Sinisa ILIC[1], Mile PETROVIC[1], Branimir JAKSIC[1], Petar SPALEVIC[1], Ljubomir LAZIC[2], Mirko MILOSEVIC[3]

University of Pristina (1), State University of Novi Pazar (2), High School of Electrical Engineering and Computers (3)

Experimental analysis of picture quality after compression by different methods

***Abstract**. In this paper we present experimental results comparing the quality of still Black & White (B/W) images compressed using four methods: JPEG, JPEG2000, EZW and SPIHT. The compression was performed on three pictures with differing levels of detail and density (bit-rates - bpp) using VCDemo software. The quality of the compressed pictures is determined by values of MSE, SNR and PSNR. The values are presented in appropriate tables and diagrams. By comparing the values obtained, we have found the methods that give best results depending on the picture bit-rate and level of detail.*

***Streszczenie.** W artykule opisano rezultaty eksperymentalnego badania kompresji obrazu czarno/białego przy wykorzystaniu czterech metod: JPEG, JPEG2000, EZW i SPIHT. Kompresję wykonywano na trzech obrazach o różnym poziomie detali i różnej gęstości. (**Eksperymentalne badanie jakości obrazu po kompresji różnymi metodami**)*

Keywords: image compression, JPEG, JPEG 2000, EZW, SPIHT, MSE, SNR, PSNR.
Słowa kluczowe: kompresja obrazu, JPEG, JPEG 2000, EZW, SPIHT, MSE, SNR, PSNR.

Introduction

Development of digital images led to the appearance of several methods to store digital pictures. In order to reduce the size of storage needed for high resolution still digital images, it is necessary to perform compression and thus reduce the file size. Compression is the process of eliminating data redundancy or converting data into a form that occupies less storage space.

JPEG

The JPEG (Joint Photographic Experts Group) method is a standard procedure for image compression. It is an established method for the compression of both B/W and coloured images in real (natural) scenes. It is used for the compression of natural images and paintings, but it is not efficient for the compression of text images, freehand and technical drawings. Together with GIF, JPEG is the most popular format for transferring images over the Internet due to a satisfactory compression ratio and support by all web browsers for these file formats.

The JPEG method is used for the compression of still images and it belongs to the group of "intra-frame" compression methods. The similar standard – MPEG is used for the compression of moving images and it belongs to the group of “inter-frame” compression methods. In order to meet the diverse needs of many applications, the JPEG standard includes two basic compression methods: a DCT (Discrete Cosine Transformation) -based method for "lossy" compression and a predictive method for "lossless" compression [1].

The "lossy" compression - called Baseline method - is the most widely implemented JPEG method. In the baseline mode, the image is divided int0 8x8 pixel blocks and each of these is transformed using the DCT. The "power" of compression lies in the quantization of DCT coefficients with a uniform scalar quantizer, zig-zag scanning of the block and entropy coding using the Huffman code.

EZW

EZW (Embedded Zero-tree Wavelet) algorithm enables the progressive transmission of a compressed image. By using this algorithm, it is possible to stop the encoding process at any moment when the desired bit-rate is achieved. In the wavelet decomposition, the image is divided into sets of frequency/spatial hierarchical sub-bands. The important premise of the zero-tree algorithm is that substantial redundancy exists between the "parent" and "child" samples within the sub-band hierarchy [2].

Zero-tree is a quad-tree where the absolute values of the wavelet coefficients in subordinate nodes are less than the absolute values of wavelet coefficients in superior nodes. The affiliation of coefficients to nodes is determined by node level thresholds – there is a threshold value calculated for each level of the tree and absolute values of node coefficients must be greater than their thresholds.

The initial threshold is set to $T_0 = 2^{\lfloor \log_2(\max(|x_i|)) \rfloor}$, and at any level i, T_i is chosen to be $T_i = T_{i-1}/2$. Through the encoding process, the coefficients are scanned and compared to a certain threshold and, according to the predefined rules, each one is assigned a symbol (P - Positive, N - Negative, T – Zero-tree root and Z - Isolated zero) during the first (dominant) pass. In the second (subordinate) pass, quantization of the coefficients assigned to appropriate (P, N) symbols is performed by successive approximation.

The coded information from dominant and subordinate passes is sent to the decoder (or stored on file) and, after re-arrangement of the coefficients, the encoding process is repeated with a lower threshold and the remaining coefficients.

The decision of when to stop the encoding process depends on the desired compression ration or, similarly, the desired bit rate (bit per pixel - bpp) [3]. In this way, the most significant bits are sent first and the coded bit-stream is embedded.

EZW algorithm has very good performance (peak signal to noise ratio - PSNR) compared to other compression algorithms with low bit-rates. It keeps significant coefficients in all levels. The main drawback of the EZW algorithm is its complexity which impacts calculation resources [3, 4].

SPIHT

The EZW algorithm is used as a base for development of large number of similar compression methods. One of the most popular methods is SPIHT (Set Partitioning In Hierarchical Trees). In the original EZW method, arithmetic coding of the bit streams was essential to compress the ordering information as conveyed by the results of the significance tests.

Unlike the EZW, SPIHT doesn't use arithmetic coding. The subset partitioning is so effective and the significance information so compact that even binary un-coded transmission achieves similar or better performance than EZW. The reduction in complexity from eliminating the arithmetic encoder is significant.

The algorithm is introduced by Said and Pearlman [5] for the compression of still images. This method gives better results for larger compression ratios than EZW. The term "Hierarchical Trees" points to quad trees that consist of "parent" and "child" nodes as defined in EZW. Set Partitioning is the operation that divides wavelet coefficients from quad trees into partitions.

The algorithm selects the coefficients $c_{i,j}$ such that, with n decremented in each pass, the coefficients are distributed into three ordered lists - List of Insignificant Sets (LIS), List of Insignificant Pixels (LIP) and List of Significant Pixels (LSP).

After initialization, the following steps are iterated: sorting pass, refinement pass and quantization step update. Through those steps the appropriate significance, sign and most significant bits are sent to the decoder or stored on file.

JPEG 2000

JPEG 2000 has several advantages over the classical JPEG. It enables new features such as superior low bit-rate performance, continuous-tone and bi-level compression, “lossless” and “lossy” compression, progressive transmission by pixel accuracy and resolution, region-of-interest (ROI) coding, open architecture, robustness to bit errors and protective image security [6].

JPEG 2000 was designed to replace the standard JPEG but hasn't succeeded yet. One of the reasons is the high compression and decompression complexity; hence the time needed for decompression is larger also. JPEG 2000 is not supported by as many web browsers as JPEG, but the use of this method is gradually increasing.

JPEG 2000 is a compression method based on wavelet transform (like EZW and SPIHT) that offers advantages over the DCT that is implemented in the standard JPEG method.

In the standard JPEG compression algorithm, a still image is divided into blocks of 8x8 pixels and a DCT transform is implemented on each block - the image is transformed to frequency domain and compression is achieved by quantization and entropy coding. In the JPEG 2000 pre-processing, the image is partitioned into rectangular and non-overlapping tiles of equal size and each tile is compressed independently using its own set of specified compression parameters without regard to neighbouring tiles [6, 7].

The disadvantage of independent block coding would appear to be that it is unable to exploit redundancy between different blocks within a sub-band or between different sub-bands.

On the other hand, wavelet compression transforms an image into wavelet series that can be stored more efficiently than blocks of pixels.

The size of the blocks determines the degree to which one is prepared to sacrifice coding efficiency in exchange for flexibility in the ordering of information within the final compressed bit-stream. This block coding paradigm is adopted by JPEG 2000, based on the concept of Embedded Block Coding with Optimal Truncation (EBCOT) [8].

The coding of code-blocks in JPEG 2000 proceeds by bit-planes where prefixes of the bit-stream must correspond to successively finer quantization of the block’s sample values.

The conditional arithmetic coding of bit-plane primitives with MQ coder is used by JPEG 2000 [9]. The reconstructed images have smoother colour tones and brighter edges where the colour gradients are sharp, and data files are smaller compared to the same level of JPEG compression.

The measures of compression quality

Three of the most used measures for the comparison of image quality are the mean square error (MSE), signal to noise ratio (SNR) and peak signal to noise ratio (PSNR).

A method for the estimation of image quality is needed in order to give a view about how “lossy” compression methods modify image quality. We may treat an image as a matrix whose elements are image pixels.

The estimation process is then based on the calculation of distances between appropriate elements of input and output matrices. In this way, not only comparison of quality of different compression methods is enabled, but also comparison of the results of the same method using different compression ratios.

We denote the matrix A at the input of the compression system with elements a_{ij}, with i∈{1...M}, j∈{1...N}, where M is the number of image elements in the vertical and N is the number of image elements in horizontal direction [10]. MxN is the total number of image elements.

The output of the compression system is the matrix A' with elements a'_{ij}. The distance between the elements of matrices A and A' represents the error or the loss of image quality. Usually, the error is larger for higher compression ratios. A user can set the compression ratio according to the desired image quality, and hence directly influence the data size of the compression image [10].

The total reconstruction error is defined as:

(1)
$$E = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left\| a_{ij} - a'_{ij} \right\|^2$$

The distance between matrices A and A' is frequently calculated using the Mean Square Error:

(2)
$$MSE = \frac{E}{MN} = \frac{1}{MN} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left\| a_{ij} - a'_{ij} \right\|^2$$

where MxN is the total number of image pixels, and the sum is applied to all image elements.

The amplitudes of image elements are in the range $[0,2^n\text{-}1]$, where n is the number of bits needed for binary representation of amplitude of each element in the original image. MSE does not consider amplitudes of image elements (it only considers differences between amplitudes) and it is the reason for introducing the Peak Signal to Noise Ratio:

(3)
$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE} \right) = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}} \right)$$

The variable MAX_I is the maximum amplitude value of image element (pixel). When the amplitude of the image pixel is represented by B bits, MAX_I is 2^B-1.

With n=8 bits/image element we can define:

(4)
$$PSNR = 10 \cdot \log_{10}\left(\frac{255^2}{MSE} \right)$$

Typical values for PSNR for “lossy” compressed images are between 30 and 50 dB.

Material and method

In order to obtain experimental results of reconstructed image quality, we used un-compressed images with an original resolution of 512 x 512, 512 x 768 and 768 x 512 available from the following web pages: http://sipi.usc.edu/database/misc.zip and http://r0k.us/graphics/kodak. We transformed colour images to 8-bit grayscale (by using the formula $Y=0.2126xR + 0.7152xG + 0.0722xB$) then, using images with resolutions of 512x768 and 768x512, we extracted the first 521x512 pixels from each to create new images.

The images are divided into three groups: low level of detail (LL), mid-level of detail (ML), and high level of detail (HL). As details in images can be recognized by large amplitudes in high frequencies, we implemented two transforms on the images: 2D Discrete Cosine (DCT) and 2D Discrete Wavelet Transforms (DWT) using CDF 9/7 wavelet. The result of both transforms are frequency components along x and y dimensions and those components can be divided into four quadrants: (1) upper-left with lower frequencies along both dimensions, (2) and (3) upper-right and lower-left with higher frequencies along one dimension and lower frequencies along the other dimension and, (4) lower-right quadrant with higher frequencies along both dimensions. Then we calculated the mean of absolute amplitude value from components belonging to:

1) DCT in quadrant (1) (dctd);
2) DCT in quadrants (2) and (3) (dctm);
3) DWT in quadrant (1) (dwtd) and;
4) DWT in quadrants (2) and (3) (dwtm).

As expected, the four measures of image detail result in differing values. When comparing two images, it may happen that one image will have more detail than the other using one measure and vice versa using another measure. We selected five images in each group of detail (low, middle and high) with a clear distinction in the range of values of all measures. The list of images with associated measures and criteria for grouping images are shown in Table 1.

Table 1. Images divided into three groups of details based on four measures

IMAGES	dctd	dctm	wvtd	wvtm
Criterion L	**<2**	**<3.5**	**<0.8**	**<1.2**
Gray21.512	0.028	0.222	0.001	0.113
4.2.01	1.451	2.287	0.656	1.076
kodim09	1.680	3.026	0.764	1.195
kodim07	1.960	3.065	0.637	1.032
kodim23	1.936	3.303	0.729	1.121
Criterion M	**3 - 4**	**4.5-6.5**	**1.4–1.8**	**2.0-2.8**
7.1.03	3.187	4.531	1.490	2.074
Boat.512	3.485	5.165	1.733	2.274
7.1.09	3.379	5.288	1.600	2.477
kodim22	3.709	5.951	1.403	2.361
kodim14	3.673	6.427	1.463	2.609
Criterion H	**> 4.9**	**>9**	**> 1.9**	**> 3.9**
5.2.10	6.417	9.198	2.627	3.942
kodim08	4.925	11.258	1.957	4.589
kodim13	8.426	12.431	3.560	5.323
4.2.03	7.977	12.475	3.658	5.391
Numbers.512	15.668	18.267	4.634	6.311

e wanted to see how image detail impacts on the quality of reconstructed images. Compression of images is performed in the VCDemo package [11] by using compression modules. Eight different bit-rates are used: 0.1, 0.2, 0.3, 0.4, 0.5, 0.7 (0.75), 1.0 and 1.5 bpp. At a level abve 2 bpp, near-lossless methods can be used which perform better than the compressions we used in our experiment [12]. For all images, the differences between the original and reconstructed images are calculated by mean square error (MSE), signal to noise ratio (SNR) and peak signal to noise ratio (PSNR).

Fig. 1 shows samples of images that belong to three different groups: a) 4.2.01 (with low level of detail), b) boat.512 (with mid-level of detail) and c) numbers.512 (with high level of detail).

a) b) c)

Fig.1. The images used for experiments: : a) 4.2.01 (with low level of detail), b) boat.512 (with mid-level of detail) and c) numbers.512 (with high level of detail)

Experimental results and discussion

The values for MSE, SNR and PSNR are calculated for each image and each compression method. For images presented in Table 1, we calculated the minimum, average and maximum values for each group and obtained results for MSE for bit-rates: 0.1, 0.2, 0.5 and 1 are presented in Table 2.

Table 2. Minimum, average and maximum values of MSE of reconstructed images in each group of detail levels for selected compression methods for bit-rates: 0.1, 0.2, 0.5 and 1 bpp

method	Image type		0.1	0.2	0.5	1
JPEG	LL	min	208.8	0.3	0.0	0.0
		avg	311.9	37.1	8.7	3.8
		max	360.7	76.9	14.7	5.4
	ML	min	384.7	80.6	39.4	23.3
		avg	459.7	147.4	60.5	29.8
		max	536.4	233.0	90.4	41.9
	HL	min	643.2	378.9	168.4	83.1
		avg	904.8	624.6	289.0	130.7
		max	1365	1087	517.0	178.6
EZW	LL	min	5.8	1.0	0.4	0.5
		avg	48.8	20.4	6.3	2.9
		max	98	42.7	10.0	4.5
	ML	min	76.9	58.4	34.9	18.8
		avg	161.8	102.0	49.2	22.8
		max	245	146.1	65.4	27.0
	HL	min	395.9	269.1	151.2	77.7
		avg	690.7	504.7	242.4	100.5
		max	1277	970.8	414.8	124.9
SPIHT	LL	min	0.1	0.0	0.0	0.0
		avg	27.8	12.5	4.2	1.9
		max	60.5	25.9	6.6	3.3
	ML	min	68.1	49.4	28.5	14.2
		avg	128.5	83.1	38.8	17.5
		max	201.1	126	54.3	21.5
	HL	min	331.7	235.3	122.1	46.2
		avg	609.2	411.8	179.0	67.7
		max	1200	778	273.1	89.8
JPEG 2000	LL	min	0.0	0.0	0.0	0.0
		avg	26.3	12.0	4.1	2.0
		max	55.8	24.1	6.6	3.4
	ML	min	69.9	51.1	29. 7	14.0
		avg	130.6	84.3	39.6	18.0
		max	202.4	129.3	56.6	22.6
	HL	min	331.8	237.8	119.8	41.7
		avg	596.4	404.4	177.3	68.4
		max	1138	759.0	267.0	93.2

From Table 2 it can be seen that, for any bit-rate, MSE values are increasing in images from lower, through middle to higher level of details.

The average values for MSE, SNR and PSNR for each group of images using eight bit-rates and the compression methods JPEG, EZW, SPIHT and JPEG 2000, are given in Table 3, Table 4, Table 5 and Table 6, respectively.

Table 3. The values of MSE, SNR and PSNR by using JPEG compression method

image group	bit-rate (bpp)	0.1	0.2	0.3	0.4	0.5	0.7	1.0	1.5
LL	MSE	311.9	37.1	17.8	11.6	8.7	5.8	3.8	2.4
ML		459.7	147.4	96.5	75.5	60.5	43.5	29.8	18.1
HL		904.8	624.6	448.9	355.5	289.0	203.2	130.7	71.9
LL	SNR [dB]	8.5	21.2	25.9	30.4	31.3	32.7	34.1	35.7
ML		5.5	10.6	12.4	13.5	14.4	15.8	17.4	19.6
HL		5.3	7.1	8.5	9.6	10.5	11.9	13.7	16.3
LL	PSNR [dB]	23.3	36.0	40.6	45.2	46.1	47.5	48.9	50.5
ML		21.5	26.7	28.5	29.5	30.5	31.9	33.5	35.6
HL		18.7	20.5	22.0	23.0	23.9	25.3	27.1	29.7

Table 4. The values of MSE, SNR and PSNR by using EZW compression method

Image group	bit-rate (bpp)	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.5
LL	MSE	48.8	20.4	11.4	8.7	6.3	4.1	2.9	1.8
ML		161.8	102.0	76.6	60.0	49.2	32.9	22.8	12.9
HL		690.7	504.7	354.1	297.8	242.4	140.9	100.5	46.7
LL	SNR [dB]	17.8	22.4	25.1	26.2	27.2	28.4	29.7	31.4
ML		10.3	12.2	13.4	14.4	15.2	17.0	18.5	21.0
HL		6.7	8.1	9.5	10.2	11.1	13.4	14.8	18.2
LL	PSNR [dB]	32.6	37.2	39.9	41.0	41.9	43.2	44.5	46.2
ML		26.3	28.2	29.5	30.5	31.3	33.1	34.6	37.1
HL		20.1	21.5	22.9	23.7	24.5	26.8	28.2	31.5

Table 5. The values of MSE, SNR and PSNR by using SPIHT compression method

image group	bit-rate (bpp)	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.5
LL	MSE	27.8	12.5	7.7	5.5	4.2	2.7	1.9	1.1
ML		128.5	83.1	61.0	48.0	38.8	25.1	17.5	9.0
HL		609.2	411.8	306.2	235.6	179.0	107.4	67.7	31.7
LL	SNR [dB]	23.1	28.3	31.9	35.1	37.3	41.0	42.3	44.2
ML		11.2	13.1	14.3	15.4	16.3	18.1	19.7	22.5
HL		7.3	8.9	10.2	11.3	12.4	14.5	16.5	19.9
LL	PSNR [dB]	37.9	43.1	46.7	49.9	52.1	55.8	57.1	59.0
ML		27.3	29.1	30.4	31.4	32.4	34.2	35.8	38.6
HL		20.7	22.3	23.6	24.7	25.8	27.9	29.9	33.3

Table 6. The values of MSE, SNR and PSNR by using JPEG 2000 compression method

Image group	bit-rate (bpp)	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.5
LL	MSE	26.3	12.0	7.4	5.3	4.1	2.7	2.0	1.2
ML		130.6	84.3	62.5	48.9	39.6	25.9	18.0	9.4
HL		596.4	404.4	302.2	229.8	177.3	106.6	68.4	30.3
LL	SNR [dB]	24.5	27.3	28.8	29.9	30.8	32.3	33.4	35.2
ML		11.1	13.0	14.2	15.3	16.2	18.0	19.6	22.4
HL		7.4	9.0	10.3	11.4	12.4	14.6	16.5	19.9
LL	PSNR [dB]	39.3	42.0	43.6	44.7	45.6	47.1	48.2	49.9
ML		27.2	29.0	30.3	31.4	32.3	34.1	35.7	38.5
HL		20.8	22.4	23.6	24.7	25.8	28.0	29.9	33.3

From Tables 3, 4, 5 and 6 can be seen that MSE values decrease as bit-rate values increase for all compression methods. For lower values of bpp MSE values are significantly higher and vice versa - for higher values of bpp MSE values are significantly lower.

One can also see that the differences in MSE values of any two images are significantly higher for standard JPEG compared with those of JPEG 2000 for low bpp values. However these differences become lower for higher bpp values. Similar conclusions can be applied to the results of MSE values by comparing EZW and SPIHT compression methods.

For all the image groups, results show that the lowest MSE values are obtained for SPIHT and JPEG 2000 compression methods, higher values are obtained for EZW, and the highest values for JPEG. There is a slight difference between the values of MSE for the groups of images with low (LL), middle (ML) and high level (HL) of details using SPIHT and JPEG 2000 compression methods. For the LL group, JPEG 2000 has lower values than SPIHT for all bit-rates. For the HL group, JPEG 2000 has lower values in lower bit-rates while SPIHT has lower values for higher bit-rates. In the ML group, SPIHT has lower values for all bit-rates as presented in Fig. 2. In Fig. 2, Fig. 3 and Fig. 4 the dependence of PSNR on bpp for described compression methods is shown. Each figure presents the dependence for the selected group of images. In this way, the quality of all compression methods applied to images within the same group of detail levels can be seen.

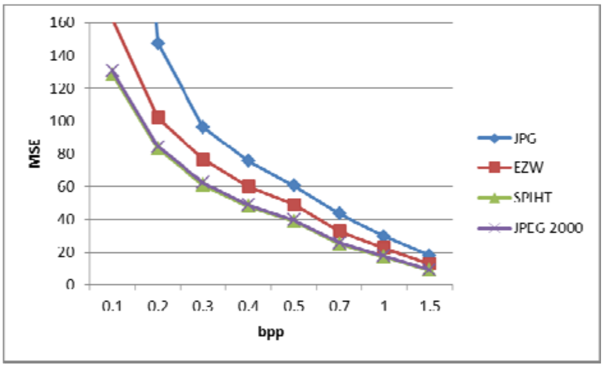

Fig.2. The dependence of MSE on bpp for different compression methods in images belonging to ML group

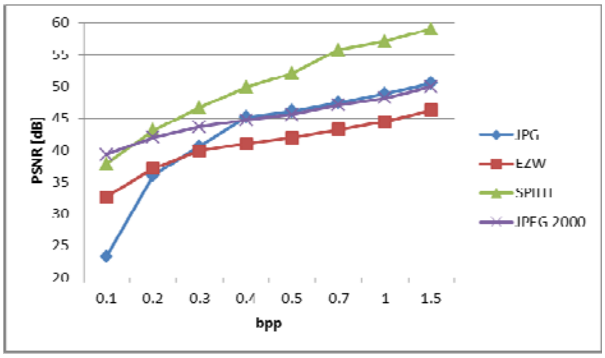

Fig.3. The dependence of PSNR on bpp for different compression methods in images belonging to LL group

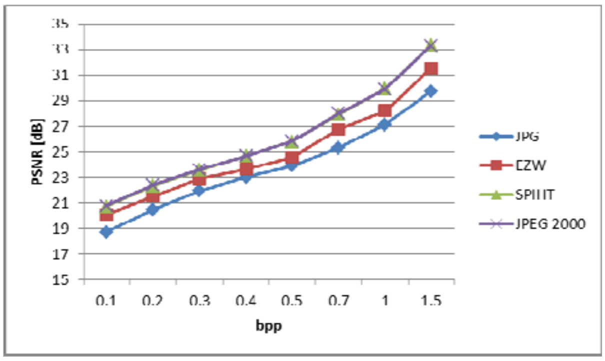

Fig.4. The dependence of PSNR on bpp for different compression methods in images belonging to HL group

Fig. 3 shows that, in images with low level of detail, SPIHT compression method produces the best results for bit-rates higher than 0.2 bpp in PSNR. JPEG 2000 method for bit-rate 0.1 bpp has the best result initially and in higher bit-rates it shows worse results even than JPEG. In bit-rates above 0.3 bpp, EZW produces the worst results.

For the reconstruction of images with high level of detail (Fig. 4), it can be seen that SPIHT and JPEG 2000 methods produce the best results. JPEG 2000 performs slightly better in bit-rates lower than and equal to 0.7 bpp, and SPIHT performs slightly better for bit-rates higher than 0.7 bpp. The PSNR values for EZW are lower than the values of SPIHT and JPEG 2000, and the lowest values are obtained for JPEG.

Conclusion

From the results obtained for the efficiency of chosen compression methods, the SPIHT and JPEG 2000 methods show best results in compression of images with a high level of detail. The standard JPEG method produces the worst results. The PSNR values increase with increase of bpp for all implemented compression methods. The JPEG 2000 method achieved better results on all bpp and for all images compared to the standard JPEG method, especially for lower bpp values (less than 1.0 bit/image element). At lower values of bit-rate, the adverse effects arising from the compression methodology appear. In reconstructed images compressed by standard JPEG method with low bit-rates, contours of blocks become visible. This does not happen in reconstructed images compressed by the JPEG 2000 method at lower bit-rates. At the edges of tiles, produced by the decomposition at the start of the compression process, a blurring effect appears which is less uncomfortable than the contour visibility in JPEG. The same blurring effect can also be produced by the EZW and SPIHT methods. For all compression methods, the lowest values of PSNR are obtained in images with high number of details for all bit-rates.

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REFERENCES

[1] Wallace G. K., The JPEG still picture compression standard, *IEEE Trans. on consumer electronics*, 38 (1992), No 1
[2] Shapiro J. M., Embedded image coding using Zerotrees of wavelet coefficients, *IEEE Trans. Signal Process.* 41 (1993), No 12, pp. 3445–3462
[3] Usevitch B. E., A Tutorial on Modern Lossy Wavelet Image Compression: Foundations of JPEG 2000, *IEEE Signal Processing Magazine*, September 2001
[4] Malnar L., Kosović B., Batan J., Kompresija slike pomoću EZW algoritma, ZESOI, 2007
[5] Pearlman W. A., Said A., New fast efficient image codec based on SPIHT, *IEEE Transactions on Circuits and Systems for Video Technology*, 6 (1996)
[6] Skodras A., Christopoulos C., Ebrahimi T., The JPEG 2000 Still Image Compression Standard, *IEEE Signal Processing Magazine*, September 2003
[7] Rabbani M., Joshi R., An overview of the JPEG2000 still image compression standard, *Signal Processing: Image Communication*, 17 (2002), pp. 3–48
[8] Taubman D., Ordentlichb E., Weinberger M., Seroussi G., Embedded block coding in JPEG 2000, *Signal Processing: Image Communication*, 17 (2002), pp. 49–72
[9] JPEG 2000 Part I: Final Draft International Standard (ISO/IEC FDIS15444-1), ISO/IEC JTC1/SC29/WG1 N1855, Aug. 2000.
[10] Jančić M., Norme za kompresiju mirnih slika, FER, 2002
[11] VCDemo, Delft University of Technology (TU-Delft) Faculty of Electrical Engineering, Mathematics, and Computer Science (EEMCS) ICT group, Delft, The Netherlands
[12]http://cdn.intechopen.com/pdfs/16270/InTech-Effective_video_encoding_in_lossless_and_near_lossless_modes.pdf

***Authors**: PhD Sinisa Ilic, Department of Electrical and Computer Engineering, Faculty of Technical Sciences, Kneza Milosa 7, 38220 Kosovska Mitrovica, Serbia, E-mail: sinisa.ilic@pr.ac.rs;*
PhD Mile Petrovic, Department of Electrical and Computer Engineering, Faculty of Technical Sciences, Kneza Milosa 7, 38220 Kosovska Mitrovica, Serbia, E-mail: petrovic.mile@yahoo.com;
PhD stud. Branimir Jaksic, Department of Electrical and Computer Engineering, Faculty of Technical Sciences, Kneza Milosa 7, 38220 Kosovska Mitrovica, Serbia, E-mail: branimir.jaksic@pr.ac.rs;
PhD Petar Spalevic, Department of Electrical and Computer Engineering, Faculty of Technical Sciences, Kneza Milosa 7, 38220 Kosovska Mitrovica, Serbia, E-mail: petarspalevic@yahoo.com;
PhD Ljubomir Lazic, State University of Novi Pazar,Serbia,Vuka Karadzica bb, 36300 N.Pazar, E-mail: llazic@np.ac.rs;
Mirko Milosevic, Department of audio and video technology, High school of Electrical Engineering and Computers, Vojvode Stepe 283, 11000 Belgrade, Serbia, E-mail: mmoorco@yahoo.com.

The correspondence address is: sinisa.ilic@pr.ac.rs