried out by superimposing the Sharr matrix, which is the basis for image compression. The imposition of any matrix on the image (or, in other words, image filtering) occurs as follows: sequentially, starting from a point with coordinates (0, 0), all points of the image are iterated over. For each point, the following operation is performed (below, the actions for a 3-by-3-point matrix are considered): a new matrix with the same dimensions as the filter matrix is taken and filled with the brightness values of the image points so that the current point is in the center of the matrix and then calculated matrix response by the formula:

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X = F[i-1,j-1]*A[0,0]+ F[i,j-1]*A[1,0]+ F[i+1,j-1]*A[2,0]+
+F[i-1,j]*A[0,1]+F[i,j]*A[1,1]+ F[i+1,j]*A[2,1]+ F[i-1,j+1]*A[0,2]+
+F[i,j+1]*A[1,2]+F[i+1,j+1]*A[2,2],

where, F is a matrix with the image brightness values, i and j are the coordinates of the current point, A is the filter matrix.

If the X (1) value is higher (lower) than a certain number, the filter is considered to have worked and the point with coordinates (i, j) is marked as important (or not important). Image borders are marked as outlines regardless of filter action [2].

In this work, the Sharr filter is applied, which uses two matrices:

-3	0	3
-10	0	10
-3	0	3

Matrix A1

e	-10	-3
0	0	0
3	10	3

Matrix A2

This filter, unlike other types of filters, such as Roberts, Prewitt, Sobela forms closed contours, which is an important condition for image restoration.

The filter response is determined by the following formula:

$$\sqrt{X_1^{\,2} + X_2^{\,2}} < K, \qquad (1)$$

where K is the response threshold, X1 and X2 are the responses of the matrices A1 and A2, respectively. As a result of this stage, only those points that form contours remain marked on the image [2].

The step parameter is the filter threshold. Points for which the result of calculating formula (1) will be less than the threshold are recognized as not belonging to any contour and are not taken into account, otherwise the brightness value of the point is stored for subsequent transmission.[3] According to the results of experiments, the most effective threshold is set to 8.

This algorithm is designed to highlight contours in a monochrome image, the brightness of which is quantized in accordance with the program settings. When defining the contours, Sharr matrices are used as the most effective. The essence of the algorithm consists in calculating the cumulative product of the image point and its vicinity 3x3 by both Sharr matrices and determining whether this product has exceeded a certain threshold value (set from the program interface) - if so, the point is considered to belong to the contour. This operation is performed for each point of the image.

In the transmission unit, the found contours are transmitted to the receiver in the form of a byte stream, using the following notation: the values of the image points are written to the stream line by line (i.e., first the first line of the image, then the second, etc.), but all three components are recorded only for points belonging to contours, and instead of “empty” points their number is recorded, for example, there is an image line (asterisks - outlines, dashes - “empty” points):

**** ----- * ------ **** - this line will be written as:

[YCbCr][YCbCr][YCbCr][YCbCr][-5][YCbCr][-6][YCbCr]
[YcbCr][YCbCr][YCbCr]

Due to this, the amount of transmitted information is significantly reduced (on the test image, the compression ratio reaches 55%).

The number of "blank" dots is written in negative numbers in order to distinguish it from the value of the color components, which are only positive. This format was created specifically for images compressed by the method of breaklines (contours) [4].

In the test program, the transmission medium is represented by the computer's file system, and the processes of transmitting and receiving an image are performed as reading and writing a file.

In the block for receiving a compressed image (YCbCr palette), the input stream is read and decoded with line-by-line filling of the image with data, while the saved contours are automatically restored. This algorithm is designed to save the contours in the image to a file. The image is saved line by line, however, to increase the compression ratio for pixels located inside the outlines, only their number in the intervals between the outlines is recorded.

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To evaluate the method of contour-structured lines, the original image “Road” in BMP format (resolution 1024x768, volume 2.25 MB) was used.

To assess the effectiveness of the proposed method of compressing the volumes of image data, a number of experimental studies were carried out on the compression of test images of various subjects and genres. At the same time, the influence of the number of levels of quantization of segmented images on the amount of video data compression and the quality of the restored images was investigated (Figure 2.).

32-level quantization

a)

b)

c)

64-level quantization

d)

e)

f)

Fig. 2. Variants of the original (a, d), segmented (b, e) and reconstructed (c, f) images at different levels of quantization

In this case, the filter response threshold is set to 8, and the smoothing filter iteration is 5 [5]. The experimental results are summarized in Table 1.

Table 1.

The results of compression of the image "Road" in BMP format (resolution 1024x768, volume 2.25 MB)

Level quantization	Compressed volume images	Standard deviation (SD)
16	425 Кб	25.3
32	627 Кб	14.5
64	928 Кб	10.4
128	1,25 МБ	8.4

As a result of the experiments, it was found that the higher the level of quantization, the less compression, but the visual quality is better.

4. CONCLUSION AND FUTURE WORK

Digital processing of video information based on the study of the specific features of objects allows for cluster analysis and quantization of pixel values using gradient information, for encoding video data and image segmentation. Methods, principles and algorithms for compressing video information, detecting points, lines and drops using the Hough transformation allow you to quickly prepare video information for further compression by the method of contour-structured lines. An algorithm that provides

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segmentation and compression of video information using the method of contour-structured lines allows you to reduce the amount of operatively processed information without degrading the visual quality of the image.

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