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An Efficient Image Compression Algorithm For Bayer-Pattern Images

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Abstract

In this paper, an efficient image compression algorithm for Bayer-pattern images is introduced. In Bayer pattern images each pixel is represented by 8-bit rather than 24-bit for colour images. The proposed algorithm separates the colour information from the Bayer-pattern image data before performing the compression operation. It partitions each colour plane into fixed size blocks. Each block is classified as a low or high intensity variation block using the standard deviation which compared against a predefined threshold. The low intensity variation blocks are encoded by its average while, the other blocks are encoded using the minimum, quantisation step and the bit plane. The quantisers that used in this paper are from 32 and 16 levels types. The effect of the block size on the output bit rate and image accuracy is studied. The results clarify that a good performance is achieved using 4×4-pixel blocks. Using 32 and 16 quantisation levels a bit rates of 1.8 to 5.2 bpp with a PSNR of 30 to 45 dB can be achieved for a range of thresholds 10 to 0.5.

Key Words: ***Image compression, Bayer pattern, Encoding, Quantising***

خوارزمية كفوءة لضغط صور من نمط باير

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الخلاصة

في هذا البحث تم تطوير خورزمية لضغط الصور من نوع Bayer . في هذا النوع من الصور كل بكسل يتم تمثيلة ب 8 بت بدلا من 24 بت كما في الصور الملونة . الخوارزمية المقترحة تفصل معلومات الالوان في الصورة الى مجاميع او مستويات (Colour planes) . ثم يتم تقسيم معلومات كل لون الى مربعات (كتل) ثابتة الابعاد . كل مربع يتم تصنيفه حسب تدرج الاضاءة اما عالي التدرج او واطيء التدرج باستخدام الانحراف المعياري لكل مربع ومقارنتة مع حد معين . المربعات واطئة التدرج يتم احتيار معدلها فقط بينما المربعات الاخرى يت م حساب اقل قيمة و ال quantisation step وال Bit Plane لكل مربع. ال quantisaters المستخدمة في هذا البحث هي من نوع 32 و 16 مستوى. كذلك تمت دراسة تاثير حجم المربعات المختارة على دقة الصورة المضغوطة . النتائج المستخلصة اثبتت ان افضل نتائج تكون عند اختيار مربعات بحجم (4×4) بكسل . وايضا تم الحصول على Bit rate بحدود 1.8 الى 5.2 لكل بكسل بدقة 30 الى 45 ديسيبل لحدود عتبة 10 الى 0.5 .

1. Introduction

The cheap digital cameras use a single sensor and Colour Filter Array (CFA) to capture the colour information of the scene. One of the well-known colour filter array is named as the Bayer filter [1] . The cameras that use the Bayer filter array capture and represent images with a rate of two green values and one for red and blue. This can be represented in Fig. 1 for four Bayer units. The regular RGB image can be obtained from Bayer images by interpolating. The interpolation operation generates the redundant colour information for the Red, Green and Blue colour bands.

This paper introduces an efficient algorithm for Bayer images compression that is suitable for mobile and small devices because of its low complexity. The proposed algorithm performs the compression operation before interpolation for further bit rate reduction.

The rest of the paper is organized as follows. Section-2 introduces some related work, Section-3 presents the proposed compression algorithm. A sample of the results obtained is discussed in Section-4, and the conclusions are listed in section-5.

G1	R	G1	R
B	G2	B	G2
G1	R	G1	R
B	G2	B	G2

Fig. 1. Bayer pattern-single plane

2. Related Work

The Bayer images represent each pixel by an eight bit, while the RGB images (after interpolation) uses 24 bit per pixel. In such a case the compression algorithms can be performed before or after interpolation. As a matter of fact that compression before interpolation can reduce the bit rate further than that obtained after the interpolation operation. A large number of compressions after interpolation algorithms is introduced [2-6]. Among these algorithms are the JPEG and JPEG2000 standards [5, 6] and the low computational complexity algorithms, such as the Adaptive Quantisation Coding (AQC) [2-4]. In this paper, the main objective is to introduce a low computational complexity algorithm for Bayer or CFA images. The AQC algorithm is selected due to its good output accuracy, low bit rate and low computational complexity. Various AQC algorithms are introduced for better performance, more details about that can be found in [2-4].

The over mentioned algorithms are used to compress the Bayer images after interpolation, such as the JPEG [7, 8] and H.264 [9] for video compression.

3. The Proposed Algorithm

The proposed algorithm composes of colour separation, partitioning each colour band into a fixed sizes blocks, thresholding and quantisation, as shown in the flowchart in Fig. 2.

The colour separation operation is performed by extrication each colour in the Bayer pattern in an individual plane. Two planes is generated for the green colour, single plane for red and the last plane is extracted for blue colour, as shown in Fig. 3. The colour separation operation produces a highly correlated colour planes which makes the compression process more efficient.

The colour bands are partitioned into none overlapping (m×m) blocks to examine the intensity variation of each block. The intensity variation is computed using the standard deviation of each block, where the standard deviation is computed using [10]:

$$Std = \sqrt{\overline{M^2} - \bar{M}^2} \qquad (1)$$

where $\bar{M}$ and $\overline{M^2}$ is the mean of each image block and the average of the intensity square of each pixels, respectively.

Further, the standard deviation is compared with a predefined threshold to compute the required encoding parameters for each image block, as described in the following equation:

$$\text{Parameters} = \begin{cases} \text{Mean} & \text{if Std} \leq \text{Threshold} \\ \{\text{Minimum, Quantisation step and bit plane}\} & \text{otherwise} \end{cases} \qquad (2)$$

Equation (2) can be explained as follows; the low intensity variation blocks are encoded by its mean, while other blocks are encoded by three parameters. These three parameters are the minimum, quantisation step and the bit plane.

The quantisation step for each image block is computed using [2, 3] :

$$Q_s = (Max-Min)/Q_L \quad (3)$$

where Q_s and Q_L are the step size and the number of the quantisation levels, respectively, Max and Min are the maximum and minimum of any image block.

The number of quantisation levels is specified by the user, in this paper the quantisation levels is selected to be 16 for the green planes and 32 for the other planes, however any other number can be used. The number of quantisation levels selection depends on the required bit rate and the output accuracy. For good output accuracy high number should by selected (32-level, as an example), however this will results in high bit rate or low compression ratio. Further, the bit plane (B_p) is computed using [4]:

$$B_p(i,j) = \frac{(B(i,j) - Min)}{Q_s} \quad (4)$$

where B(i,j) represents the intensity values of the input image block.

The preceding procedure reduces the bit rate to:

$$\text{Bit Rate} = \lceil \log_2(Q_L) \rceil + \frac{16}{m \times m} \quad (5)$$

As an example, if the number of quantisation levels is 32 and a block size of 4×4-pixel is selected; the bit rate of the compressed image will be 6 bit per pixel (bpp) rather than an eight bpp. The proposed algorithm reduces the bit rate further using a predefined threshold. In such case many blocks are classified as a low intensity variation blocks, and the bit rate of such blocks can be computed as follows:

$$\text{Low intensity variation blocks Bit Rate} = \frac{8}{m \times m} \quad (6)$$

While the bit rate of the high intensity variation blocks or edge blocks is computed using (4).

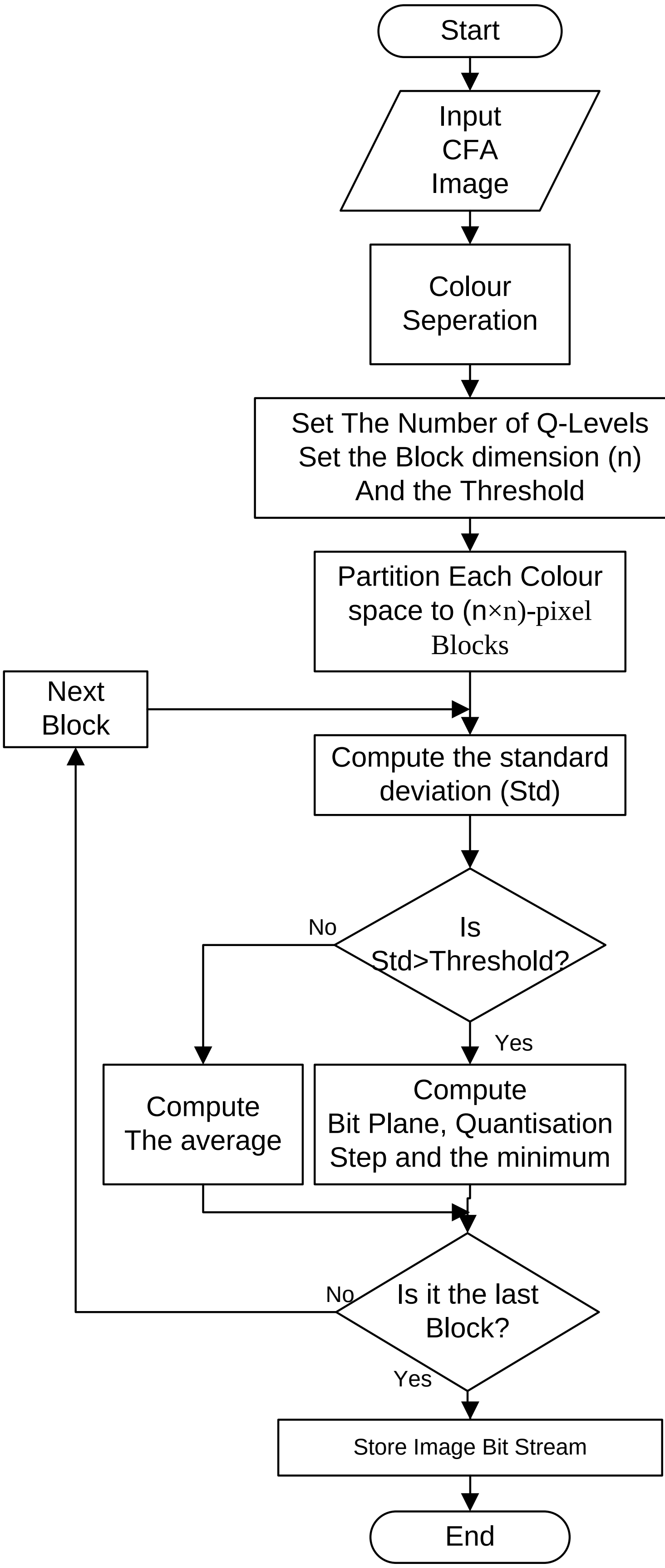


Fig. 2. Flowchart of the Proposed Encoder.

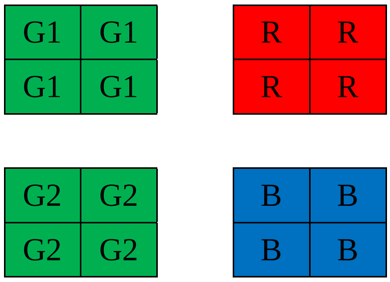


Fig. 3. Colour separation operation

The thresholding operation has a good impact on bit rate reduction specifically for image that contains large low intensity variation areas. Further, the bit rate can be reduced without much affect the output accuracy by an appropriate selection of the number of the quantisation levels, block sizes and threshold.

4. Results

The proposed algorithm is tested using six CFA images, as shown in Fig. 4 before interpolation and in Fig. 5 after interpolation. In Fig. 4, then buyer pattern is obvious by the thin horizontal and vertical lines.

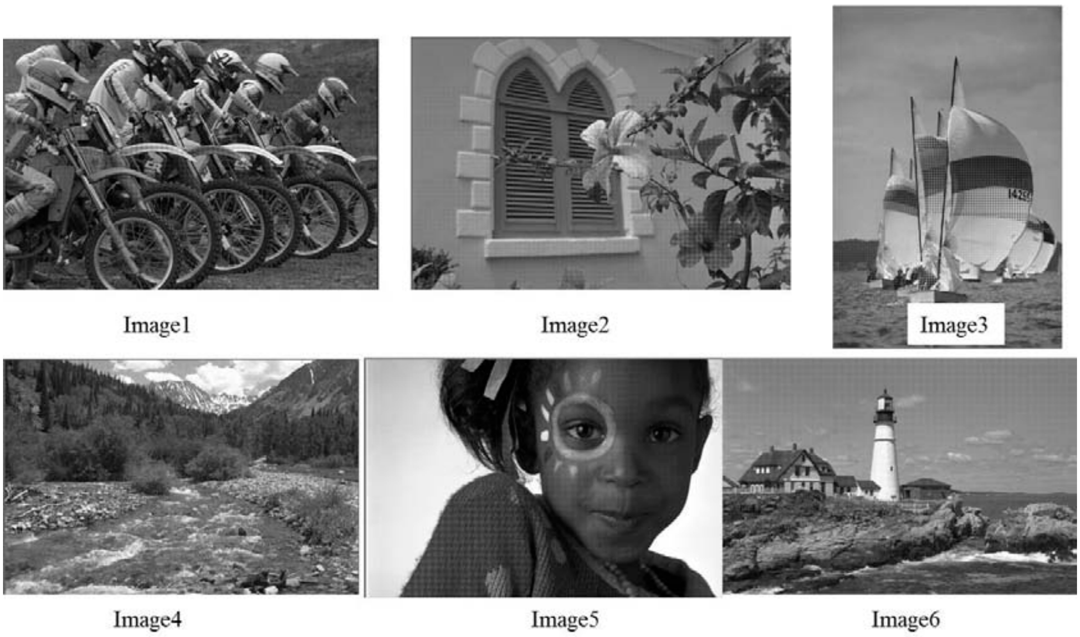


Fig. 4. CFA test images before interpolation.

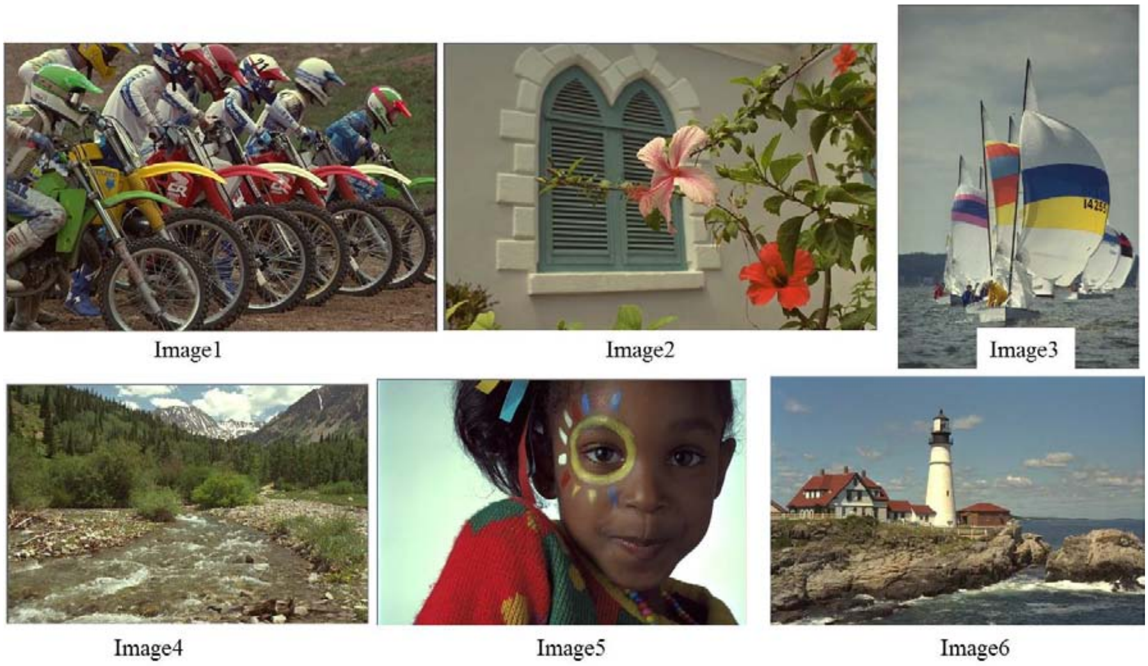


Fig. 5. CFA test images after interpolation.

The Peak Signal to Noise Ratio (PSNR) test is used to test the performance of the proposed algorithm; it can be computed using the following equation[10]:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{255^2 \times 3PQ}{\sum_{i,j,k}^{P,Q,3}\left(I_{O(i,j,k)-}I_{R(i,j,k)-}\right)^2}\right) \qquad (7)$$

where I_R is the reconstructed image, I_O is the original interpolated image, P and Q are the dimensions of the original image, i=1, 2, ... P, J=1, 2, ...q and k=1,2,3.

The bit rate is also evaluated using various block sizes and threshold values. In Fig. 6 and Fig. 7 the PSNR (dB) and the bit rate (bpp) for image6 using 4×4, 8×8 and 16×16-pixel block sizes. The comparison between both figures shows that a good performance is achieved using a block size of 4×4-pixel due to the high correlation between pixels in a small area. This is clear in the high thresholds which results in low bit rate with a good PSNR.

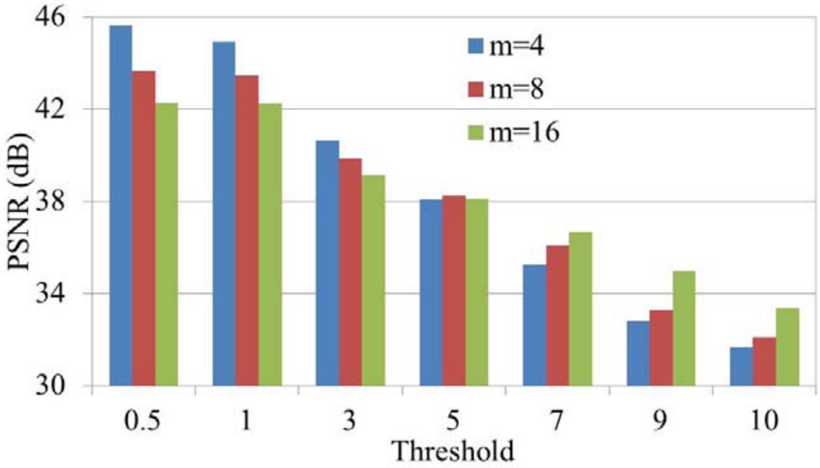


Fig. 6. The PSNR of the reconstructed Image6 using block of 4×4, 8×8 and 16×16-pixel

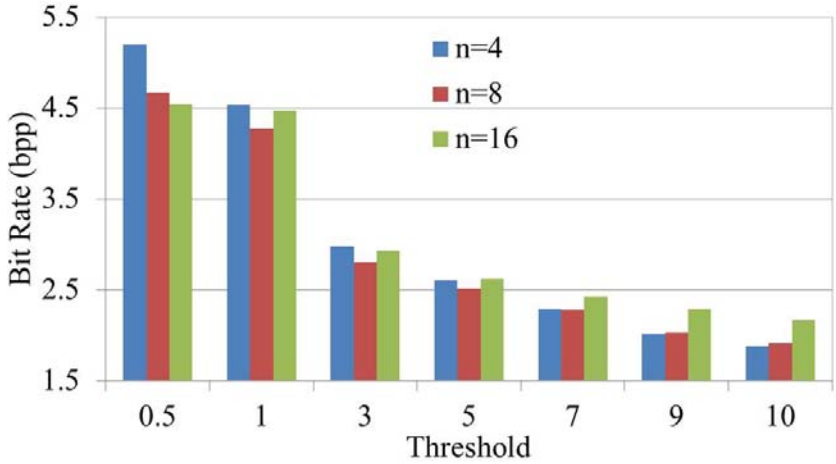
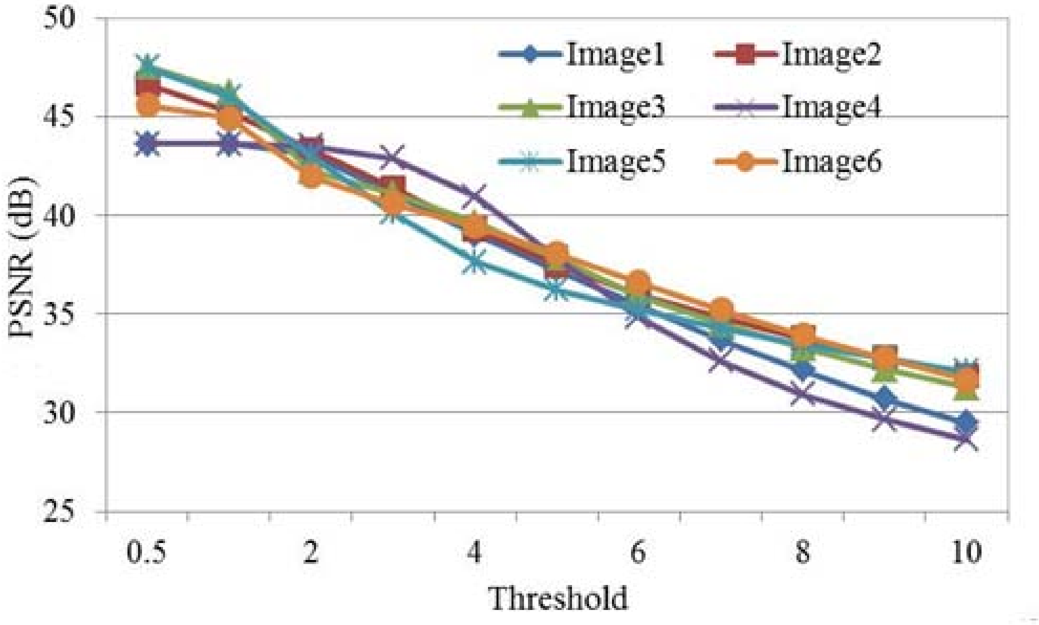


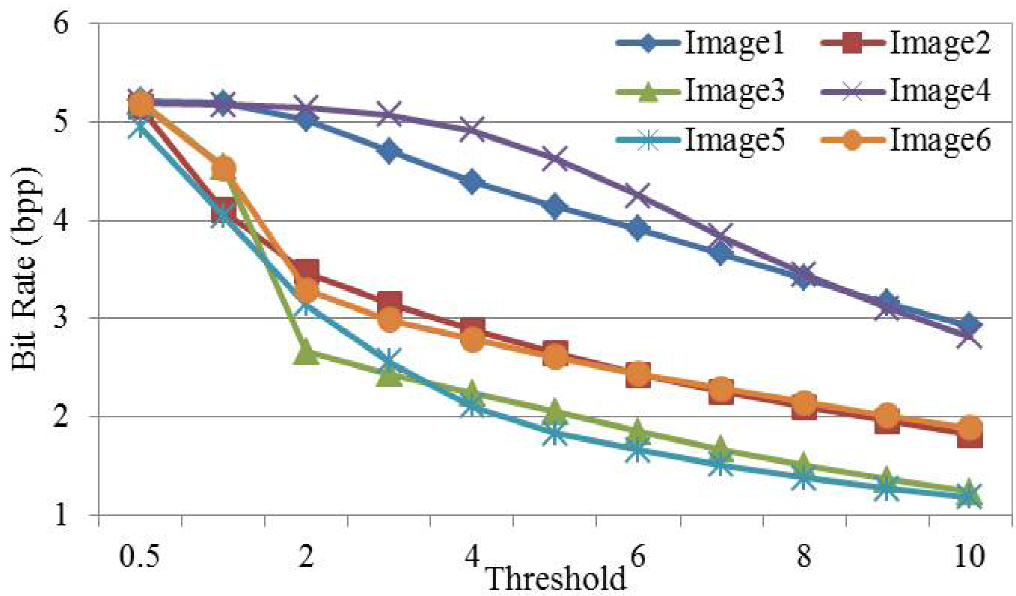
Fig. 7. The bit rate of the reconstructed Image6 using block of 4×4, 8×8 and 16×16-pixel

Further, the PSNR and the bit rate of the reconstructed test images are shown in Fig. 8 and Fig. 9. 4×4 and 8×8 –pixel are used with a range of thresholds starting from 0.5 to 10 to evaluate the bit rate and PSNR of the proposed algorithm. It is obvious from both figures that, the image1 and 4 introduces high bit rate which can be explained as these two images contains high intensity variations regions. While the other test images comprises large smooth areas and the can be considered as a low intensity variation images. The compression ratios of the selected six images are shown in Table 1. It can be noticed that a compression ratio of 90% can be obtained using the proposed algorithms.

In addition, to introduce an important sight about the performance of the proposed algorithm, the reconstructed images using high thresholds are shown in Fig. 10. The features of the reconstructed images are clear, however, a little blocking artefact in the boundaries between some blocks is appeared in few images. This can be explained because high compression ratio is achieved and many images blocks are represented by its average.

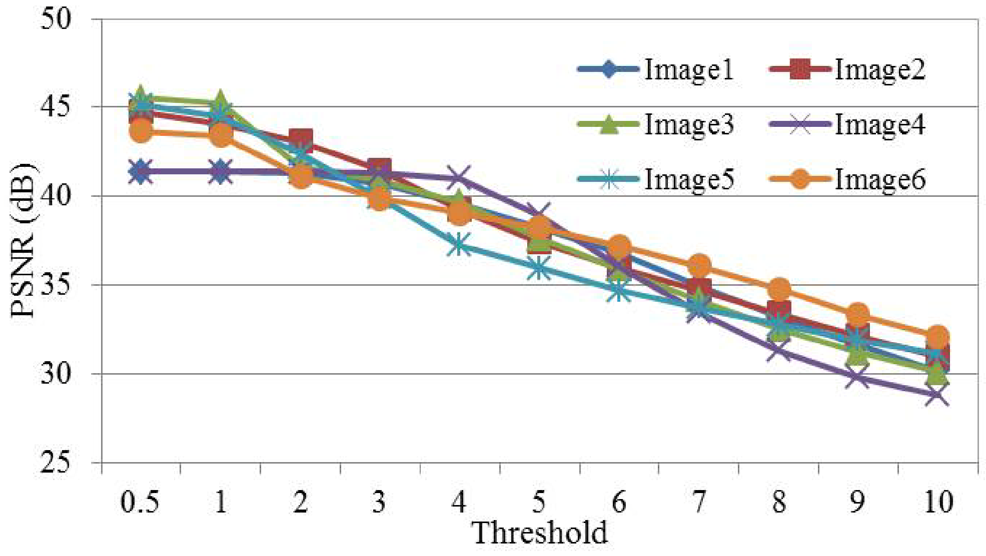


a. PSNR

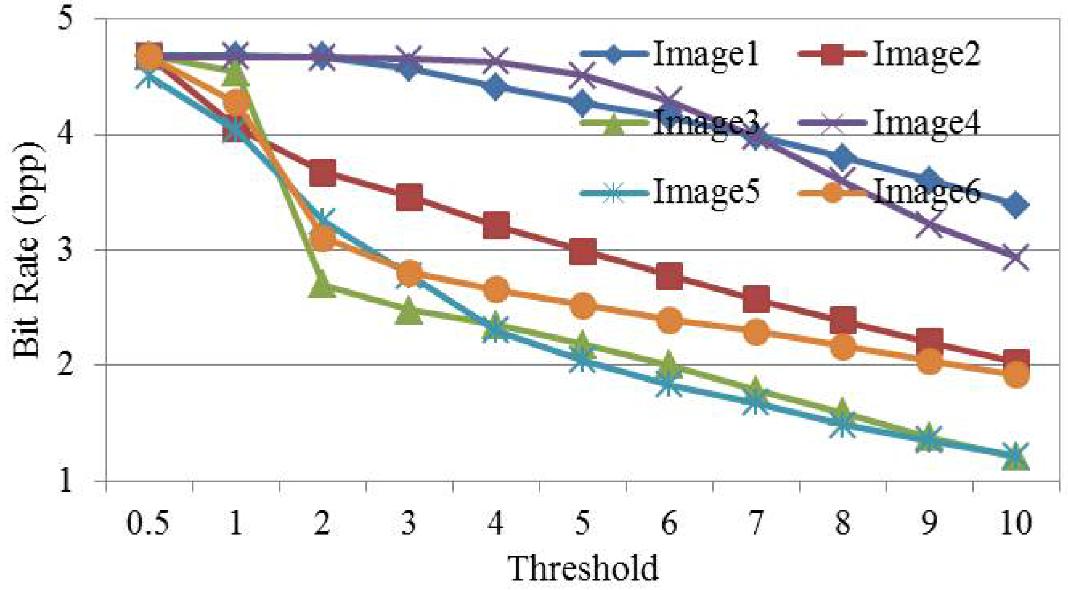


b. Bit Rate

Fig. 8. PSNR and Bit rate of the test images using block sizes of 4×4–pixel and various thresholds.



a. PSNR



b. Bit Rate

Fig. 9. PSNR and Bit rate of the test images using block sizes of 4×4–pixel and various thresholds.

Table 1: Compression ratios of the selected images using block sizes of 4×4 and 8×8–pixel for various thresholds.

Compression Ratio (%)												
Thres -hold	Image1		Image2		Image3		Image4		Image5		Image6	
	4×4	8×8	4×4	8×8	4×4	8×8	4×4	8×8	4×4	8×8	4×4	8×8
0.5	78	81	79	81	78	81	78	81	79	81	78	81
2	79	81	86	85	89	89	79	81	87	86	86	87
3	80	81	87	86	90	90	79	81	89	88	88	88
4	82	82	88	87	91	90	80	81	91	90	88	89
5	83	82	89	88	91	91	81	81	92	91	89	90
6	84	83	90	88	92	92	82	82	93	92	90	90
7	85	83	91	89	93	93	84	83	94	93	90	90
8	86	84	91	90	94	93	86	85	94	94	91	91
9	87	85	92	91	94	94	87	87	95	94	92	92
10	88	86	92	92	95	95	88	88	95	95	`92	92

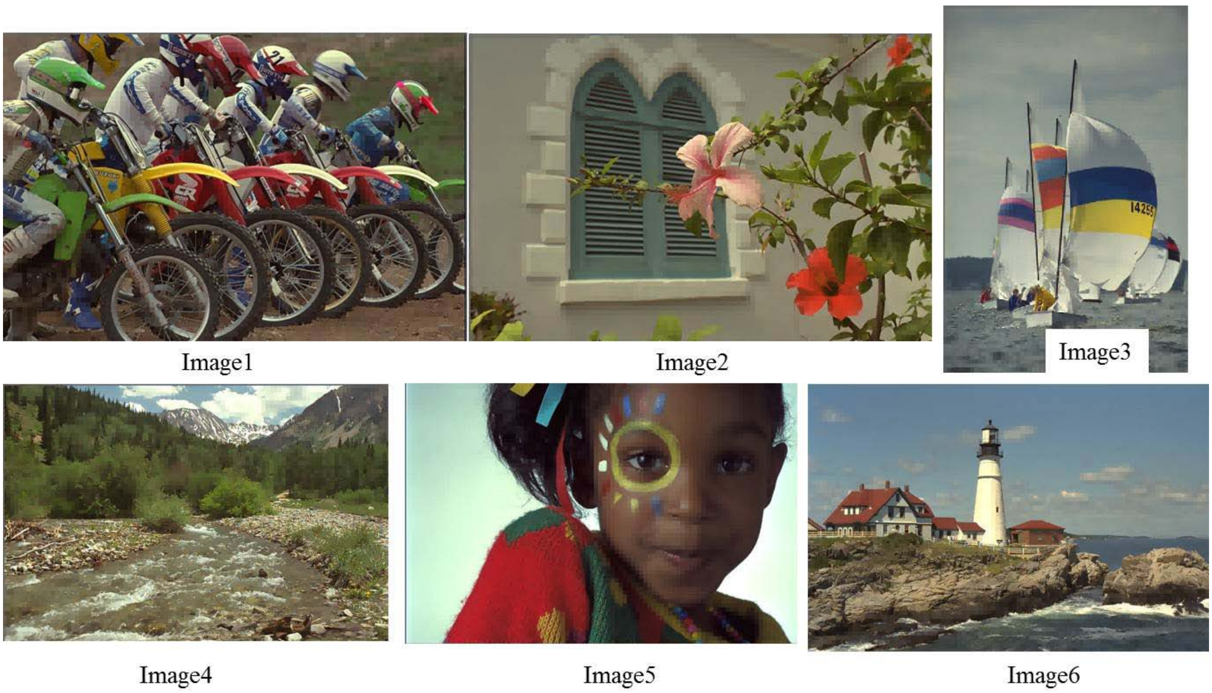


Fig. 10. The reconstructed images using block size of 4×4–pixel and a threshold value of 10 (high compression ratio).

5. Conclusions

The proposed algorithm is tested using various Bayer-pattern images. The main characteristics of the proposed algorithm are its low computational complexity and high compression ratio. The low complexity represents an important factor for small or mobile devices applications. The obtained results demonstrate that the proposed algorithm can be considered as an efficient compression algorithm for such type of images. Low bit rate with a good output images are obtained. Better bit rate has been achieved for 4×4-pixel image blocks.

The reconstructed images introduces low blocking artefact even high thresholds are used which may consider as an additional advantage for the proposed algorithm. Further, the relation between bit rate and image quality can be improved using an appropriate number of the quantization levels and threshold values.

6. References

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