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New Approaches for DCT-Based Image Compression Using Region of Interest Scheme

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In this paper, new techniques for the DCT image coding based in pixels classifications are proposed. Two image coding approaches based on the object extraction are presented to study the effect of the object based image coding on the compression quality. Moreover, modification of the traditional JPEG method based on Region-of-interest coding is achieved. In the beginning, the image is subdivided into a block of pixels with block size of NxN. Firstly; the block must be classified as foreground block or background block based on a pre-processing step. The foreground blocks will be compressed via JPEG technique but with significant quantized coefficients and the DC coefficient only from one block in the background is used to code it. The simulation result shows that the proposed technique provides competitive compression performance relative to the most recent image compression techniques.

Keywords: Image segmentation, edge detection, image coding, object extraction, JPEG standard, DCT, Quantization, Region of interest (ROI).

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1 Introduction

Image compression maps an original image into a bit stream suitable for storage or transmission over suitable channel in a digital medium, such as multimedia communications, integrated services digital networks (ISDN), storage of medical images, archiving of finger prints and transmission of remote sensing images. The number of bits required to represent the coded image should be smaller than that required for the original image, so that one can use less communication time or storage space [16], [7]. A fundamental goal of data compression is to reduce the volume of data for transmission or storage while maintaining an acceptable fidelity or image quality. Consequently, pixels must not always be reproduced exactly as the originated also, the human visual system (HVS) should not detect the difference between original image and reproduced image. The redundancy (both statistical and subjective) can be removed to achieve compression of the image data. The basic measure for the performance of a compression algorithm is original data size and compressed data size. In a lossy compression scheme, the image compression algorithm should achieve a tradeoff between compression ratio and image quality.

One of the solutions of this problem is to code the image based on the feature extraction [24]. In this method, the pixels are classified in the pre-processing step to code each block of pixels related to its significant. It does not need to send any information about the classification process to the decoder. Another solution to this goal is the region of interest (ROI) coding. The general theme is to preserve the quality for diagnostically important regions, whereas the rest of the image (background) is highly compressed. ROI coding usually supports progressive transmission by quality, which may further reduce the transmission time and storage cost.

The problem of using regions of interest (ROI) to increase the efficiency of image transmission over constrained bandwidth channels has received considerable attention in the image processing literature. This is due to the fact that various applications can strongly benefit from the uneven distribution of resources (bits, error protection, resolution, etc) through different image regions. For example, images can be robustly packetized by assigning higher priority to packets that cover a region deemed to require higher resiliency to transmission errors due to a noisy network [25] [26]. Also, in very low bit rate coding (e.g. video conferencing over cell phones) it is important to encode some image areas (e.g. faces) with higher fidelity than others (e.g. tree leaves moving in the background).

Object-based ROIs can also be useful in applications such as web browsing, or image retrieval. While the detection of ROIs has been studied by various researchers, existing solutions have significant practical limitations. These include ROI definitions based on low-level image attributes (e.g. edges [14], [3] or spatial homogeneity [19]) of small semantic significance, or the requirement for manual specification of ROI shape (or other geometrical properties) by eventual users [9]. More recently there have been efforts to formalize ROIs as perceptually salient regions [18] [6] but these methods are still based on bottom-up definitions of saliency that cannot account for high-level image interpretation. More recently, an advanced DCT-based coder [22] providing compression ratio higher than the discrete wavelet transform (DWT) based method. The image is divided into blocks of different sizes by a rate-distortion-based modified horizontal-vertical partition scheme. A post-filtering in [15] is used to remove the blocking artifacts in the decompressed image.

The remainder of this paper is organized as follows. Section 2 presents a short overview of the proposed methods, section 3 focuses on object-edge extraction in the image, section

4 introduces the image coding based on ROI, followed by experimental results in Section 5. Finally, concluding remarks are given in Section 6.

1. Overview of the work.

Although there are several mechanisms available in JPEG to encode and decode images with different spatial details [1], there are only two ROI coding methods specifically described in the JPEG standard: the Maxshift, described in Part 1 [11]; and the General Scaling Based, described in Part 2 [12]. The main restriction of the General Scaling Based is that it can be only applied over ROIs with regular shapes, such as ellipses and rectangles. On the other hand, the Maxshift method allows the ROI to be irregularly shaped, at the cost of losing control concerning to the relative importance of ROI and background.

Region of interest (ROI) coding has recently drawn much attention in image compression community. ROI applications include browsing, digital image archive, telemedicine, and among other [8]. Generic coding schemes compressing image as a whole can produce a high compression ratio but with considerable loss of overall quality. Recently, image compression techniques that support the ROI coding have received a lot of attention. C. doukas and I. maglogiannis [5] focused on ROI coding (applied on medical images) is to allow the use of multiple and arbitrarily shaped ROIs within images, with arbitrary weights describing the degree of importance for each ROI including the background so that the latter regions may be represented by different quality levels. [10] presented an excellent method that allows: codification of multiple ROIs at various degrees of interest, arbitrary shaped ROI coding, and flexible adjustment of the compression quality of the ROI and the background.

Four new techniques for the DCT image coding based in pixels classifications are proposed in this paper. Two of these algorithms are called PCIC1 and PCIC2 (where PCIC denotes Pixel Classification Image Coding) and are introduced in section 3. The other two algorithms are called RCIC1 and RCIC2 (where RCIC denotes Region Classification Image Coding) and are introduced in section 4. Algorithm PCIC1 and PCIC2 provides the image coding based on edge detection. Algorithm RCIC1 and RCIC2 provides the image coding based on ROI.

In PCIC methods, we explored modification of the quantized image based on preprocessing (object edge extraction). The modification will be done after the quantization step. The image is subdivided into a block of pixels and then these blocks is classified into edge and non-edge blocks. For each block we shall keep a certain number of NxN blocks in the top left hand corner and multiplied the rest of our DCT coefficients with 0. This would simplify the coding process and improve the compression ratio, but the quality of the compressed image will be reduced. This ”mask” matrix determined what dimension of the upper left-hand corner of quantized DCT coefficients would be kept and the rest of the coefficients multiplied by 0.

In this work, two image coding approaches are presented to study the effect of the object based image coding on the compression quality. In the first method (PCIC1), the non-edge blocks (insignificant regions) are compressed using the DC coefficient only and all significant coefficients are used for the edge blocks (significant regions). In the second method (PCIC2), the DC coefficient only is used for coding the non edge blocks (insignificant regions). The edge blocks (significant regions) will be compressed via JPEG standard but with significant quantized coefficients only. Moreover, modification of the traditional JPEG method based on Region-of-interest coding is achieved (RCIC1 and RCIC2). In this mode, a region of interest (ROI) in an image is defined. The ROI can then be encoded and transmitted with better quality than the rest of the image.

The performance evaluation of using these methods with different images is discussed in this work. The improvement of the compression ratio is calculated in each case using the bit-rate difference (BRD) [24]. The BRD is defined as the difference between the bit-rate (bit/pel) result from the JPEG method and the bit-rate result from the modified technique. The positive sign of BRD means an improvement in the compression ratio. The perceptual quality and the PSNR of the reconstructed image are used to demonstrate the performance of these methods.

2. Image coding based on object- edge extraction.

Edges often occur at points where there is a large variation in the luminance values in image, and consequently they often indicate the edges, or occluding boundaries, of the object in the scene. However, large luminance changes can also corresponding to surface marking on objects. Points of tangent discontinuity in the luminance signal (rather than simple discontinuity) can also signal an object boundary in the scene. In this section, some of famous methods for object edge extraction are tested. The Canny edge detector, the rainfalling watershed technique, the gradient edge detector and the fuzzy edge detector are used to extract the edges in the image [13], [23], [17], [20]. Experimentally these techniques do achieve a good result for different images.

In the case of rainfalling watershed technique, gradient edge detector and fuzzy edge detector, the threshold method (thre1) is calculated automatically by using the maximum cross-entropy methods [4].The second threshold (thre2) is hysteresis threshold, which is performs edge tracking, and is used to find chains of connected edge maxima, or connected contours [4].

As an example, Figure 1.1 shows the results of the object edge detection using the rainfalling watershed technique and fuzzy edge detector with the noisy free images. In this Figure, from top to bottom, the cameraman image, the Lena image and the Fruit image. From the simulation results of the edge detection process, the edge detection based on the rainfalling watershed technique is the best technique with the testing images.

The first technique (PCIC1) is described as follows: after the classification process, the non-edge blocks are compressed using the DC coefficient only of the DCT coefficients and all significant DCT coefficients are used for the edge blocks. In the second technique

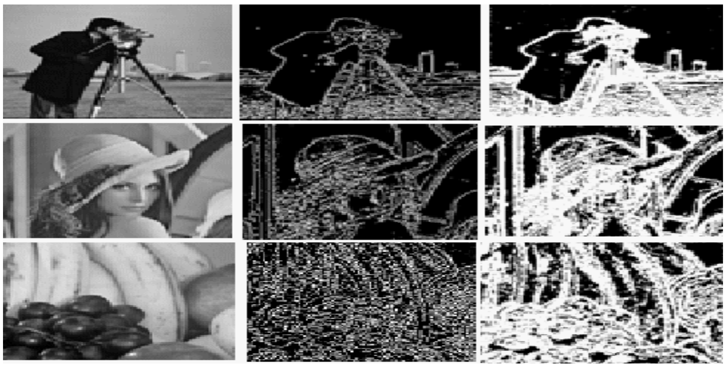

Figure 1.1: From the left: the image, the result of rainfalling watershed technique on the image, and the result of fuzzy edge detector on the image, respectively.

(PCIC2), we tried to reduce the number of AC coefficients used to code the edge blocks. This will reduce the effect of image noise, increase the compression ratio, and fast the coding process. Only the quantized DC coefficient value will be used for non edge blocks.

For edge blocks, some of the non-zero quantized AC coefficients will be eliminated based on its power. The modification of the quantized values of the quantized DCT coefficients is related to the very difficult problem of developing a criterion for human visual system. As Known, the quantization matrix is computed based on the variance of the DCT coefficients. The quantization of a single coefficient in a single block causes the reconstructed image to differ from the original image by an error image proportional to the associated basis function in that block. Moreover, the elimination of some quantized coefficients may give clearly visible errors i.e. the blockness of the artifacts distinguishes them from the original image content. In the PCIC2 technique, we tried to attack this problem using two experimental tests. These tests can be summarized as follows:

(1) For edge blocks the statistical variances of the DCT coefficients will be estimated and the normalized cumulative variance (NCV) of the AC coefficients will be computed. The NCV values are recorded according to the spectral component index. The NCV at the n^{th} spectral component, $n \in [0, N-1]$, is defined as

$$NCV(n) = \frac{\sum_n \sigma_{i,j}^2}{\sum_N \sigma_{i,j}^2} \tag{1.1}$$

where $\sigma_{i,j}^2$ is the variance of the (i,j) spectral component (Ahmed and Rao, 1975 [21]). Clearly, NCV(n) provides a measure for the percentage of the AC coefficients that can be selected for accepted quality. A set of images with different details has been used to test the NCV(n). On the average, 18% of the DCT coefficients contain about 80% of the total power of the image signal.

(2) Assume that the edge variance V is the sum of the squared difference for all such pixel pairs.

$$V = \sum (X_1 - X_2)^2 \tag{1.2}$$

where X_1 and X_2 are the image values of two pixels that are next to each other in the same raw, but are in different blocks. The edge variance is estimated for the original image (V_o) and the reconstructed image (V_r) using the pixels just inside the edge on both side and taking the average. Experimentally, for ($V_r/V - o$) ¿ 1.3 the blocking artifact will be clearly visible. A set of images are tested to estimate the minimum number of AC quantized coefficients that gives an edge variance less than the critical value with different block size.

Related to these two steps, 70% of the non-zero quantized AC coefficients have been used in the coding of edge blocks. The basic steps of the PCIC1 or PCIC2 algorithm are composed of the following steps:

1. Read in the image data and subdivide it into an NxN block of pixels.

2. Apply the edge detection technique to classify the image blocks.

3. Transform each matrix using the Discrete Cosine Transform. Quantize the matrix using a predetermined quantization table.

4. Apply the modification of the quantized coefficient based on the classification is step 2.

5. Assemble the blocks into a continuous stream.

6. Apply adaptive arithmetic coding (Q-coder) to the resulting values.

The Q-coder is an adaptive arithmetic coding [27] and is a lossless compression technique that benefits from treating multiple symbols as a single data unit but at the same time retains the incremental symbol-by-symbol coding approach of Huffman coding. Arithmetic coding separates the coding from the modeling. This process allows for the dynamic adaptation of the probability model without affecting the design of the coder. Provisions for substituting Huffman coding for arithmetic coding are contained in many of the image compression standards.

3. Image coding based on region of interest

In the ROI coding, images are segmented into the region of interest, which is considered important, and the background, which is less important. By allowing the ROI to be coded with higher fidelity than background, a high compression ratio with good quality in the ROI can be achieved. Therefore, the greatest benefit of ROI coding is its capability of delivering high reconstruction quality over certain spatial regions at high compression ratios.

To identify the ROI, in the beginning the image edges are detected by rainfalling watershed technique (the best detecting technique), and then a morphological filter is used to fill in holes and small gaps. The operation shows the outline of the cell quite nicely, but there are still holes in the interior of the object (cell). To overcome this problem, the area enclosed by the boundary is tested. If the area of the holes is greater than 40% of the total area then the algorithm will combine this area with the total area enclosed by the boundary.

Two techniques based on ROI are used to improve the compression ratio of the traditional JPEG algorithm (RCIC1 and RCIC2): These techniques are described as follows: after the classification process, all the background area is compressed using the DC coefficient of one block only. The foreground area is compressed using two techniques. In the first Technique (RCIC1), all coefficients is used in the coding of the foreground blocks. In the second technique (RCIC2), only 70% of the non-zero quantized AC coefficients have been used in the coding of foreground blocks.

4. Simulation results The performance of the proposed techniques is introduced in this section. The simulation results are compared with each other and with the traditional JPEG results. The proposed algorithms are applied to a set of images to study the performance of these algorithms with different types of image. The block size of 8x8 pixels is used.

4.1. Simulation results of the image coding based on object edge extraction. PCIC1 and PCIC2 were performed on 256x256 byte gray scale images. These images (cameraman, Lena and Fruit) are used to compare the performance of the object-edge extraction based image coding algorithms and the performance of the traditional JPEG technique.

4.1.1. Simulation results of the image coding based on object edge extraction. PCIC1 and PCIC2 were performed on 256x256 byte gray scale images. These images (cameraman, Lena and Fruit) are used to compare the performance of the object-edge extraction based image coding algorithms and the performance of the traditional JPEG technique.

Simulation results of the PCIC1 Technique. Table 1 and Table 2 show the result of the JPEG technique and the performance of the PCIC1 algorithm, respectively. In Table 2, the Canny method, rainfalling watershed method, gradient method and fuzzy method is used in the edge extraction processing to study the performance of each technique in the coding process. Moreover, in Table 2, the peak signal to noise ratio (PSNR) of the reconstructed image, MSE (Mean Square Error) and the BRD are given. The maximum improvement in the BRD is approximately 0.05 with an accepted image quality. It is clear that the improvement of the compression ratio relative to the JPEG is small when using the PCIC1 technique. In the first row of Figure (1.2) is the reconstructed image when using the rainfalling watershed technique in the classification process. The Second row of this Figure shows the reconstructed image using the fuzzy edge detector technique in the classification process. From this figure, it is clear that the quality of the reconstructed images is accepted.

Table 1 The result of the JPEG technique for noise free images

$Image$	PSNR	MSE	Compression ratio
Cameraman	35.7846	17.1640	12.8247
Lena	38.1735	9.9021	19.6274
Fruit	39.6716	7.0133	23.8085

Figure 1.2: The results of the PCIC1 for noise free images

Table 2 PCIC1 results for noise free images

Image	Methods	PSNR	MSE	Compression ratio	BRD
Cameraman	Canny	35.692	17.531	13.8047	0.0443
	Watershed with thre1	35.700	17.499	13.5566	0.0337
	Watershed with thre2	35.567	18.044	13.7735	0.043
	gradient with thre1	35.715	17.441	13.5443	0.0331
	Gradient with thre2	35.576	18.008	13.6626	0.0383
	Fuzzy	35.752	17.290	13.3180	0.0231
Lena	Canny	36.557	14.364	22.5938	0.0535
	Watershed with thre1	37.727	10.972	20.5934	0.0191
	watershed with thre2	37.053	12.816	21.7195	0.0393
	gradient with thre1	37.682	11.086	20.7392	0.0219
	Gradient with thre2	37.113	12.638	21.5535	0.0364
	Fuzzy	38.134	9.9912	19.8219	0.004
Fruit	Canny	37.115	12.634	27.3694	0.0437
	Watershed with thre1	39.360	7.5346	24.0026	0.0027
	watershed with thre2	36.335	15.120	28.2803	0.0531
	gradient with thre1	39.660	7.0312	23.9019	0.0013
	Gradient with thre2	36.400	14.894	28.0563	0.0509
	Fuzzy	39.659	7.0324	23.8812	0.001

Simulation results of the PCIC2 Technique. The second technique (PCIC2), as mentioned earlier, a 70% of the non- zero AC coefficients of the edge blocks provides an accepted results. After quantization and zigzag scan the non-zero of the quantized coefficients is counted and only the first 70% of the non- zero AC coefficients will be used as the input of the Q-coding. The non-edge block will be coded using only the DC coefficient. The results of the PCIC2 are given in Table 3. The Canny method, rainfalling watershed method, gradient method and fuzzy method is used to study the performance of each technique in the coding process. The result in this table shows that the PCIC2 provides improvement in the bit-rate from 0.05 to 0.20 relative to the JPEG method with a little decreasing of the image quality and PSNR. The best edge extraction method that provides a good quality in the reconstructed image and good compression ratio relative to the JPEG technique is the rainfalling watershed method and the fuzzy method. Although the PSNR of the reconstructed images is not closed to the results of the JPEG technique, the BRD is positive in all cases.

In the first row of Figure (1.3), the visual result of the reconstructed image using the rainfalling watershed technique in the classification process, and the second row shows the reconstructed image using the fuzzy edge detector technique in the classification process.

Table 3 PCIC2 results for noise free images

Image	Methods	PSNR	MSE	Comp. Ratio	BRD
Cameraman	Canny	34.2692	24.3311	19.2082	0.2073
	Watershed with thre1	34.2800	24.2704	18.8865	0.2002
	Watershed with thre2	34.1956	24.7470	19.1241	0.2055
	gradient with thre1	34.2861	24.2365	18.8905	0.2003
	Gradient with thre2	34.1976	24.7354	19.0346	0.2035
	Fuzzy	34.3096	24.1056	18.6215	0.1942
Lena	Canny	34.6110	22.4896	28.9630	0.1314
	Watershed with thre1	35.2304	19.5003	26.6015	0.1069
	watershed with thre2	34.8875	21.1023	27.9174	0.121
	gradient with thre1	35.2058	19.6108	26.7548	0.1086
	Gradient with thre2	34.9146	20.9710	27.7592	0.1194
	Fuzzy	35.3867	18.8110	25.7914	0.0974
Fruit	Canny	35.2854	19.2547	32.6863	0.0912
	Watershed with thre1	36.4576	14.7001	29.1255	0.0613
	watershed with thre2	34.7723	21.6697	33.6968	0.0986
	gradient with thre1	36.5636	14.3456	28.9214	0.0594
	Gradient with thre2	34.8123	21.4710	33.5094	0.0973
	Fuzzy	36.5647	14.3421	28.9167	0.0593

4.1.2. Simulation results of the image coding based on ROI extraction. Extensive experiments were conducted to test the performance of the proposed ROI coding method (RCIC1 and RCIC2). The results were compared with those obtained by JPEG standard. Results are reported for different images. One frame of the MISS_AM, the Mthr_dot, the AKIYO, the CLAIRE sequence (176x144, 8 bpp) are used to perform the evaluation. Moreover, the previous images in the last Section (Cameraman, Lena and Fruit) are used to compare the performance of the RCIC1 and RCIC2 techniques with the PCIC1 and PCIC2.

Table 5 shows the result of using the JPEG coding technique with the current five

Figure 1.3: The results of the PCIC2 for noise free images

frames. In addition, it is clear in Table 6 that the smaller ROI, the lower bit rate and the higher compression ratio are achieved. In conclusion, the proposed image coding technique based on ROI improves the compression ratio from 1:31 to 1:53 when applying the RCIC2 technique on MISS_AM image. The compression ratio when applying the RCIC2 technique on MTHR_DOTR is increased from 1:15 to 1:24. The compression ratio when applying the RCIC2 technique on MTHR_DOTR and AKIYO images is increased from 1:24 to 1:33 and with the CLAIRE image is increased from 1:28 to 1:58. Figs.1.4, 1.5

Figure 1.4: The results of the JPEG for some of current frame used

Figure 1.5: The results of the RCIC1 for some of current frame used

and 1.6 show the reconstructed frame of MISS_AM, MTHR_DOTR and CLAIRE images when using the standard JPEG coding technique, the RCIC1 coding scheme and the RCIC2 coding scheme, respectively. This demonstrates that the proposed ROI improves the compression efficiency with a small decreasing in the PSNR values.

Figure 1.6: The results of the RCIC2 technique for some of current frame used

Table 5 the result of the JPEG technique for noise free images

Image	PSNR	MSE	Compression ratio
MISS_AM	42.7887	3.4215	31.7544
MTHR_DOTR	37.5419	11.4521	15.3798
AKIYO	39.0732	8.0494	24.3108
CLAIRE	42.2485	3.8746	28.7266

Table 6 RCIC1 and RCIC2 results for noise free images

Image	background	foreground	RCIC(1/2)	PSNR	MSE	C. Ratio	BRD
MISS_AM	168	228	RCIC1	42.951	3.295	41.0263	0.0569
	168	228	RCIC2	39.803	6.803	53.3839	0.102
MTHR_DOTR	90	306	RCIC1	37.202	12.382	17.5878	0.0653
	90	306	RCIC2	34.110	25.237	24.6867	0.1961
AKIYO	59	337	RCIC1	38.007	10.287	27.7781	0.0411
	59	337	RCIC2	34.519	22.969	33.6574	0.0914
CLAIRE	248	148	RCIC1	42.068	4.0382	48.7854	0.1145
	248	148	RCIC2	37.663	11.135	58.6497	0.1421
cameraman	365	659	RCIC1	34.191	24.770	15.8371	0.1187
	365	659	RCIC2	30.330	60.265	23.2140	0.2792
Lena	87	937	RCIC1	35.795	17.122	20.9950	0.0266
	87	937	RCIC2	32.951	32.953	28.0218	0.1221
Fruit	0	1024	RCIC1	39.607	7.1174	25.0952	0.0172
	0	1024	RCIC2	35.810	17.063	30.9918	0.0779

The performance of the RCIC2 method were compared with the performance of the traditional JPEG (with post-filtering [15]), JPEG2000 (wavelet 9/7) [12]), the set partitioning in hierarchical tree (SPIHT) coding technique [2], and the image compression technique based on the modified horizontal-vertical (MHV) partition scheme [22][24].

Table 7 shows PSNR values in dB for different bit rates for these methods used with 512x512 byte Lena, Barbara and Goldhill images in the performance analysis.

Table 7 comparative analysis of coding efficiency

$Image$	Methods	Lena	Barbara	Goldhill
CR=8 (bpp=1)	JPEG	39.15	36.55	35.63
	JPEG 2000	40.33	38.07	36.54
	SPIHT	40.46	37.45	36.55
	MHV	40.85	39.91	37.38
	RCIC2	44.04	34.224	41.66
CR=16 (bpp=0.5)	JPEG	35.88	31.73	32.28
	JPEG 2000	37.27	32.87	33.24
	SPIHT	37.25	32.10	33.13
	MHV	37.87	35.28	33.81
	RCIC2	40.05	33.392	38.58
CR=32 (bpp=0.25)	JPEG	32.49	27.77	29.78
	JPEG 2000	34.15	28.89	30.56
	SPIHT	34.14	28.13	30.56
	MHV	34.75	31.21	31.22
	RCIC2	36.86	30.46	33.99

The results clearly show that the PSNR performance of the RCIC2 coding methods are outperform the PSNR performance of the traditional JPEG, JPEG2000, SPIHT and MHV coding techniques when applying to the Lena and the Goldhill images. But the performance of our approach is approximately outperforming the performance of the traditional JPEG, JPEG2000, and the SPIHT coder. It is important to note that the proposed approaches are applied to the images without using a post-filtering. For fair comparison with the MHV method, post-filtering must be used to reduce the blocking artifacts. The blocking artifact reduction will be the extension of this work.

5.CONCLUSION

In this paper, we have presented four techniques for the DCT image coding based in pixels classifications. The performance comparison of these techniques with the JPEG technique is conducted. It has been demonstrated that the proposed coding schemes improves the compression efficiency with good quality. The performance evaluation of using these methods with different images is discussed in this work. The improvement of the compression ratio is calculated in each case using the bit-rate difference (BRD). The BRD is defined as the difference between the bit-rate (bit/pel) result from the JPEG method and the bit-rate result from the modified technique. The best coding results are achieved with the image coding based on ROI is applied to the image.

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