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DECOMPRESSION OF IMAGES ON BASE OF METHOD OF DECODING ACCORDING TO THE AMOUNT OF BIT CHANGES

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The algorithm of restoration of images, based on the method of decoding by the amount of bit changes, is developed. The substantiation of choice of the stages of decompression processing procedure, based on the method of decoding by the amount of bit changes, is provided. The estimation of quality of rebuild images on the base of value peak signal/noise ratio is provided. The results allow to come to the conclusion, that the offered algorithm of compression-decompression of coloured images brings in curvatures in the admissible limits of sensitiveness of human organs.

Keywords: compression, structural code, structural signs, bit transitions, structural group, peak signal/noise ratio.

Розроблено алгоритм відновлення зображень, оснований на методі декодування за кількістю бітових переходів. Здійснено обґрунтування вибору етапів обробки зображення декодером основаним на методі декодування за кількістю бітових переходів. Проведено оцінку якості відновлених зображень на підставі значення пікового співвідношення сигнал/шум. Отримані результати дозволяють дійти висновку, що запропонований алгоритм стиснення-відновлення кольорових зображень вносить у відновлене зображення викривлення у допустимих межах чутливості людських органів.

Ключові слова: стиснення, структурне кодування, структурні ознаки, бітові переходи, структурна група, пікове співвідношення сигнал/шум.

Introduction

By the main function of modern information and communication systems (ICS) is an organization of operative and reliable information exchange between subscribers and decrease of time spending on transmission of data. For reduction of time of spending of data the special standards, protocols and methods of processing, which form information, program and mathematical base of functioning of ICS, are developed.

Main reasons of heightened expenditure of time on transmission of data are the limited capability of the technical equipment of ICS, at first, and secondly are volumes of digital data which are processed and transmited in them.

As known, the biggest part of information is contained in video- and graphic data. Therefore part of information stream on the base of graphics occupies to 90 % from the general stream of information which is processed in ICS. At the same time the essential disadvantage of graphic information is its large volume which can change in a wide range.

Modernization and setting of modern telecommunication hardware is usually highly expensive way to increase the efficiency of functioning of ICS, and consequently except of the improvement of technical base it is necessary to provide the modernization of the information base of ICS.

The integration of technologies of data in the communication systems is the one of variants of such modernization.

Thus one of major tasks of modern information theory is the development and realization of new methods of compression, which provide the maximal level of compression with simultaneous minimization of level of distortions in the rebuild informative structure.

In [1] the algorithm of compression of images, built on the base of method of coding on the amount of bit changes (ABC) is described [2]. The algorithm of compression on the base of code of ABC includes the followings stages [1]:

1. The first stage is — preprocessing. The coloured image turns into the format of presentation with a model RGB. In the offered technology the compression of data the transition from the colour model of RGB to the model of YUV is used. This technology of compression does not foresee the use of procedure of enlargement of pixelsls, which results in the considerable losses of quality of image.

Pixels of each component era grouped into blocks 8×8, that is called segments. The segmentation of matrix of image is provided to decline of amount of operations on processing of data in and to increase of degree of coherentness of the processed information.

2. The second stage — transformation. To every segment images the discrete cosine transformation (DCT) is applied. As a result of transformation of matrix of image on a base DCT, the blocks 8×8 of frequencies are got.

3. The third stage — quantum. After the calculation of all coefficients of DCT their quantum is provided.

Every number from the matrices of coefficients of DCT is divided by the special number — coefficient of quantum from the table of quantum, and a result rounds to nearest whole.

As on this stage the quantized segments contain negative values, it is useful to form the matrices of signs by rule:

$$sign_{i,j} = \begin{cases} 0, \rightarrow com_{i,j} \geq 0; \\ 1, \rightarrow com_{i,j} < 0. \end{cases}$$

$sign_{i,j}$ — element of matrix of signs, which gives information about a sign of component $com_{i,j}$; $i = \overline{0, L-1}$, $j = \overline{0, C-1}$, L and C — amount of rows and columns raster of image accordingly.

4. The fourth stage — coding of transforms. It was suggested to plug in technology of compression a coding method which uses the different from statistical algorithms method of coding of transforms of image — method of coding on the base of the amount of bit changes in binary sequence (ABC).

This method of coding refers to the class of structural methods [3] which provide the removal of structural surplus on the basis of value of structural signs: an amount of changes from '1' to '0' $p_{1\rightarrow 0}$ and an amount of changes from '0' to '1' $p_{0\rightarrow 1}$ [2].

Each of 64 numerical values of the quantized transform presents as a 8-bit binary number (every segment is a parallelepiped with length 8 bits and a width and height equal the dimension of segment 8×8). Every segment consists of eight layers.

The task of this stage is to form the sequence number with an ABC method for each of layers of segment on the base of exposure of structural surplus taking into account the structural signs. Thus for a segment 8 codes-numbers will be formed.

The fifth stage — additional compression. On this stage the coding of sequence numbers with the method of RLE is used with the purpose of increase of degree of compression of source image.

Also on this stage with the same principle the coding of content of array of signs *sign* is provided *sign*.

The aim of the article

The aim of the article is the development of algorithm of proceeding of images on the base of method of binary sequences decoding on the base of amount of bit changes (dABC). Thus the tasks of the article are:

– determination of the basic stages of procedure of proceeding of information by a decoder while forming of the decoded flow of data;

– estimation of divergence of the rebuild and initial images.

Algorithm of restoration of images on the base of dABC

The offered algorithm of compression is symmetric, that is why reffering on the structure of technology of compression, described in [1], lets define the basic general stages of algorithm of restoration of images:

1. Decoding of compressed data.
2. Dequantum of image transforms.
3. Inverse transformation of colour components.
4. Presentation of initial image by a colour model.

Lets pass from a formal model to concrete realization.

RLE decoding

In obedience to procedure of coding, described in [2], on the entrance of decoder the next data is given: value of numbers of ABC, value of amount of bit changes in the binary sequences of every bit layer of image matrix, for which a ABC number is formed, matrices of signs, — all are coded in obedience to the method of RLE. Therefore there is decoding of RLE on the first stages of procedure of renewal.

Principle of decoding of RLE consists in the following: if decoder is get a zero (mark), then it means that the sequence of zero elements must be rebuild, length of rebuild sequence is determined by a number which follows the mark, farther a decoder passes to the element which follows the value of lengths of sequence of zeros. If on the entrance of decoder an unzero element is given, then it is written down in the rebuild sequence without changes and decoder passes to the next element.

On this stage with the same principle renewal of next data: to the array with the value of numbers of ABC *NUM*, the array S_ar, which contains the value of structural signs for every bit layer, for which a code-number is formed, and matrices of signs *sign* — is provided.

Decoding after the amount of bit transitions

On this stage the base method of decoding - dABC — is used. The task of this stage is to renew the certain bimary sequence in the structure of image in obedience to a sequence number and proper structural signs. The principle of this procedure in detail is described in a source [2]. lets remind, which component of image structures will be rebuild.

The quantized image is divided on the segments with dimension 8×8. Each of numerical values presents as a 8-bit binary number (thus every segment is a parallelepiped with length 8 bits, and a width and height equal the dimension of segment 8×8). Every segment consists of eight layers. Every layer consists of 8 columns with a dimension in 8 bits.

While coding the ABC sequence number was formed for every bit layer of segments. Consequently on this stage of decoding on the base of every sequence number one of eight layers to the image segment will be renewed. 8 sequence numbers will determine a certain quantized image segment.

The next entrance values are given on the entrance of decoder:

1. The array S_ar with the values of the first structural sign — the amounts of bit changes from a zero to one and from one to the zero.

2. NUM — an array of values of ABC numbers for binary sequences in structureof the bit layers of image.

Structurally this stage of algorithm of decompression can be described by a scheme, represented on fig. 1.

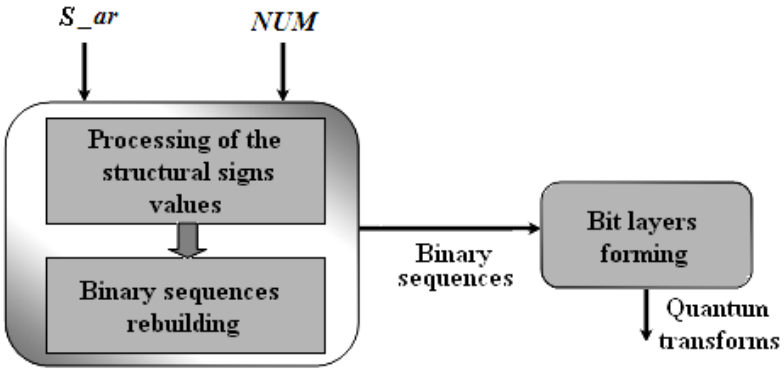

Fig. 1. Structural scheme of the decoding procedure on the base of amount of bit changes

Dequantum

On this stage negative values of component of the quantized segments are rebuild. Renewal takes place in obedience to content of matrices of signs by the rule:

$$com_{i,j} = \begin{cases} com'_{i,j} \to sign_{i,j} = 0; \\ -com'_{i,j} \to sign_{i,j} = 1. \end{cases}$$

$com_{i,j}$, $com'_{i,j}$ — a value of components before the renew of information about its sign;

$sign_{i,j}$ — the element of matrix of signs, which gives information about a sign of component; $i = \overline{0, L-1}$, $j = \overline{0, C-1}$, L and C — amount of raws and columns of raster of image.

Each of 64 elements in quantized segment is multiplied on a number — coefficient of quantum and is rounded to integer.

Content of tables of quantum for component of colour and luminance is described on fig. 2.

17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

Colour

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Luminance

Fig. 2. Recommended tables of quantum

Inverse discrete cosine transformation

To every transformed segment of image the inverse DCT is applied [4]. As pixels are correlated in two directions, while rebuilding the two-dimensional inverse DCT is used, according to a formula:

$$p_{xy} = \frac{1}{4} C_i C_j G_{ij} \sum_{x=0}^{7} \sum_{y=0}^{7} \cos\left(\frac{(2y+1) j\pi}{16}\right) \times \cos\left(\frac{(2x+1) i\pi}{16}\right), \quad (1)$$

$$C_f = \begin{cases} \frac{1}{\sqrt{2}}, f = 0; \\ 1, f > 0. \end{cases}$$

p_{xy} — numerical values of pixels of image, which are contained in segments of imagea dimension $n \times n$, $G_{i,j}$ — numerical values of cells of transforms by a dimension $n \times n$ (in this case n = 8).

Values i and j change in range from 0 to n – 1.

1. Despite of size of image, only 32 values of cosine function are used. They can be calculated once and used in operations with units of information henceforth. Then the calculation of expression

$$\cos\left(\frac{(2y+1)j\pi}{16}\right)\cos\left(\frac{(2x+1)i\pi}{16}\right)$$

will consists only of two operations of increasemultiplication. A double sum (1) will include 128 increases and 63 additions.

2. The analysis of double sum (1) allows to rewrite it as multiplication of matrices $C^{-1}P^{*}(C^{T})^{-1}$ (2), P^{*} — matrix of pixels, rebuild after dequantum, and matrix C :

$$C_{ij}=\begin{cases}\frac{1}{\sqrt{8}}, i=0;\\ \frac{1}{2}\cos(\frac{(2j+1)i\pi}{16}), i>0.\end{cases}$$

Expression (2) will be used for practical realization of this stage.

During procedure of compression on the stage of quantum and DCT there is an irreversible loss of information appears, that is why segments there are some distortions after renewing in initial image.

Rebuilding of the initial structure of image

After inverse discrete transformation a decoder gets the value of intensities of pixels in the components of Y, U, V colour model of image. It is necessary to carry out a reverse transition from presentation the colour model of YUV to presentation the colour model of RGB. Reverse transformation is carried out in obedience to formulas:

$$R = Y + 1{,}371\cdot(V-128),$$
$$G = Y - 0{,}698\cdot(V-128) - 0{,}336\cdot(U-128),$$
$$B = Y + 1{,}732\cdot(U-128).$$

Arter passing from space of YUV to space of RGB, the values of components will lie in an interval 16-235 with a possible values in an area 0-15 and 236-255.

On the last stage of procedure of renewing raws and columns of image repeated to necessary amount to multipleness with eight are rejected.

Structural scheme which describes the basic stages of certain algorithm of restoration of imageson the base of the method of coding according to amount of bit changes, presented on fig. 3.

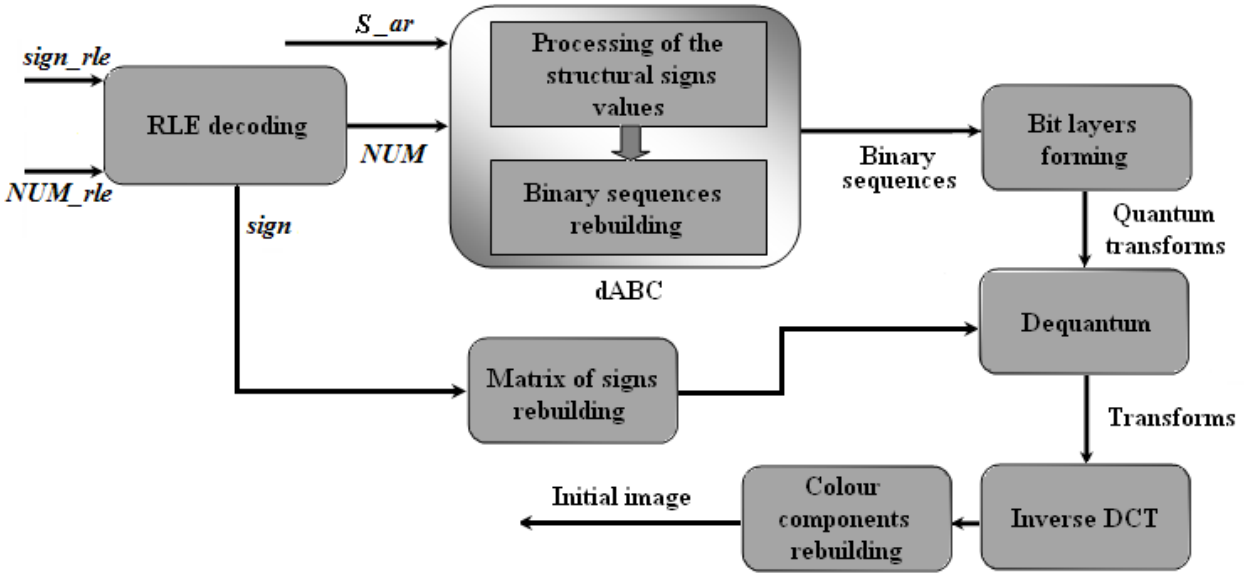

Fig. 3. Structural scheme of the improved algorithm of proceeding of images on the base of the method of dABC

Estimation of quality of the picked up thread image

The index of quality of the rebuild images is estimated on the base of value of peak signal-to-noise ratio (PSNR) (3):

$$d = 10\ell g[((2^{q}-1)^{2}\times L\times C)/\sqrt{\sum_{i=1}^{L}\sum_{j=1}^{C}(x_{ij}-x^{*}_{ij})^{2}}],$$

x_{ij}, x^{*}_{ij} — values of elements of colour matrix of components accordingly for a initial and rebuild images after the compression; L and C — amount of raws and colmns in raster of image, and q — depth of digitising of pixel.

For the estimation of quality of rebuild images, compressed with the offered technology, test continuously-tone (natural) and discretely-tone

(artificial) colour images with dimension 128×128 were compressed and rebuild.

In a software environment the values of peak signal-to-noise ratio and also the average value of peak signal-to-noise ratio for test images of different degree of correlation were calculated according to the formula (3):

Middle-correlated images

art2	66,48 дБ
art9	62,71 дБ
art16	65,84 дБ
nat2	65,91 дБ
nat9	65,53 дБ
nat19	64,12 дБ

Average peak signal-to-noise ratio, $\overline{\delta}$: **65,1 дБ**

High-correlated images

art7	65,55 дБ
art10	65,31 дБ
art20	61,80 дБ
nat1	64,44 дБ
nat3	65,66 дБ
nat5	65,21 дБ
nat6	65,38 дБ
nat8	65,40 дБ
nat10	66,51 дБ
nat13	66,24 дБ
nat15	66,00 дБ
nat18	65,22 дБ
nat20	66,71 дБ

Average peak signal-to-noise ratio, $\overline{\delta}$: **65,34 дБ**

Very high-correlated images

art1	69,26 дБ
art3	63,45 дБ
art4	64,62 дБ
art5	63,81 дБ
art6	68,00 дБ
art8	64,24 дБ
art11	64,74 дБ
art12	66,30 дБ
art13	63,90 дБ
art14	64,31 дБ
art15	66,70 дБ
art17	65,81 дБ
art18	62,54 дБ
art19	64,93 дБ

Very high-correlated images

nat4	66,63 дБ
nat7	66,28 дБ
nat11	66,82 дБ
nat12	65,91 дБ
nat14	66,21 дБ
nat16	64,41 дБ
nat17	64,42 дБ

Average peak signal-to-noise ratio, $\overline{\delta}$: **65,39 дБ**

The results allow to come to the conclusion, that the offered algorithm of compression-restoration of the coloured images in obedience to the value of correlation of peak signal-to-noise ratio brings into rebuild images the losses that are in the possible limits of sensitiveness of human.

Conclusion

The scientific novelty of research consists in the following: the algorithm of restoration of images on the base of method of decoding of binary sequences according to the amount of bit changes is developed for the first time.

In the process of research the basic stages of procedure of restoration of information by a decoder at forming of the decoded flow of data were defined.

The estimation of divergence of rebuild and initial images is provided on the basis of value of peak signal-to-noise ratio.

The results allow to come to the conclusion, that the offered algorithm of compression-restoration of the coloured images in obedience to the value of correlation of peak signal-to-noise ratio brings into rebuild images the losses that are in the possible limits of sensitiveness of human.

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