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# On a high performance image compression technique

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**ABSTRACT**: We introduce an optimal approach to colour image compression using a new scan method. We propose efficient methods to increase the compression ratio for colour images by dividing the colour image into non-overlapping blocks and applying a different compression ratio for these blocks depending on the classification of blocks into edge and non-edge blocks. In an edge block (a region that contains important information) the compression ratio is reduced to prevent loss of information, while in a non-edge block (a smooth region which does not have important information), a high compression ratio is used. The new proposed scan is used instead of the zigzag scan. A particular implementation of this approach was tested, and its performance was quantified using the peak signal-to-noise ratio. Numerical results indicated general improvements in visual quality for colour image coding.

**KEYWORDS**: JPEG, zig-zag scan, DCT, colour image

## INTRODUCTION

Image compression is an inevitable solution for image transmission since the channel bandwidth is limited and there is a demand for faster transmission[1]. Storage limitation also requires image compression as the colour resolution and spatial resolutions are increasing according to quality requirements. A huge amount of online information is used either graphical or pictorial in nature. As the requirements for storage and communications are high, compressing the data is a way to solve this problem. Thus methods of data compression prior to storage and/or transmission are essential in real-world and viable concern.

Broadly, image compression[2–4] may be lossy or lossless. Lossless compression[5,6] is preferred for archiving and often for medical imaging, technical drawings, etc. This is because lossy compression methods[7,8], especially when used at low bit rates, introduce compression artefacts. Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate. The lossy compression that produces imperceptible differences may be called visually lossless. Recently, four image models based on fractional total variation have been presented[8]. The models can deal with space and wavelet domain damages for images with or without noise. Different aspects such as image compression, image restoration, and image coding have been discussed[9–17].

Developing innovative schemes to accomplish effective compression has gained enormous popularity in recent years. A brief review of some recent significant research is presented here. Gupta and Anand[18] introduced algorithm based on adaptive quantization coding (AQC) algorithms. The objective is to reduce bitrate produced by AQC while preserving the image quality. The proposed algorithms used only selected bit planes of those produced by encoder using bit plane selection using threshold (BPST) technique. The bit planes are selected by using an additional processing unit to check the intensity variation of each block according to a predefined threshold. John and Girija[19] proposed novel and high performance architecture for image compression based on representation in the frequency domain. The digitized image is compressed using discrete Hartley transform (DHT), discrete Walsh transform, discrete Fourier transform, and discrete Radon transform and their combinations with DHT. DHT is used as a basic transform because of its reversibility, hence other transform kernels can be developed. The proposed architecture is developed using verilog hardware descriptive language and has been tested for still images.

Raju et al[20] presented new approach to colour image compression based on image demosaicing. In the encoder, a mosaic of primary colours is encoded instead of the full colour image. This mosaic is

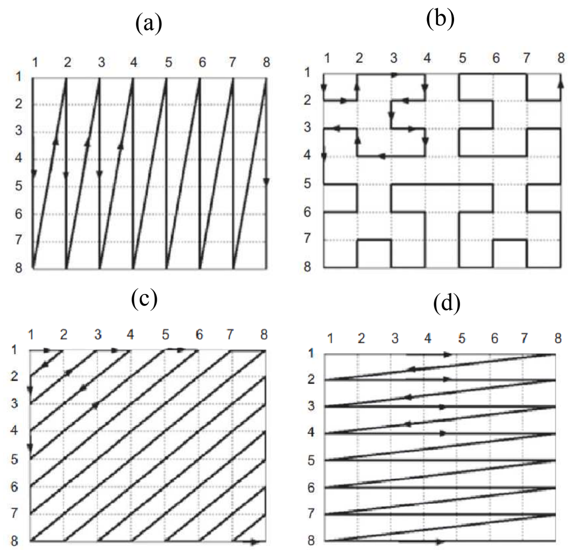



**Fig. 1** The different ways for DCT blocks scanning: (a) vertical, (b) Hilbert, (c) zigzag, and (d) horizontal.

considered as four different colour channels that are compressed using sub-band transform coders. They proposed to use a colour transfer based on the DCT for the coded channels. The proposed demosaicing technique employs an optimized colour transfer in the reconstruction of the red and the blue colours to impose higher smoothness in the new colour space in terms of minimal gradient energy. Douak et al[21] have proposed a new algorithm for colour images compression. After a preprocessing step, the DCT transform is applied and followed by an iterative phase including the threshold, the quantization, dequantization, and the inverse DCT. To obtain the best possible compression ratio, the next step is to apply a proposed adaptive scanning providing, for each $(n, n)$ DCT block a corresponding $(n \times n)$ vector containing the maximum possible run of zeros at its end. The last step is the application of a modified systematic lossless encoder.

In this article, the proposed method achieves a new colour image compression based on a new scan scheme, which makes a balance on compression ratio and image quality by compressing the vital portions of the image with high quality. In this approach, the main subject in the image is more significant than the background image. The performance of the proposed scheme is evaluated in terms of the peak signal to noise ratio and the compression ratio attained. The experimental results demonstrate the effectiveness of the proposed scheme in image compression.

## Compression scheme

In the image compression algorithm, the input colour image is RGB colour space, and then the image is initially classified into edge and non-edge portions using Canny method[22]. Then the image is subdivided into $8 \times 8$ blocks and DCT coefficients are computed for each block. The quantization is performed conferring to a quantization table. The quantized values are then rearranged according to a new scan arrangement as described in next section rather than zigzag scan order shown in Fig. 1c. A new scanning needs reordering of coefficients to form run of non-zeros which can be encoded using run length coding.

## The new proposed scanning

For the aim to obtain the best possible compression ratio (CR). Discrete cosine transform (DCT) has been widely used in image and video coding systems, where zigzag scan is usually employed for DCT coefficient organization and it is the last stage of processing a compressed image in a transform coder, before it is fed to final entropy encoding stage. Multiple scanning are used (i.e., vertical, Hilbert, zigzag, and horizontal, see Fig. 1) for different spatial prediction direction on the block. However, due to local prediction errors the traditional zigzag scan is not always efficient. Hence we applied a simple and efficient scanning providing, for each DCT block vector containing the maximum possible run of zeros at its end. Sorting is the important step of the proposed scan. Descending sort is used for non-zero coefficients. Then the non-zero coefficient is entered to the entropy encoder.

The basic idea of the new approach is to divide the image into $8 \times 8$ blocks and then extract the consecutive non-zero coefficients preceding the zero coefficients in each block. In contrast to the zigzag scan (Fig. 3), the output of this scan consists of the number of the non-zero coefficients followed by the coefficients themselves for each block. The decompression process can be performed systematically and the number of zero coefficients can be computed by subtracting the number of non-zero coefficients from 64 for each block. Following is a short example of this algorithm. In this example, there are two $8 \times 8$ blocks of coefficients as input to the suggested scan. The output of this scan is shown in the right side of Fig. 2.

## Experimental results

Here, the experimental results for compression using the proposed technique are presented. For demonstration purposes, the image is compressed by the pro-

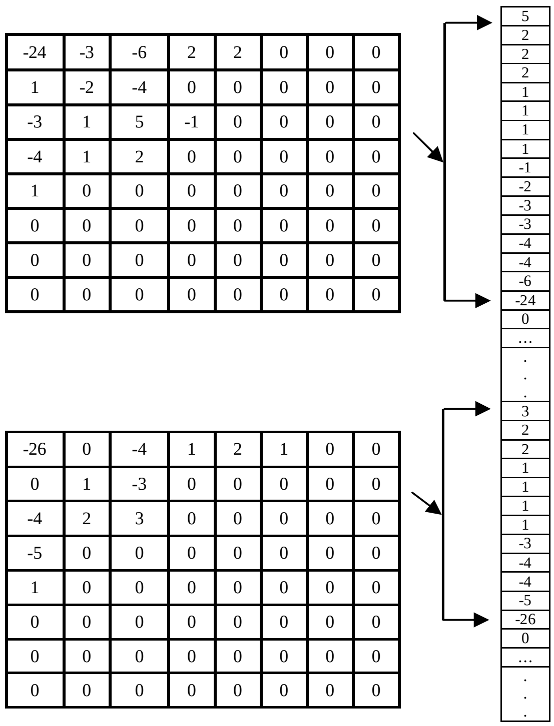



**Fig. 2** Demonstration example of the proposed algorithm.

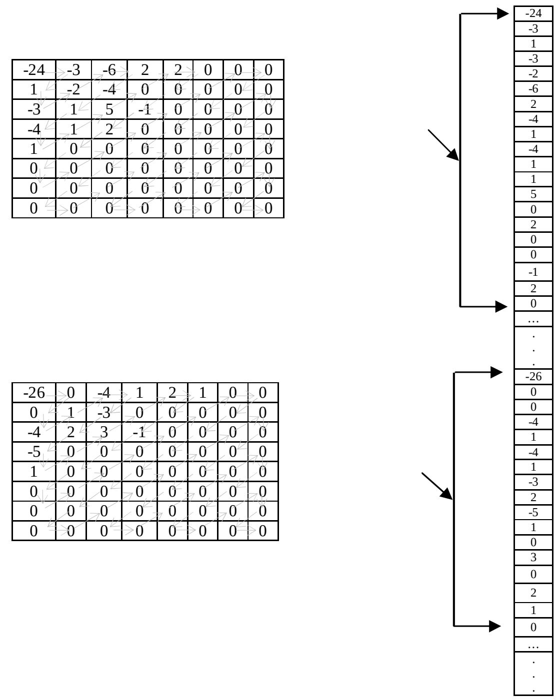



**Fig. 3** Demonstration example of the zigzag algorithm.

posed algorithm at different compression depths. We evaluate the efficiency of compression by evaluating the peak signal to noise ratio (PSNR)[23]. Images of different sizes (512 × 512 and 256 × 256) are considered in the experiment, most of which are commonly used in the evaluation of computer vision and image processing algorithms.

*Method 1 (M-0):* without classification the image to edge and non-edge, all AC coefficients of the edge blocks and non-edge blocks on each component (RGB colour space) are used.

*Method 2 (M-1):* all AC coefficients of the edge blocks on each component (RGB colour space) are used. After quantization and new scan the non-zero of the quantized coefficients is counted and all AC coefficients will be used as the input of the Huffman coding. The non-edge block will be coded using only the DC coefficient (Fig. 4).

*Method 3 (M-2):* in this method, we tried to reduce the number of AC coefficients used in coding the edge blocks. This will reduce the effect of image noise, increase the compression ratio, and accelerate the coding process, which 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.

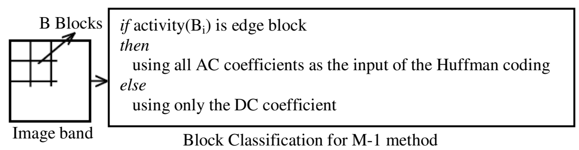



**Fig. 4** Classification stage.

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 blockiness of the artefacts distinguishes them from the original image content. We tried to address this problem using two experimental tests. These tests can be summarized as follows.

Step 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, where

**Table 1** Comparison of performance measures of M-0, M-1 and M-2 compression scheme with the proposed coding scheme M-3 with $8 \times 8$ block size.

| Image | | M-0 | M-1 | M-2 | M-3 |
|---|---|---|---|---|---|
| Lena | MSE | 15.1701 | 16.8520 | 30.0489 | 30.7891 |
| | PSNR | 36.3209 | 35.8643 | 33.3525 | 33.2468 |
| | CR | 19.6539 | 21.2864 | 28.1180 | 32.3393 |
| | bpp | 1.2211 | 1.1275 | 0.8535 | 0.7421 |
| tree | MSE | 32.0557 | 33.9042 | 55.8740 | 56.2028 |
| | PSNR | 33.0717 | 32.8283 | 30.6587 | 30.6332 |
| | CR | 12.2213 | 13.1022 | 18.8667 | 22.4955 |
| | bpp | 1.9638 | 1.8318 | 1.2721 | 1.0669 |
| baboon | MSE | 43.1518 | 45.0712 | 63.7159 | 65.5085 |
| | PSNR | 31.7808 | 31.5918 | 30.0883 | 29.9678 |
| | CR | 10.7246 | 11.1156 | 16.1561 | 19.9218 |
| | bpp | 2.2379 | 2.1591 | 1.4855 | 1.2047 |
| house | MSE | 20.3410 | 22.2544 | 44.3013 | 45.8392 |
| | PSNR | 35.0471 | 34.6567 | 31.6666 | 31.5184 |
| | CR | 14.5782 | 15.4048 | 21.5744 | 25.5430 |
| | bpp | 1.6463 | 1.5580 | 1.1124 | 0.9396 |
| airplane | MSE | 12.6756 | 13.4152 | 29.7522 | 30.6810 |
| | PSNR | 37.1011 | 36.8548 | 33.3956 | 33.2621 |
| | CR | 18.5453 | 19.6583 | 26.6326 | 31.0726 |
| | bpp | 1.2941 | 1.2209 | 0.9011 | 0.7724 |

$n \in [0, N-1]$, is defined as

$$\mathrm{NCV}(n) = \frac{\sum_{n} \sigma_{i,j}^2}{\sum_{N} \sigma_{i,j}^2},$$

where $\sigma_{i,j}^2$ is the variance of the $(i, j)$ spectral component[24]. Clearly, $\mathrm{NCV}(n)$ 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 $\mathrm{NCV}(n)$. On the average, 18% of the DCT coefficients contain about 80% of the total power of the image signal.

Step 2: Assume that the edge variance $V$ is the sum of the squared difference for all such pixel pairs,

$$V = \sum (X_1 - X_2)^2,$$

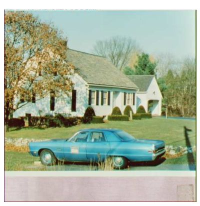
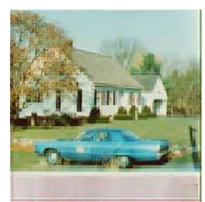
where $X_1$ and $X_2$ are the image values of two pixels that are next to each other in the same row, but are in different blocks. The edge variance is estimated for the original image ($V_{\mathrm{o}}$) and the reconstructed image ($V_{\mathrm{r}}$) using the pixels just beside the edge on both sides and taking the average. Experimentally, for $(V_{\mathrm{r}}/V_{\mathrm{o}}) > 1.3$ the blocking artefact will be clearly visible. A set of images are tested to estimate the minimum number of AC quantized coefficients that give an edge variance less than the critical value with different block size.

Related to these two steps, 70% of the non-zero AC coefficients on each component (RGB colour space) provides a good results. After quantization and new scan the non-zero of the quantized coefficients is counted and only the first 70% of the non-zero AC coefficients on each component will be used as the input of the Huffman coding. The non-edge block will be coded using only the DC coefficient.

*Method 4 (M-3):* a 50% (chosen experimentally) of the non- zero AC coefficients of the edge blocks on R component, 50% of the non-zero AC coefficients of the edge blocks on G component, and 50% of the non-zero AC coefficients of the edge blocks on B component provides an accepted results. After quantization and new scan the non-zero of the quantized coefficients is counted and only the first 50% of the non-zero AC coefficients on each component (R, G, and B component) will be used as the input of the Huffman coding. The non-edge block will be coded using only the DC coefficient.

For five test images, the original image and the reconstructed image obtained using the proposed coding schemes are given in Table 1. The comparison of

**Table 2** Results obtained from experimentation with five test images.

| Test image | Original | Reconstructed (M-0 method) | Reconstructed (M-1 method) | Reconstructed (M-3 method) |
|---|---|---|---|---|
| Lena (512 × 512) |  |  |  |  |
| baboon (256 × 256) |  |  |  |  |
| airplane (512 × 512) |  |  |  |  |
| tree (256 × 256) |  |  |  |  |
| house (512 × 512) |  |  |  |  |

performance measures (compression rate measured in bitrate (bpp) and distortion measured in PSNR) of the proposed coding scheme (M-3) against results of M-0 coding, M-1 coding and M-2 coding schemes are presented in Table 1. Further discussion can be done using the improved image segmentation algorithm which has been presented in Ref. 25.

Table 2 shows the subjective quality comparison of the different images compressed by different methods (M-0, M-1, and M-3).

As shown in Fig. 5, the performance of new proposed method (M-0) is examined under different bitrate (bpp) condition.

Fig. 6 shows a comparison between the PSNR obtained with our method and the compression scheme proposed in Ref. 26. It can be seen that our method outperforms the compression method in Ref. 26 with at least 1–2.4 dB for PSNR up to and at least 1.4–2.9 dB for compression ratios. The difference is much greater at high bit-rate and less compression ratios. In fact, it can be seen that the proposed scheme (M-0) maintains an acceptable PSNR (higher than 33 dB) even at a bit-rate as high, where the compression method in Ref. 26 image quality is quite poor dB.

The best coding results are achieved with the proposed image coding based on adaptive scan. The adaptive scan has a not effect on the complexity of the proposed method. The proposed method, represent a complexity of $O(N)$, where $N$ corresponds to the total number of pixels in the image.

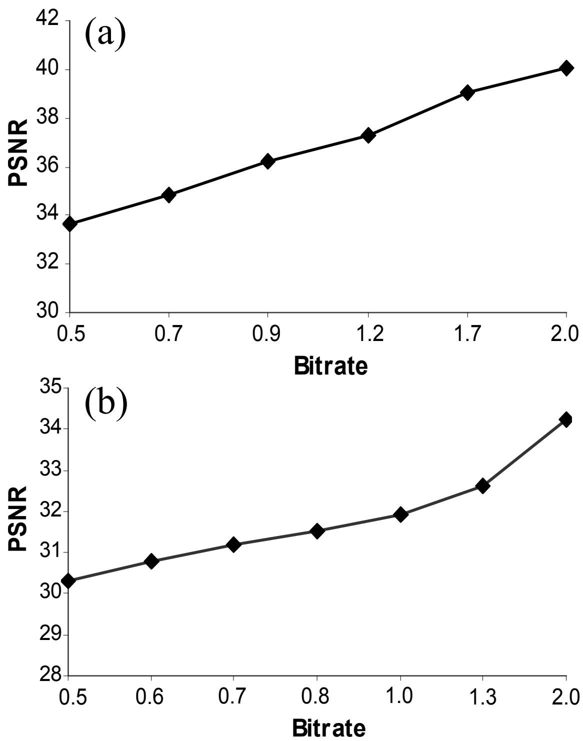



**Fig. 5** The PSNR versus bitrate (bpp) for: (a) Lena (b) tree based compression scheme M-0.

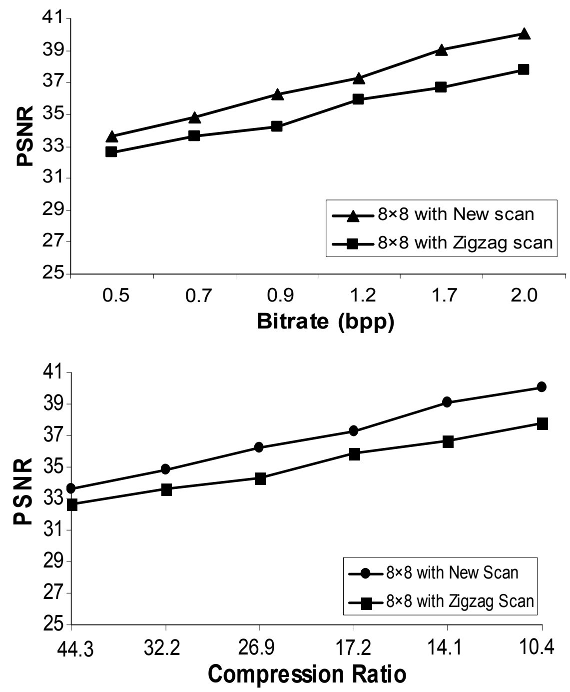



**Fig. 6** Use of zigzag scan against new scan for the colour Lena image with block size $(8 \times 8)$ based compression scheme (M-0).

## CONCLUSIONS

In this paper, we have proposed a scheme combining anew adaptive scan and colour image coding for effectual compression of images. The performance comparison of this technique with the recent paper is conducted, and shown superior performance of our algorithm in terms of quantitative distortion measures, as well as visual quality and PSNR. The experimental results demonstrate the effectiveness of the proposed scheme in image compression.

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