IJDI-ERET

INTERNATIONAL JOURNAL OF DARSHAN INSTITUTE ON ENGINEERING RESEARCH AND EMERGING TECHNOLOGIES
Vol. 2, No. 1, 2013
www.ijdieret.in

(Research Article)

Analysis of different influence of compression algorithm on the image filtered Laplacian, Prewitt and Sobel operator

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Abstract

In this paper, using the analysis of the objective quality of a static image compression algorithm using four compression: JPEG, JPEG2000, EZW and SPIHT. The algorithms were applied to the original image and the filtered image Laplacian, Prewitt and Sobel operator. Compression algorithms are applied with different values of bit rate (bpp). The quality of compressed images is evaluated on the basis of the values of the mean square error of the signal / noise ratio and peak signal / noise ratio. The obtained results were tabulated and graphed presented. According to the graphics given, comparing of compressions from original image has been made to the image filtered by Lapalcian, Prewitt and Sobel operator, and it is established which compressions give the best results according to bit rate and filtrating operator.

Keywords: compression, Laplacian, Prewitt, Sobel, bit rate (bpp, bit per pixel), peak signal to noise ratio (PSNR).

1. Introduction

The rapid development of technology has enabled the commercial application of digital image processing techniques that until recently were reserved for the well-equipped research laboratories. In such applications, such as video conferencing, video telephony, multimedia systems, processing and record keeping systems for the transmission of television images of standard and high definition, biomedicine, and other procedures have an important role in image compression. Image compression algorithms are essential in order to reduce memory usage and a capacity of telecommunication channels, since it is a transfer or record huge amounts of data needed for the national team image. For example, to store a digital monochrome image resolution of 512 × 512 pixels requires a memory of 256 KB, while keeping color images of the same resolution needed 768 KB. Upscaled memory usage increases proportionally [1], [2].

Due to the high demands for image compression, compression methods are extensively developed last twenty years of research in this area is very intense today. Methods have been developed which can compress the still images up to 50 times without significant impact on the quality of the reproduced image. In the case of image sequence compression ratio can be much higher [1], [2].

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ISSN 2320-7590

The most general classification of all compression algorithms can be classified into two groups: lossless image compression and lossy image compression [1], [2], [3]. Methods of lossless compression of images used in cases where it is difficult or impossible to regain uncompressed image. A second case is when uncompressed image contains some important information that could be damaged by the compression process (for example, medical images). On the other hand, the methods of image compression with losses used in cases where it is easy to repeat the recording process, or when it can tolerate some degree of loss of information (video telephony, television, multimedia systems, etc.).

2. Compression algorithms

2.1 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 [4]. 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 JPEG standard includes two basic compression methods: a DCT (Discrete Cosine

Transformation) -based method for "lossy" compression and a predictive method for "lossless" compression. The "lossy" compression - called Baseline method - is the most widely implemented JPEG method. In the baseline mode, the image is divided into 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 [5], [6].

2.2 JPEG 2000: JPEG 2000 has the advantage over the original JPEG. Allows extraction of various parameters (resolution, pixel fidelity, region of interest, and other components). The foundation of the new JPEG 2000 compression based on wavelet compression, which provides many advantages over discrete cosine transform (DCT) used by the JPEG format. DCT compress image in blocks of size 8x8 and puts them in a row in the file. In the compression process, the blocks are compressed individually, without taking into consideration the neighboring blocks. This is a problem in the compressed JPEG files. With high level of compression, only the most important information's are used in order to convey the most important parts of the image [7].

On the other hand, wavelet compression converts the image into a series of wavelet that can be stored more efficiently than blocks of pixels. Even though wavelets have sharp edges, they are in condition to show a better image eliminating "blocks" of pixels that are common in the DCT compression. Not only because we get a finer color tones , crisper edges where the sharp color transitions, but files of smaller size compared to the same JPEG compression [3], [6].

JPEG 2000 compression involves several stages. First, separate the component images (luma and chroma), and then performs image tiling, or the division of images into blocks and then, after the change of DC level as needed, each block is processed independently. Wevelet transformation applies, then the quantization is performed so that the blocks are encoded by bit planes, and finally entropy coding. When decoding is done scanning each bit plane for each of the components [8]. Quality determines the number of degrees wavelet

2.3 EZW: EZW (Embedded Zerotree Wavelet) algorithm allows the encoding process in which the coefficient transformation is done that there has been a progressive transmission of compressed images. Using this algorithm, it is possible to break encryption encoder at any time in order to achieve the desired data rate. Zerotree coding symbols allow concise position of significant value by creating highly compressed description of the location of lesser value. Zerotree is quad-tree in which all nodes are less than or equal to the square root, which is smaller than the threshold with which we compare the wavelet coefficients [9], [10], [11].

EZW algorithm has good performance if it's compared to other compression algorithms on a lower transfer. It saves significant coefficients on all scales. The main disadvantage of the EZW algorithm is its need for complex calculations, which is a significant burden on resources.

Coder based on EZW algorithm assumes that most of the images has a spectrum with a dominant low frequency components. This implies that the more energy after wavelet transform coefficients will be saved which correspond to these low frequencies, and that value will be higher. Smaller ratios correspond to higher bands, which only add details.

EZW algorithm consists of several steps that need to be done [10]:

- Send decoder some basic information, "depth" of the wavelet transform, the initial threshold or maximum value pixel image, image size etc.
- The first pass or classification coefficients; images are scanned, and on this basis is determined by the type of coefficient.
- Second passage or "finer" positioning coefficients. The purpose of this loop is the positioning of important coefficients in the intervals of the current threshold (which is variable for this loop, decreases) between the threshold and the maximum threshold. Each grade will end up in such an interval, and he is over the middle of the interval assigned to units or zero. On this way every following series must be required during decoding.

Through the algorithm passes until the threshold becomes smaller than unity.

2.4 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 [11], [12].

The algorithm is introduced by Said and Pearlman [13] 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.

3. Operators for image filtering

There are three operators that have been applied to image filtering in this paper: Laplacian, Prewitt and Sobel.

First one, the Laplacian, two-dimensional scalar operator, which is used over the discrete parts of the image. It is therefore independent of the direction of propagation of discontinuities of the image, and it provides a number of advantages in image processing. Therefore, for realization is needed single filter. It is also important to mention that the same results will be obtained if image is first filtered and rotated or rotated and filtered (rotation invariant) [14, 15].

Laplacian is the simplest isotropic differential operator and is given by replacing the partial derivative of the coordinates *(x,y)*. It is implemented by formatting the filter mask: the central coefficient is -4, and 4 are adjacent-1 (90° rot.). Laplacian contains other partial derivative on the main coordinates. If it's diagonally performed, the central one is 8 and all 8- are neighbors to 1 (45° rot.), and if logic is negative central is positive. In this paper is used mask filter -4.

The low-pass frequency range of the image carries a significant portion of energy, but is relatively small but useful from the point of view of the visual image quality as well as for machine vision. On the other hand, the high throughput of the spectrum of image is low energy but has a significant portion of the information for both, human and for machine vision. The main problem of high frequency part is low energy, so this part of the spectrum quickly, "sink" in the noise [14], [16].

Edges are the most important part of the high-frequency part of the spectrum. Object and image are totally recognizable only by the edges. The edges can be written in binary form, and as such effectively treated. Based on the detected edges it can be adjusted size of the local neighborhood algorithms for filtering. Edge can be defined as the image zone in which comes to sudden changes in illumination. The basic idea of edge detectors is that by comparing the response of the detector *e(x,y)* with a threshold that can be dependent on the position of *T(x,y)* make a binary decision: is or is not on the edge [14], [16]. Therefore, the image that represents edges is binary:

$$iv(x,y) = \begin{cases} 1 & e(x,y) \geq T(x,y), \quad \text{belongs of the edge} \\ 0 & e(x,y) \geq T(x,y), \quad \text{does not belong of the edge} \end{cases} \quad (1)$$

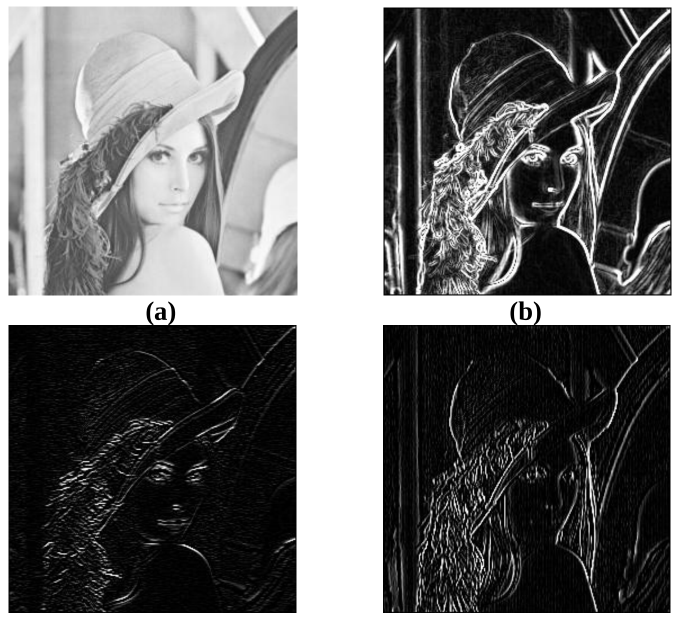
Similar science literature books that are dealing with the same topics rarely take into consideration design of edge detection since there is a problem of consistency establishment. In this paper it will be demonstrated how it can be usually done as for the class of detectors which Sobel and Prewitt's belongs to.

Detector response can be defined through response that we are calculating it as direction of the *x* axis meaning *y* axis:

$$e(n,m) = e_x^2(n,m) + e_y^2(n,m) \quad (2)$$

where *n* and *m* are presenting ordinal number of image pixels in line and column of the image matrix, and $e_x^2(n,m)$, $e_y^2(n,m)$ detector response.

Figure 1 presenting the original black and white image and the image that can be made after applying Sobel's detector and appropriate operations.



(a) **(b)** **(c)** **(d)**

Figure 1. a) Original black and white image; Response of Sobel's filter to applied OR operation: b) Vertical and horizontal, c) Only horizontally, d) Only vertically

4. System Model

For objective image quality analysis 24-bit uncompressed imagess in bmp format were used, with original resolution 512x512 pixels, available on web page http://sipi.usc.edu/database/misc.zip. Before applying different compression algorithms original image was filtrated with Lapacian, Prewitt and Sobel filter.

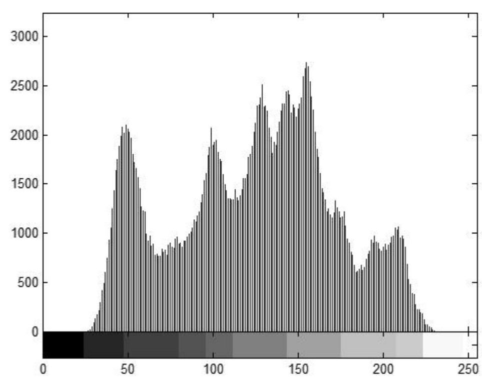
Four algorithm of compression (JPEG, JPEG 2000, EZW and SPIHT) was applied over the original image, the filtered by Laplacian, Prewitt and Sobel filter. For each algorithm were applied to nine bit rates: 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, 1.0, 1.5 and 3.0 bits per pixel images (bpp). Analysis was done using the software package Matlab 7.0.

Figure 2 shows an example of one analyzed in the original image and the filtered form, in Figure 3 the corresponding histograms.

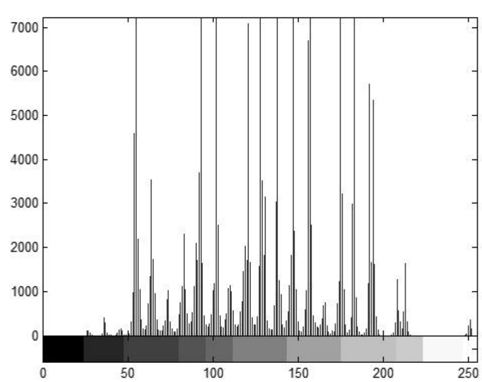

(a) **(b)**


(c) **(d)**

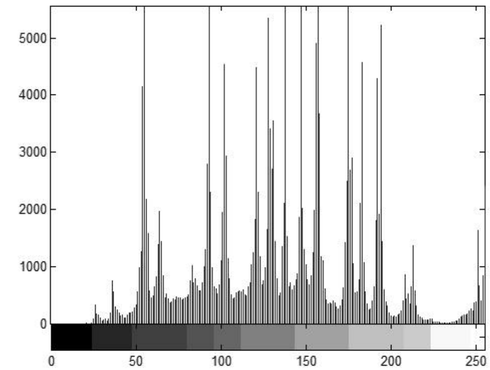
Figure 2. a) Original image; Image filtered by: b) Laplacian operator, c) Prewitt operator, d) Sobel operator



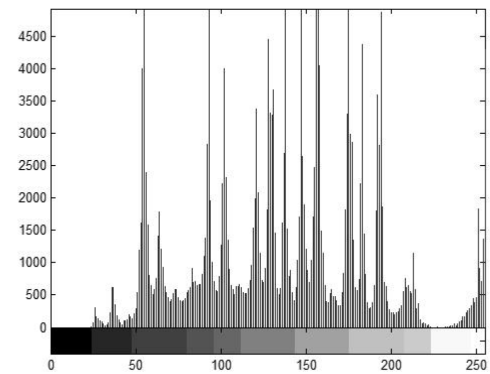
(a)



(b)



(c)



(d)

Figure 3. Histograms: a) Original image, b) Image filtered by Laplacian operator, c) Image filtered by Prewitt operator, d) Image filtered by Sobel operator

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) [17].

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 $i \in \{1...M\}$, $j \in \{1...N\}$, where M is the number of image elements in the vertical and N is the number of image elements in horizontal direction [15]. 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 [15].

The total reconstruction error is defined as:

$$E = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} || a_{ij} - a_{ij}^{'} ||^2 \qquad (3)$$

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

$$MSE = \frac{E}{M \cdot N} = \frac{1}{M \cdot N} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} || a_{ij} - a_{ij}^{'} ||^2 \qquad (4)$$

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 $[0,2^n-1]$, 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 (PSNR):

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \qquad (5)$$

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.

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).

5. Analysis

In Table 1, Table 2, Table 3 and Table 4 are given the values of mean square error (MSE) obtained by using the JPEG, JPEG 2000, EZW and SPIHT compression algorithm, respectively.

In Table 5, Table 6, Table 7 and Table 8 are given the value of the signal to noise ratio (SNR) obtained by using the JPEG, JPEG 2000, EZW and SPIHT compression algorithm, respectively.

Table 1. MSE change under JPEG algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	417.1	425.5	640.4	726.4
0.2	83.8	111.3	313.5	379.9
0.3	44.1	83.2	185.2	251.9
0.4	29.5	74.5	133.1	186.6
0.5	22.3	68.3	111.7	153.1
0.75	15.7	60.8	79.8	115.0
1	10.9	51.4	56.5	78.9
	7.0	37.9	36.1	49.3
	2.8	9.1	9.8	13.9

Table 2. MSE change under JPEG 2000 algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	66.7	96.1	259.7	350.6
0.2	32.7	74.8	147.6	202.2
0.3	21.2	63.3	102.1	143.8
0.4	15.7	55.7	81.3	113.3
0.5	12.2	49.1	66.8	94.0
0.75	8.1	38.2	45.7	63.2
1	5.9	29.8	33.3	44.5
1.5	3.4	16.3	18.1	25.3
3	0.8	2.4	2.7	3.8

Table 3. MSE change under EZW algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	126.9	144.5	432.5	550.7
0.2	57.6	93.4	236	311.6
0.3	34.4	75.7	143.8	197.2
0.4	25.5	65.9	119.8	161.2
0.5	19.6	61.9	91.3	136.2
0.75	12.4	50.4	64.3	82.1
1	8.9	33.5	47.1	66.5
	5.5	24.7	26.8	32.5
	1.4	4.7	5.6	7.6

Table 4. MSE change under SPIHT algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	61.5	95	265.5	342
0.2	31.2	72.7	144.9	202.2
0.3	20.5	62.4	102.8	146.3
0.4	15.2	55.1	80.8	114.9
0.5	12.1	48.6	66.8	93.3
0.75	7.9	35.9	45.3	62.9
1	5.8	27.9	32.2	44.2
1.5	3.2	14.3	17.1	24.3
3	0.6	2.1	2.4	3.5

Table 5. SNR change under JPEG algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	7.4	6.7	5.9	5.6
0.2	14.4	12.5	9.0	8.4
0.3	17.2	13.8	11.2	10.2
0.4	18.9	14.2	12.7	11.5
0.5	20.1	14.6	13.4	12.3
0.75	21.6	15.1	14.9	13.6
1	23.2	15.8	16.4	15.2
	25.1	17.2	18.3	17.2
	29.1	23.4	24.0	22.7

Table 6. SNR change under JPEG 2000 algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	15.4	13.1	9.8	8.7
0.2	18.5	14.2	12.2	11.1
0.3	20.3	14.9	13.8	12.6
0.4	21.6	15.5	14.8	13.6
0.5	22.7	16.0	15.7	14.4
0.75	24.5	17.1	17.3	16.2
1	25.9	18.2	18.7	17.7
	28.3	20.8	21.3	20.1
	34.5	29.2	29.6	28.4

Table 7. SNR change under EZW algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	12.6	11.4	7.6	6.8
0.2	16.0	13.3	10.2	9.2
0.3	18.2	14.2	12.3	11.2
0.4	19.5	14.8	13.1	12.1
0.5	20.7	15	14.3	12.8
0.75	22.7	15.9	15.8	15
1	24.1	17.7	17.2	15.9
	26.2	19	19.6	19
	32.1	26.2	26.5	25.3

Table 8. SNR change under SPIHT algorithm compression

	IMAGE			
bpp	Original	Laplacian	Prewitt	Sobel
0.1	15.7	13.2	9.8	8.8
0.2	18.7	14.3	12.3	11.1
0.3	20.5	15	13.8	12.5
0.4	21.8	15.5	14.8	13.6
0.5	22.8	16.1	15.7	14.5
0.75	24.6	17.4	17.4	16.2
1	26	18.5	18.8	17.7
	28.6	21.4	21.6	20.3
	36.2	29.7	30.1	28.8

From these tables it can be seen that with the increase bpp reduces mean squared error for the original and filtered images. With increasing bpp comes from the increase in the signal to noise ratio (SNR). This rule applies to all forms of compression algorithms. Because of better reflection of quality of compression differently filtered images is determined by the peak signal to noise ratio (PSNR) and its change is graphically shown in response to the change bpp.

In Figure 4, Figure 5, Figure 6 and Figure 7 are given the graphics changes PSNR are obtained for different values of bpp when using JPEG, JPEG 2000, EZW and SPIHT compression algorithm, respectively. Compression algorithms are applied over the original image and the filtered Laplacian, Prewitt and Sobel operator.

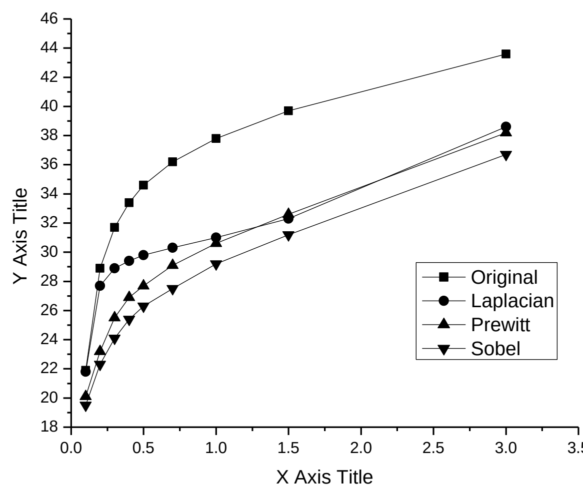


Figure 4. PSNR change under JPEG algorithm compression

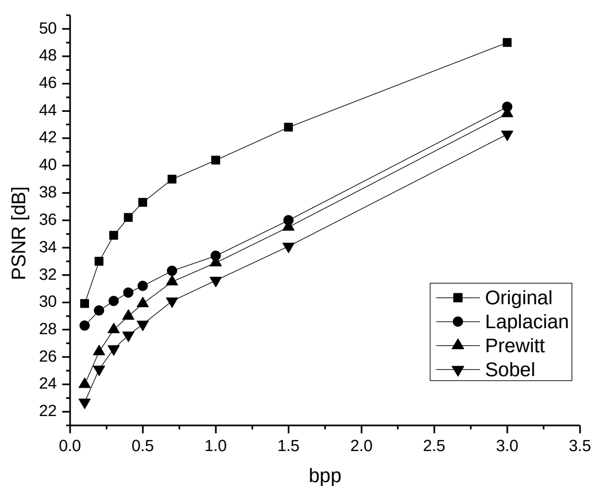


Figure 5. PSNR change under JPEG 2000 algorithm compression

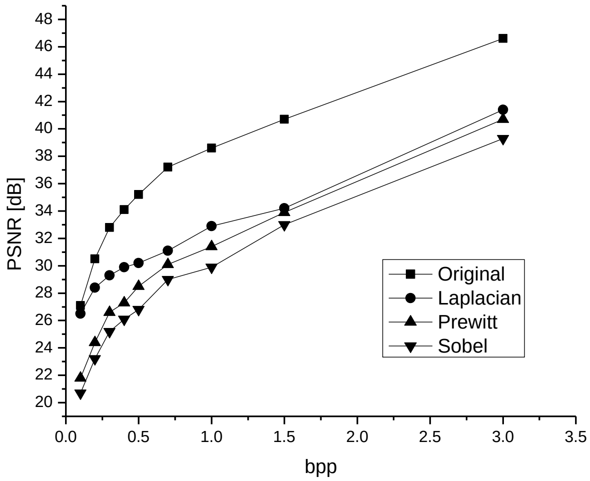


Figure 6. PSNR change under EZW algorithm compression

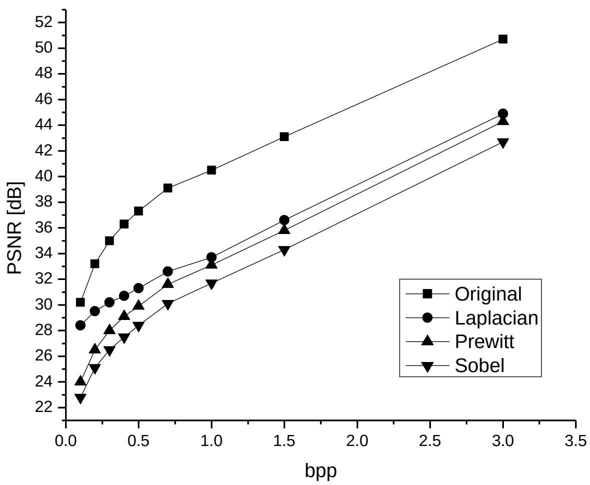


Figure 7. PSNR change under SPIHT algorithm compression

From the graph it can be seen that with the increase of the growth coming bpp PSNR for all compression algorithms applied over the original and the filtered image. Most PSNR values are obtained for all four forms of compression algorithm applied to the original image. PSNR for all four forms of compression applied at the image of the filtered Laplacian and Prewitt operator is approximately the same. The difference only exists at low bit rates compression. The strongest increase in PSNR are occurring at low bit rates, and if the compression is applied over the original image.

In Figure 8, Figure 9, Figure 10 and Figure 11, given the graphic changes PSNR are obtained for different values of bpp original compressed, filtered Laplacian, Prewitt and Sobel operator, respectively. Of the original and filtered image is applied as JPEG, JPEG 2000, EZW and SPIHT compression algorithms.

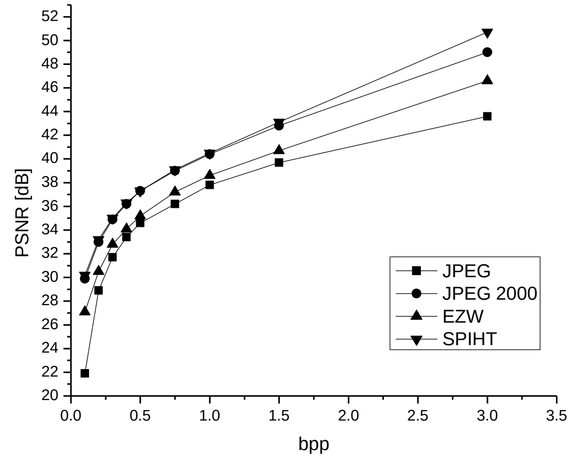


Figure 8. PSNR change with different forms of compression of the original image

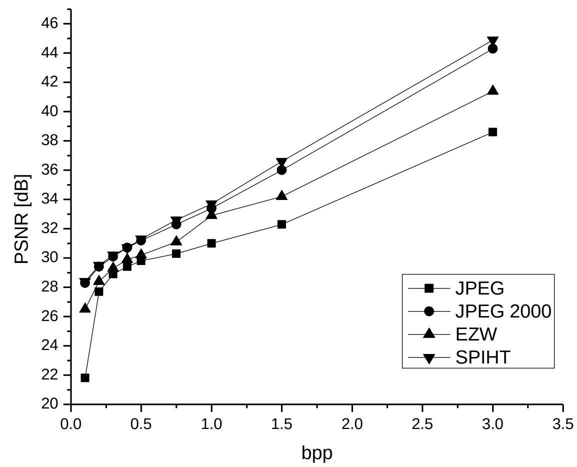


Figure 9. PSNR change with the various image compression filtered Laplacian operator

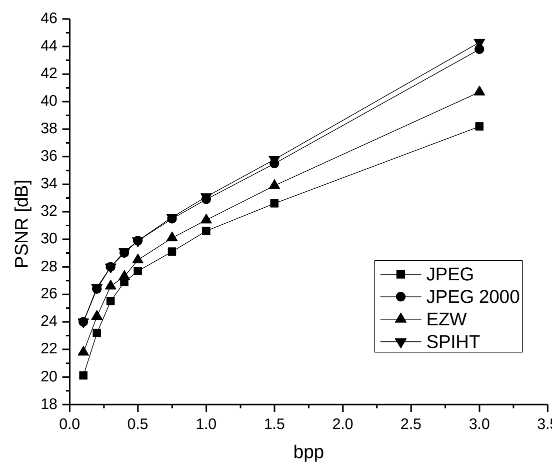


Figure 10. PSNR change with the various image compression filtered Prewitt operator

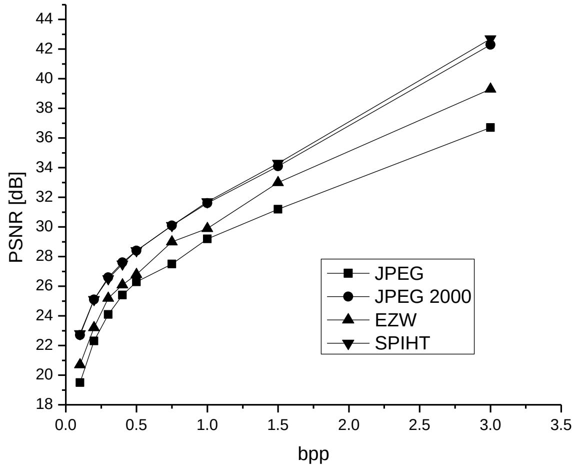


Figure 11. PSNR change with the various image compression filtered Sobel operator

From the given graphs can be seen that the highest PSNR values are obtained using the SPIHT and JPEG 2000 compression algorithm. Followed PSNR values obtained EZW and JPEG compression ratio of the algorithm. This rule applies to all forms of the analyzed images (original and filtered Laplacian, Prewitt and Sobel operator). The difference between a PSNR of EZW and SPIHT compression is more pronounced at higher bit-rate values, while the lower is almost the same. The difference is most pronounced in the application of these two algorithms over the original image.

6. Conclusions

By the analysis of different forms of compression of algorithms it was concluded that with increasing of bpp is a reduction in mean square error, or an increase in the signal to noise ratio (SNR) and peak signal to noise ratio (PSNR).

According to the given parameters it can be confirmed that the best quality of compressed images obtained by using all four algorithms of compression of the original image. In the case of the images that have been filtered, the best results give image filtered by Laplacian and Prewitt operator. By using Sobel operator, gets worse results than the other two operators. Quality image compression filtered by Laplacian operator is slightly better than the image filtered by Prewitt operator. The difference is slightly more expressed at low bit rates.

In all analyzes, algorithms SPIHT and JPEG 2000 present the best results in compression of the original and filtered images. Then, the compression quality below the EZW algorithm, and JPEG gives the worst results in the previous three algorithms. These results are for both, the original and filtered images. SPIHT is slightly superior in comparison to JPEG 2000 only at higher bpp. For other values of bpp compression quality SPIHT and JPEG 2000 algorithm are the same.

JPEG 2000 algorithm has at all bit rates transfers of (bpp) and all images achieved better result in comparison to JPEG process. In images compresses by JPEG speed reduction causes a visible control of the blocks on image. In JPEG 2000 compression algorithm does not block structure but reducing the transmission speed blur effect occurs that is less troublesome than the visible edges of the blocks. Blur effect is also observed in the EZW and SPIHT compression methods at low bit rates.

Acknowledgement

This work was done within the research project of the Ministry of Science and Technological Development of Serbia III47016 and TR35026.

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