V. V. Garmash, O. V. Vaskovskiy

APPLICATION OF WAVELET CONVERSION FOR REDUCTION OF BLOCKING – EFFECT

New algorithm elaborated in space – frequency domain is suggested. The given algorithm is based on diade wavelet transformation and on the method of optimum interpolation. Main advantage of this algorithm is its simplicity of realization. "Threshold techniques" are not available in the process of development. The suggested algorithm can improve visual quality of image and peak signal ratio (PSNR).

Key word*: artifacts, images, compression, blocking effect, discrete cosine transformation, wavelet, diade wavelet transformation, image quality.*

Actuality of the problem

Greater part of problems dealing with information processing and analysis is connected with images. The examples of this statement can serve processing and analysis of data of Earth remote monitoring, volume images of the object, obtained with the help of holographic devices, results of application of non – destructive testing and control in industry, elaboration of "industrial vision" systems in robots and modern medical diagnostics systems. For successful solution of the problems of search and identification of the objects, determination of their numerical characteristics, it is necessary to obtain high quality initial image, but the initial quality is not sufficient due to conditions of image obtaining , drawbacks in the reflection, influence of noise etc. [1].

The problem of images conversion to improve their visual quality and information content increase remains very actual.

Analysis of recent research

Discrete cosine conversion (DCC) plays very important role in methods of compression of static images and video information. With the development of videocommunication DCC attracts more attention. International standards organization (ISO) uses it as a standard component for image and video information compression in standards JPEG and MPEG [2].

In accordance with the theory of coding and some standards the image is divided into small p x q rectangular blocks. Generally, the block is selected as square, i.e. p = q. Let us introduce the designation of each block dimension as R x B. Processing of DCC block is known as block discrete cosine conversion (BDCC). The process of division of the whole image into blocks stimulates efficient development of hardware facilities and reduces time of computation. But, since BDCC is used block by block without considering correlation between two neighboring blocks, it leads to the advent of the block artefacts, which appear at boundaries between two neighboring blocks. This phenomenon is known as blocking – effect. it lowers the quality of decoding image. Blocking – effects are obvious when data transmission rate of binary data continues to decrease or in case of greater compression.

Methods aimed at solution of blocking – effect problem in space – frequency area are known. These methods comprise some efficient methods, using wavelet representation and methods of threshold processing. In 1994 the algorithm of wavelets post processing based on noise assumption was suggested [3].

In 1995 two methods of optimization, based on the method of boundary orthonormalized function were proposed [4, 5]. In 1997, the method, based on correlation factor of cross – section scale of overcomplete wavelet representation, transforming the problem in noise clearance was suggested [6]. In 1998, the new method, using wavelet conversion of maximum value modulus was presented [7]. Later, the algorithm, that could adaptively select the threshold for various images was suggested [8].

Main advantage of these methods was the possibility to improve visual quality of the image and peak signal ratio (PSNR) by means of correct selection of the threshold. Main drawback of all these methods, based on wavelet representation – is the necessity of correct selection of the threshold, since only in this case blocking – effect can be considerably reduced.

Problem set up

Existing methods, applied for solution of blocking – effect problem are either too complicated for realization or are not able to cope successfully with the problem of blocking – effect. Hence, it is necessary to continue research, aimed at determination of factors, influencing the reduction of blocking effect and quality enhancement. It is necessary to elaborate method, enabling to reduce considerably blocking – effect and, at the same time, having law computational complexity realization and able to improve the quality of compressed image.

Method of blocking – effect reduction

Let us use diade wavelet transformation and optimum interpolation for processing of each row and column for compressed matrix of "block"-structured image.

Hence the problem of blocking – effect reduction in 2 D image signals processing becomes the processing of 1 D signals.

Wavelet transformation for *f(x)* in 2^j scale and *x* position is determined by the convolution

$$W_{2^j} f(u) = \left(f(x) * \psi_{2^j}(x)\right)(u) = \int_{-\infty}^{\infty} f(x) \frac{1}{\sqrt{2^j}} \psi\left(\frac{x-u}{2^j}\right) dx .$$

It implies, that the scale for continuous wavelet – transformation is discrete during diade sequence $\{2^j\}$, where j belongs to integer set Z.

Diade wavelet transformation is the sequence of functions

$$Wf = \left(W_{2^j} f(x)\right)_{j \in Z} ,$$

where W – operator of diade wavelet transformation.

Let function $\phi(x)$ be corresponding smoothing function of wavelet function $\Psi(x)$ and S_{2^j} be as smoothing operator determined as convolution

$$S_{2^j} f(u) = \left(f(x) * \phi_{2^j}(x)\right)(u) = \int_{-\infty}^{\infty} f(x) \frac{1}{2^j} \phi\left(\frac{x-u}{2^j}\right) dx ,$$

where $\phi_{2^j}(x)$ is determined as

$$\phi_{2^j}(x) = \frac{1}{\sqrt{2^j}} \phi\left(\frac{x}{2^j}\right).$$

Hence, it follows from the above – mentioned definition that more details of *f(x)* are eliminated by S_{2^j}, and the scale 2^j becomes larger.

If original signal is discrete sequence $f = \left(f(n)\right)_{n \in Z}$ and finite energy, let us assume, that fragment $a_0(n)$ of input discrete signal are not equal to *f(n)*, but local average *f* in the vicinity of $t = n$. Thus, $a_0(n)$ can be written by the following formula:

$$a_0(n) = < f(t), \phi(t-n) > = \int_{-\infty}^{\infty} f(t) \phi(t-n) dt .$$

For each $j > 0$ note

$$S_{2^j} f = a_j(n) = < f(t), \phi_{2^j}(t-n) > = \int_{-\infty}^{\infty} f(t) \phi_{2^j}(t-n) dt .$$

Diade wavelet – transformation is

$$W_{2^j} f = d_j(n) = Wf\left(n, 2^j\right) = < f(t), \psi_{2^j}(t-n) > .$$

For each scale 2^J sequence of discrete signals $\left(S_{2^J} f, \left(W_{2^j} f\right)_{1 \le j \le J}\right)$ is called discrete diade wavelet - transformation $f = \left(f(n)\right)$.

Thus, diade wavelet - transformation *(S_2f, W_2f)* as *(Sf, Wf)* for function *f(n)*, where *Sf* expresses low frequency information *f(n)*, and *Wf* – for frequency information *f(n)*.

Decoded matrix *N x N* of *X* image with blocking – effects can be expressed in submatrix form:

$$X = \begin{pmatrix} X_{1,1} & X_{1,2} & \dots & X_{1,n} \\ X_{2,1} & X_{2,2} & \dots & X_{2,n} \\ \dots & & & \\ X_{n,1} & X_{n,2} & \dots & X_{n,n} \end{pmatrix},$$

where $X_{i,j}$ – submatrix *B x B*, *i,j* = 1,2,3, ..., *n* and *n = N/B* and is the integer. Each $X_{i,j}$ is called block. Between contiguous boundaries of blocks there exist block artifacts, such artifacts are called blocking – effect.

Block N x N image X can be expressed as $X = \left(x(i, j)\right), i, l \in \{1, 2, ..., N\}$. Blocking effect increase between each contiguous block boundaries, i.e. between each $j = pB$ and $j = pB + 1$ columns $i = qB$ and $i = qB + 1$ rows, where $p, q \in \{1, 2, ..., n-1\}$.

For the given integer *i* we define row vector $x_i \overset{def}{=} \left(x(i, j)\right), j = 1, 2, ..., N$. Vector xi can be evaluated as discrete signal with finite energy, *j* - element in vector x_i is $x_i(j)$, being equivalent to *x(i,j)* . “Blocking effects” make each two points *xi(pB)* and *xi(pB+1)* discontinual, where *p* = 1,2, ... *n*-1. Thus, there are high frequencies near positions of these points where signal x_i is converted in space – frequency area. Main idea of the method – usage of diade wavelet – transformation for conversion of x_i signal into two subbands, one - low frequency sudbband $x_i^l \overset{def}{=} Sx_i$, which expresses low- frequency information of x_i signal, and the second high frequency subband $x_i^h \overset{def}{=} Wx_i$,.which expresses high frequency information of x_i signal. Futher we use the same transformation for high subband x_i^h, and obtain two subbands-high – low frequency subband $x_i^{hl} \overset{def}{=} SWx_i$ and high – high frequency $x_i^{hh} \overset{def}{=} WWx_i$. Both subbands present low – frequency and high – frequency information of x_i^h signal, correspondingly. After that, we let the signal $x_i^{hh} = \left(x_i^{hh}(j)\right)$ for the given *i* pass across the developed optimum interpolation filter F_{opt}, which can smooth the signal at the boundaries of the block and save original information for other positions. Obtained signal $\overset{-hh}{x_i} \overset{def}{=} F_{opt}\left(x_i^{hh}\right)$ together with high – low frequency signal x_i^{hl} is transformed into new high frequency subband of the signal $\overset{-h}{x_i} = \left(\overset{-h}{x_i}(j)\right)$, corresponding to high – frequency subband of x_i^h signal. Let the signal of new high - frequency subband $\overset{-h}{x_i}$ pass across the same interpolation filter F_{opt} we denote this new signal of high – frequency subband as $\hat{x}_i^h(j) \overset{def}{=} F_{opt}\left(x_i^{-h}\right)$. Taking reverse transformation of this signal with the signal of low – frequency subband x_i^l, we obtain a new signal $\hat{x}_i$, which corresponds to original signal x_i with decreased blocking – effect. The process is shown in Fig 1.

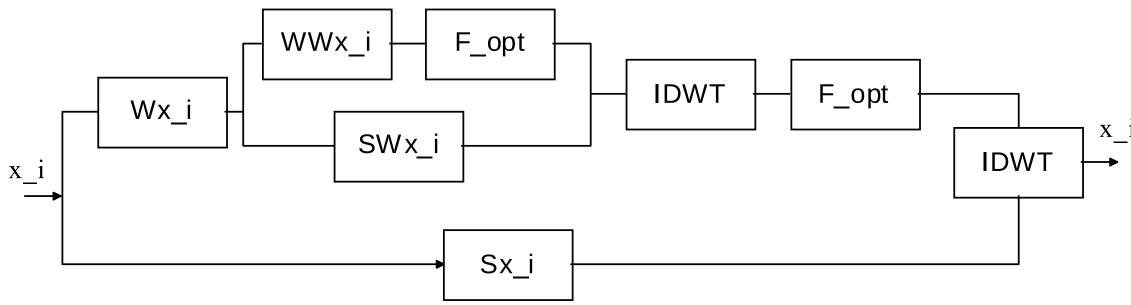

Fig 1. Deblocking process

Results

For the experiment the image, shown in Fig 2was used. The image was compressed according to the standard JPEG with the quality q = 10, PSNR of compressed image 26,5125 dB. After that the method, intended for PSNR improvement was applied to compressed image. New index of PSNR equals 27,0533 dB, the increase was 0,5408 dB. New image is shown in Fig 3, improvement of visual quality is obvious.

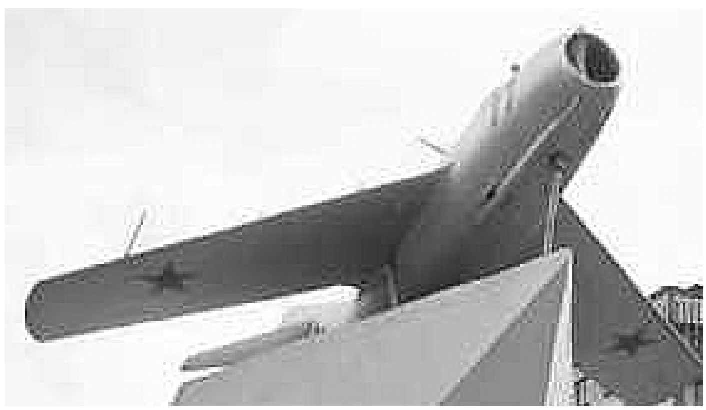

Fig 2 Compressed image (PSNR = 25.5125 dB)

Fig 3. Image after deblocking process (PSNR = 27.053 dB)

Conclusions

New algorithm for blocking – effect elimination, elaborated in space – frequency area is

suggested. The algorithm is based on discrete wavelet transformation and on the method of optimum interpolation. Main advantage of the given algorithm is its simplicity and easy realization as compared with the existing methods. In the process of elaboration there is no need to apply "threshold techniques". Experiments show that the suggested algorithm can improve visual quality of image and peak signal ratio (PSNR).

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Garmash Volodymyr – Assistant of the Department of automation and information measuring instruments.

Vaskovskyy Oleksandr – Master of Sc.(Eng), Department of automation and information – measuring instruments.

Vinnytsia National Technical University.