Composite Techniques Based Color Image Compression

Zainab Ibrahim Abood
Instructor
Engineering College-Baghdad University
Email:zainab2012254@yahoo.com

ABSTRACT

Compression for color image is now necessary for transmission and storage in the data bases since the color gives a pleasing nature and natural for any object, so three composite techniques based color image compression is implemented to achieve image with high compression, no loss in original image, better performance and good image quality. These techniques are composite stationary wavelet technique (S), composite wavelet technique (W) and composite multi-wavelet technique (M). For the high energy sub-band of the 3rd level of each composite transform in each composite technique, the compression parameters are calculated. The best composite transform among the 27 types is the three levels of multi-wavelet transform (MMM) in M technique which has the highest values of energy (En) and compression ratio (CR) and least values of bit per pixel (bpp), time (T) and rate distortion (R(D)). Also the values of the compression parameters of the color image are nearly the same as the average values of the compression parameters of the three bands of the same image.

Key words: image compression, color images, composite techniques, composite transforms, compression parameters.

التقنيات المركبة المستندة على ضغط الصورة الملونة

زينب ابراهيم عبود
مدرس
كلية الهندسة- جامعة بغداد

الخلاصة

ضغط الصورة الملونة حاليا ضروري للنقل والتخزين في قواعد البيانات حيث ان اللون يوحي الى الطبيعة السارة والطبيعية لأي جسم. لذلك ثلاث تقنيات مركبة مستندة على ضغط الصورة الملونة تم تنفيذها للحصول على ضغط أعلى، عدم فقدان معلومات من الصورة الاصلية، أداء أفضل والحصول على الجودة في الصورة. هذه التقنيات هي تقنية المويجات الثابتة المركبة (S)، تقنية المويجات المركبة (W) وتقنية المويجات المتعددة المركبة (M). تم حساب معاملات الضغط للجزء العالي الطاقة للمستوى الثالث لكل تحويل مركب في التقنية المركبة. التحويل المركب الافضل من بين 27 نوع هو المستويات الثلاثة لتحويل المويجات المتعددة (MMM) في تقنية M والتي فيها قيمة الطاقة (En)ونسبة الضغط (CR) أعلى القيم وعدد ال bit per pixel (bpp) والوقت (T) ومعدل التشويه (R(D)) أقل القيم. كذلك قيم معاملات الضغط للصورة الملونة تقريبا مساوية لمعدل قيم معاملات الضغط للحزم الثلاثة لنفس الصورة.

الكلمات الرئيسية: ضغط الصورة، الصور الملونة، التقنيات المركبة، التحويلات المركبة، معاملات الضغط.

1. INTRODUCTION

In the color image, the spatial component correlation among the three bands red, green, and blue is significant. In order to get a good compression performance, the correlation among the three bands must be reduced by converting the color image into the de-correlated color space, **Miry, 2009**.

For three different kinds of images, standard Lena, satellite urban and satellite rural image, various statistical parameters of the image such as Rate Distortion, Kurtosis, symmetry and Skewness, are derived for Set Partitioning in Hierarchical Trees (SPIHT) compression scheme, they are derived for a fixed level and fixed rate of decomposition for the three kinds of images and they are used for explanation of the Peak Signal to Noise Ratio (PSNR) and Compression Ratio (CR). The results of urban images are the best for SPIHT compression scheme as compared with the satellite rural image, **Nagamani, and Ananth, 2012**. **Abood, 2013** introduced three dimension two level, wavelet transform, multi-wavelet transform and hybrid (wavelet-multi-wavelet) techniques. The parameters root-mean-square difference, energy retained, Peak Signal to Noise Ratio, entropy and compression ratio are measured for each 3-D two-level technique. According to these parameters, a comparison between these techniques is presented and the results illustrated that the three dimension two level hybrid technique is the best for image compression.

Dhumal and Deshmukh presented image compression technique using Singular Value Decomposition (SVD) transform. This (SVD) can transform the matrix into product, which allows anyone to refactor the digital image into three orthogonal matrices. The using of the singular values of the refactoring allows representing any image with a set of decreased values, which can store the original image useful features, take less storage space in the memory, so it is used for image compression, **Dhumal and Deshmukh, 2016**. **Sudhakar, and Sudha, 2011** introduced an efficient color compression technique i.e. higher compression ratio and better quality by using multi-wavelet transform and the embedded coding of the multi-wavelet coefficients through (SPIHT) algorithm.

2. COLOR IMAGE COMPRESSION

Images use either 24-bit or 8-bit color. In the case of 8-bit, the range of the pixel value is 0-255 (i.e. 256 different colors). In the case of 24-bit, each pixel in the image uses 24-bit and each 8-bit in the 24-bit is used to represent three band colors red, green and blue (R, G, B).

For Images compression, the needing for efficient techniques is usually increasing because the images need large size of disk space so it is a big disadvantage during storage and transmission, **Dutta, et al., 2012**.

3. COMPRESSION PARAMETERS

3.1 Bit per Pixel (bpp)

The precision of a sample can be represented by a number of bits in the pixel; the higher precision value is better which represents the picture quality. Here the compression ratio is measured in terms of the bpp, **Dutta, et al., 2012**.

$$bpp = \frac{8 \times compressed\ image\ size}{original\ image\ size} \quad (1)$$

3.2 Computation Time (T)

The computation time is normalized and calculated by:

$$T = \frac{2}{3}\,(1 - 4^{-L})\,N^2 \qquad (2)$$

where N^2 is the size of the image, and L is the number of the level, **Dia, et al., 2009**.

3.3 Energy (En)

Energy is the sum of squared elements in the image, **Abood, et al., 2013**:

$$En = \sum_i \sum_j x^2\,(i, j) \qquad (3)$$

3.4 Compression ratio (CR)

A logical way to measure how good the compression algorithm compresses an image is to look at the compression ratio which is the ratio of the number of bits that required to represent the image before compression to the number of bits that required to represent the image after compression, **Sayood, 2006**, so the ratio between the size before compression and the size after compression, **Shini, et al., 2016**:

$$CR = \frac{size\ befor\ compression}{size\ after\ compression} \qquad (4)$$

3.5 Mean Absolute Error (MAE)

If $x(i,j)$ is the original image and $y(i,j)$ is the reconstructed image, then the Mean Absolute Error will be, **Kumar, and Rattan, 2012**:

$$MAE = \frac{1}{N^2}\sum_{I=1}^{N}\sum_{j=1}^{N}|(x(i,j) - y(i,j))| \qquad (5)$$

3.6 Rate Distortion R (D)

Rate is the average number of the bits used in representing each sample value. Distortion is the measure of a difference between original image and compressed image. R (D) function is the lowest rate that while keeping the distortion equal to or less than D, the output can be encoded.

$$R(D) = \frac{1}{2} \times log_{10}\,(\frac{\sigma^2}{MSE}) \qquad (6)$$

where (σ^2) represents the Variance, **Nagamani, and Ananth, 2012**, and

$$MSE = \frac{1}{N^2}\sum_{I=1}^{N}\sum_{j=1}^{N}(x(i,j) - c(i,j))^2 \qquad (7)$$

where $c(i,j)$ represents the compressed image, **Abood, 2013**.

4. TRANSFORMATION

In image compression, it is desirable to select the useful transform that reduces the size of resultant image as compared to the original image, **Kharate, and Patil, 2010**. If the sampled functions have discrete time and frequency then wavelet transform used is so called Discrete Wavelet Transform (DWT). This technique is based on sub-band coding algorithm. Compression is based on the approximation of regular signal components using the filter coefficients and detailed coefficients, **Hamsalakshmi, and Kalaivani, 2016**.

Stationary wavelet transform (SWT) is designed to overcome the lack of the translation-invariance of the DWT. The SWT is a redundant scheme, as its output in each level contains a similar number of samples as in the input, **Saminu, and Özkurt, 2015**.

Algorithms based on the wavelets have been worked well in the image compression. Scalar wavelets don't possess all properties wanted for a better performance in the compression but 'Multi-wavelet' overcomes this problem because it possesses multi-filters, **Radhakrishnan, and Subramaniam, 2008**. Theoretically, Multi-wavelets should work even better because of the extra freedom in the multi-filters' design, **Miry, 2008**.

5. THE PROPOSED ALGORITHM

Fig. 1 shows the block diagram of the overall proposed system, which is illustrated as follows:

1. Input color image, in the other side input the same color image but with isolated bands i.e. taking the red, green and blue bands of the same color image.
2. Convert the color image, red, green and blue bands to gray image.
3. As a preprocessing, convert each gray image to a double-precision and resize them to be of size (1024*1024).
4. Input the processed images to three composite techniques S, W and M as shown in **Fig. 2**.

There are " 3^n " different cases, where " 3 " refers to 3-level composite stationary wavelet transform (s), 3-level composite wavelet transform (w), and 3-level composite multi-wavelet transform (M), while " n " refers to the number of level. The three composite techniques are:

a. Composite technique S, which contain (3^{n-1}) different cases of a 3-level composite transform of s, w and M, i.e. sss, ssw, ssM, sws, sww, swM, sMs, sMw and sMw. For example, in swM, the 1st level is "s", the 2nd level is "w" and the 3rd level is "M". Wavelet transform is applied to the high energy sub-band of "s" and multi-wavelet transform is applied to the high energy sub-band of "w".

b. Composite technique W, which contain (3^{n-1}) different cases of a 3-level composite transform of w, s and M, i.e. www, wws, wwM, wsw, wss, wsM, wMw, wMs and sMM. For example, in wsM, the 1st level is "w", the 2nd level is "s"and the 3rd level is "M". Stationary wavelet transform is applied to the high energy sub-band of "w" and multi-wavelet transform is applied to the high energy sub-band of "s".

c. Composite technique M, which contain (3^{n-1}) different cases of a 3-level composite transform of M, s and w, i.e. MMM, MMs, MMw, MsM, Mss, Msw, MwM, Mws and Mww. For example, in Msw, the 1st level is "M", the 2nd level is "s" and the 3rd level is "w". Stationary wavelet transform is applied to the high energy sub-band of "M" and wavelet transform is applied to the high energy sub-band of "s".

5. For each high energy sub-band of the 3rd level in each composite technique, the compression parameters are calculated according to Eq's.1, 2, 3, 4, 5 and 6.
6. The final decision is taken for the techniques that have best compression.

6. RESULTS AND DISCUSSION

In all tables, the best values are written as red values and the suffix " av " in S_{av}, W_{av} and M_{av} refers to the average of parameters' measurements of the images in the composite S, W and M techniques respectively. Table 1 shows the results of the compression parameters for the color images in the S composite technique, the sMM composite technique has the least values of Bpp, T (in second) and R(D), and has the highest values of En and CR, while ssM has the least value of MAE (3.7004 e-16). **Fig. 3** illustrates the chart of these results.

Table 2 shows the results of the compression parameters for the color images in the W_{av} composite technique, the wMM composite technique has the least values of Bpp, T and R(D) (0.0078, 0.0006, 4.5269) respectively, and has the highest values of En and CR (5.247 and 1024) respectively, while www has the least value of MAE (2.8291 e-16). **Fig. 4** illustrates the chart of these results.

Table 3 shows the results of the compression parameters for the color images in the composite M_{av} technique, the MMM composite technique has the least values of Bpp (0.0020), T (0.0001) and R(D) (2.7253), has the highest values of En (41.6531) and CR (4096), while Mww has the least value of MAE (0.6679e-15). **Fig. 5** illustrates the chart of these results.

Therefore, using multi-wavelet in the image compression improves the image reconstruction, image compression and decrease the computation time, so, for good compression in the color image the composite techniques sMM, wMM and MMM must be used.

Tables 4, 5 and 6 show the results of the compression parameters for the color (red, green and blue bands) images in the S_{av} composite technique, where RS_{av}, GS_{av} and BS_{av} refer to the average of parameters' measurements of the images in the red, green and blow bands of S technique, all bands have the same bpp, T and CR in each composite technique (i.e., in RS_{av}, GS_{av} and BS_{av}, sss has bpp (8), T (0.6562) and CR (1)). The sMM composite technique has the least values of bpp, T and R, and has the highest values of En and CR, while ssM has the least value of MAE (3.7122e-16). **Fig. 6** illustrates the chart of the compression parameters for the color (red-band) images in the S_{av} composite technique.

Tables 7, 8 and 9 show the results of the compression parameters for the color (red, green and blue bands) images in the W_{av} composite technique, all bands have the same bpp, T and CR in each composite technique (i.e., in RW_{av}, GW_{av} and BW_{av}, www has bpp (0.1250), T (0.0102) and CR (64). The wMM composite technique has the least values of bpp, T and R(D), and has the highest values of En and CR, while www has the least value of MAE (2.0579e-16). **Fig's. 7 and 8** illustrate the charts of the compression parameters for the color (red and blue bands) images in the W_{av} composite technique.

Table 10, 11 and 12 show the results of compression parameters for the color (red, green and blue bands) images in the M_{av} composite technique, all bands have the same bpp, T and CR in each composite technique (i.e., in RM_{av}, GM_{av} and BM_{av}, Mww has bpp (0.0313), T (0.0025) and CR=256). The MMM composite technique has the least values of bpp, T and R, and has the highest values of En and CR, while Mww has the least value of MAE (5.764e-16). **Fig's. 9, 10 and 11** illustrate the charts of the compression parameters for the color (red, green and blue bands) images in the M_{av} composite Technique.

Therefore, for good compression in the color image of isolated bands the composite techniques sMM, wMM and MMM must be used, so for either color image or color image of isolated bands the composite techniques sMM, wMM and MMM can be used for good compression.

Fig. 12 shows samples of database images used in this work.

7. CONCLUSIONS

In this study, three composite techniques S, W and M based color image compression is implemented. For color image and color image of isolated bands the best composite technique among the 27 types is the MMM in M technique which has the highest values of En and CR which are 41.6531 and 4096 respectively, and least values of bpp, T and R(D) which are 0.002, 0.0001 and 2.7253 respectively for color image. Also it is concluded that the values of the compression parameters of the color image are nearly the same as the average values of the compression parameters of the three bands of the same image.

This work is useful to achieve image with high compression, no loss in original image, better performance and good image quality. As future works, one can use these composite techniques in speech compression, speech recognition and image recognition to show which technique is the best that gives a high speech compression performance, speech recognition performance and image recognition performance.

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9. NOMENCLATURE

bpp	bit per pixel
c(i, j)	compressed image
CR	compression ratio
DWT	discrete wavelet transform
En	energy
L	number of the level
M	composite multi-wavelet technique
M_{av}	average of parameters measurements of the images in the composite M technique
MMM	three level of multi-wavelet transform
N^2	size of the image
PSNR	peak signal to noise ratio
R(D)	rate distortion
R, G, and B	three band colors red, green and blue
S	composite stationary wavelet technique
S_{av}	average of parameters measurements of the images in the composite S technique
SPIHT	Set Partitioning in Hierarchical Trees

SVD singular value decomposition
SWT stationary wavelet transform
T time in second
σ^2 variance
W composite wavelet technique
W_{av} average of parameters measurements of the images in the composite W technique
x(i, j) original image
y(i, j) reconstructed image

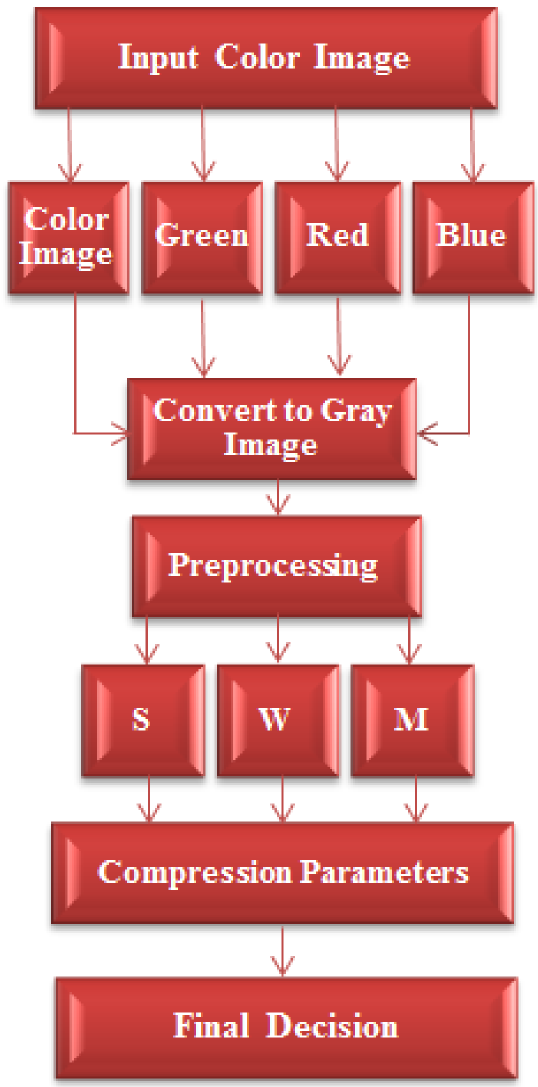

Figure 1. Block diagram the proposed system.

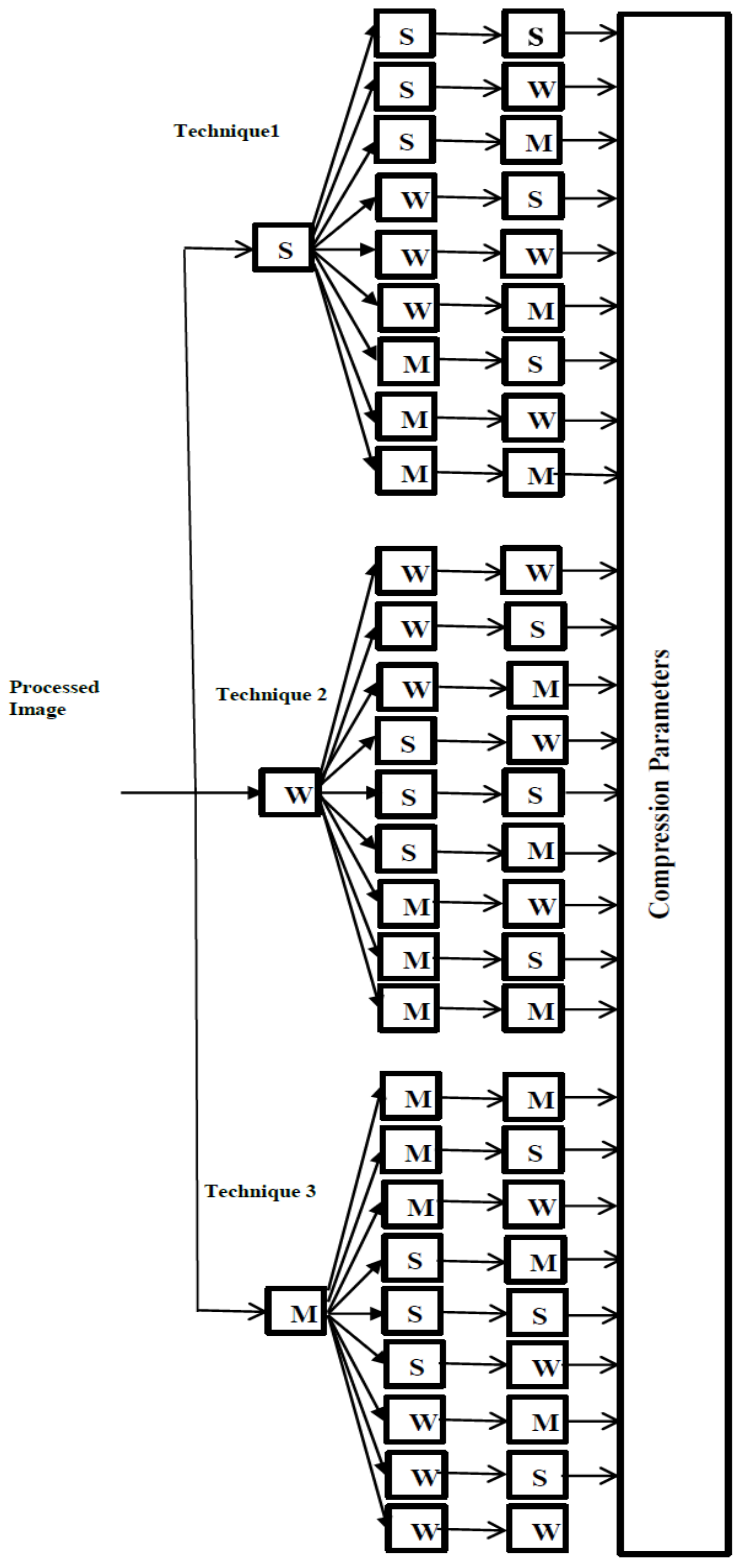

Figure 2. Three composite techniques S, W and M.

Table 1. Compression parameters for color S_{av} technique.

S_{av}	Bpp	T	En	CR	MAE	R(D)
SSS	8.0000	0.6562	0.0104	1	3.6349 e-08	46.9122
SSW	2.0000	0.164	0.0418	4	4.3843 e-16	29.77
SSM	0.5000	0.041	0.1668	16	3.7004 e-16	19.1907
SWS	2.0000	0.164	0.0209	4	7.4415 e-08	29.9228
SWW	0.5000	0.041	0.0418	16	4.4821 e-16	18.74355
SWM	0.1250	0.0102	0.8333	64	3.9505 e-16	11.9701
SMS	0.5000	0.041	0.1668	16	1.5224 e-07	19.4199
SMW	0.1250	0.0102	0.3336	64	8.9287 e-16	12.0112
SMM	0.0313	0.0025	2.6671	256	8.3379 e-16	7.481

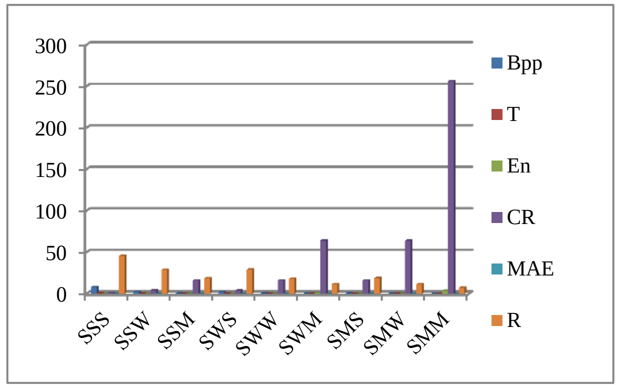

Figure 3. Chart of compression parameters for color S_{av} technique**.**

Table 2. Compression parameters for color W_{av} Technique.

W_{av}	bpp	T	En	CR	MAE	R(D)
WWW	0.1250	0.0102	0.0835	64	2.8291 e-16	11.6792
WWS	0.5000	0.041	0.0417	16	8.0035 e-08	18.9526
WWM	0.0313	0.0025	0.6676	256	4.0864 e-16	7.3689
WSW	0.5000	0.041	0.0417	16	4.453 e-16	18.8101
WSS	2.0000	0.164	0.0209	4	7.2764 e-08	30.0081
WSM	0.1250	0.0102	0.3331	64	4.4041 e-16	11.9957
WMW	0.0313	0.0025	0.6663	256	6.6639 e-16	7.3927
WMS	0.1250	0.0102	0.3329	64	1.5659 e-07	12.2132
WMM	0.0078	0.0006	5.247	1024	8.8067 e-16	4.5269

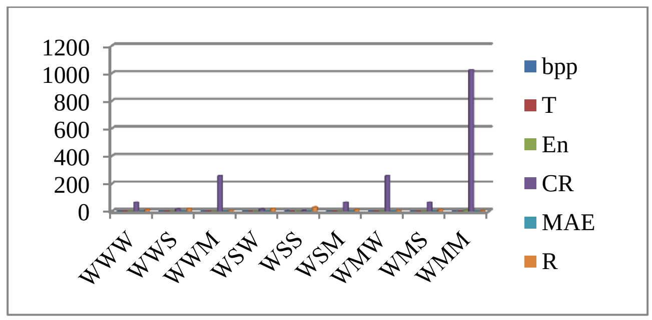

Figure 4. Chart of compression parameters for color W_{av} Technique.

Table 3. Compression parameters for color M_{av} Technique.

M_{av}	bpp	T	En	CR	MAE	R(D)
MMM	0.0020	0.0001	41.6531	4096	1.7564 e-15	2.7253
MMS	0.0313	0.0025	2.6599	256	3.1418 e-07	7.7415
MMW	0.0078	0.0006	5.3211	1024	1.7487e-15	4.5744
MSM	0.0313	0.0025	2.6618	256	0.8773e-15	7.5056
MSS	0.5000	0.041	0.1668	16	1.4258e-07	19.5198
MSW	0.1250	0.0102	0.3336	64	1.038e-15	12.0967
MWM	0.0078	0.0006	5.2578	1024	0.8868e-15	9.0584
MWS	0.1250	0.0102	0.6667	64	1.5535e-07	12.2269
MWW	0.0313	0.0025	1.3342	256	0.6679e-15	7.4038

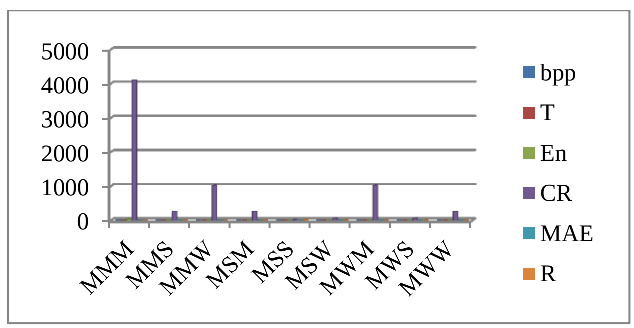

Figure 5. Chart of compression parameters for color M_{av} technique.

Table 4. Compression parameters for color RS_{av} technique.

RS_{av}	Bpp	T	En	CR	MAE	R(D)
SSS	8.0000	0.6562	0.0139	1	2.6766e-08	45.6397
SSW	2.0000	0.164	0.0278	4	4.9682e-16	28.8685
SSM	0.5000	0.041	0.4444	16	3.7122e-16	18.5319
SWS	2.0000	0.164	0.0278	4	1.7694e-07	28.9787
SWW	0.5000	0.041	0.0556	16	5.0499e-16	18.0765
SWM	0.1250	0.164	0.8867	64	4.0739e-16	11.4774
SMS	0.5000	0.041	0.2218	16	1.7711e-07	18.7105
SMW	0.1250	0.164	0.4439	64	10.028e-16	11.5127
SMM	0.0313	0.0025	3.5285	256	8.8049e-16	7.1199

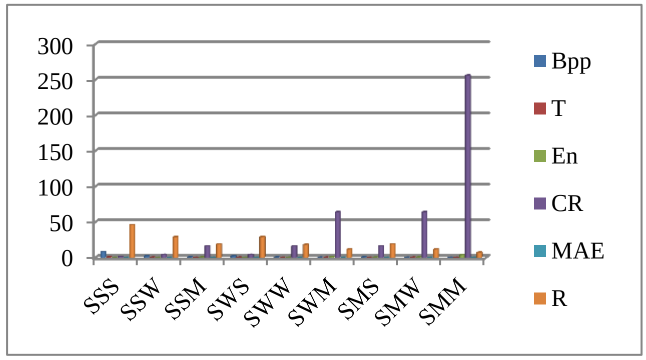

Figure 6. Chart of compression parameters for color RS_{av} technique.

Table 5. Compression parameters for color GS_{av} Technique.

BS_{av}	Bpp	T	En	CR	MAE	R(D)
SSS	8.0000	0.6562	0.0077	1	2.4355 e-08	43.5858
SSW	2.0000	0.164	0.0154	4	4.109 e-16	27.4134
SSM	0.5000	0.041	0.1233	16	3.139 e-16	17.5073
SWS	2.0000	0.164	0.0291	4	7.3346 e-08	27.5322
SWW	0.5000	0.041	0.0308	16	4.182 e-16	17.053
SWM	0.1250	0.164	0.2464	64	3.4341 e-16	10.7557
SMS	0.5000	0.041	0.1232	16	1.4695 e-07	17.6896
SMW	0.1250	0.164	0.2465	64	8.3144 e-16	10.7892
SMM	0.0313	0.0025	1.9658	256	7.3989 e-16	6.6005

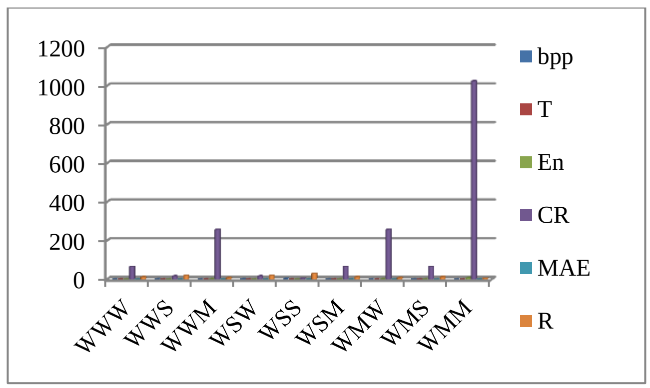

Figure7. Chart of compression parameters for color RW_a Technique.

Table 6. Compression parameters for color BS_{av} Technique.

GS_{av}	Bpp	T	En	CR	MAE	R(D)
SSS	8.0000	0.6562	0.0109	1	3.5877 e-08	46.2749
SSW	2.0000	0.164	0.0219	4	4.6147 e-16	29.3214
SSM	0.5000	0.041	0.1753	16	3.7439 e-16	18.9114
SWS	2.0000	0.164	0.0219	4	8.1965 e-08	29.5521
SWW	0.5000	0.041	0.0439	16	4.7271 e-16	18.4816
SWM	0.1250	0.164	0.3503	64	4.0381 e-16	11.829
SMS	0.5000	0.041	0.1752	16	1.649 e-07	19.2451
SMW	0.1250	0.164	0.3506	64	9.3767 e-16	11.8875
SMM	0.0313	0.0025	2.8057	256	8.4953 e-16	7.4211

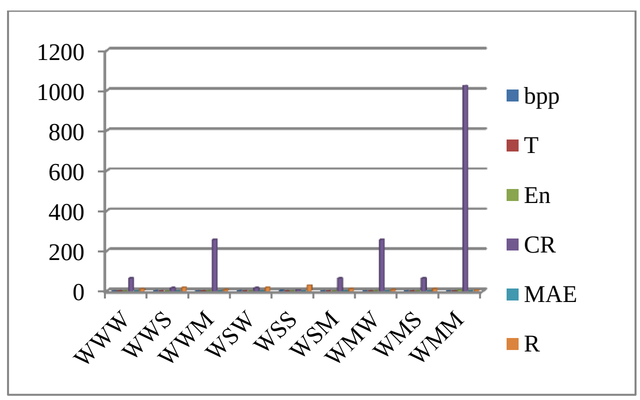

Figure 8. Chart of compression parameters for color BW_{av} technique.

Table 7. Compression parameters for color RW_{av} Technique.

RW_{av}	bpp	T	En	CR	MAE	R(D)
WWW	0.1250	0.0102	0.0978	64	2.0579e-16	11.1799
WWS	0.5000	0.041	0.0489	16	0.8846e-07	18.2415
WWM	0.0313	0.0025	0.7809	256	4.2887e-16	7.0084
WSW	0.5000	0.041	0.0489	16	5.0518e-16	18.127
WSS	2.0000	0.164	0.0244	4	0.8650e-07	29.0439
WSM	0.1250	0.0102	0.3904	64	4.8328e-16	11.4992
WMW	0.0313	0.0025	0.7802	256	5.7518e-16	7.0322
WMS	0.1250	0.0102	0.3898	64	1.6985e-07	11.685
WMM	0.0078	0.0006	6.1716	1024	0.9338e-15	4.2573

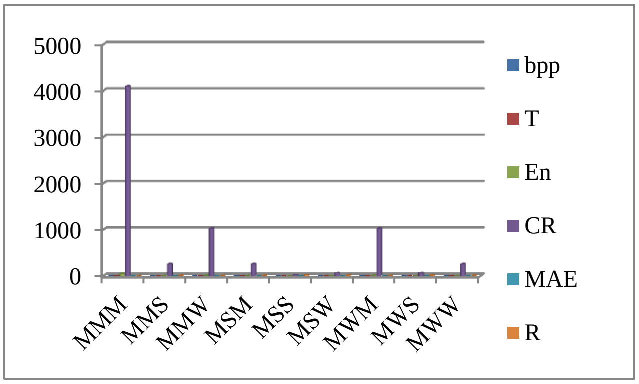

Figure 9. Chart of compression parameters for color RM_{av} Technique.

Table 8. Compression parameters for color GW_{av} Technique.

GW_{av}	bpp	T	En	CR	MAE	R(D)
WWW	0.1250	0.0102	0.0878	64	2.5422e-16	11.5605
WWS	0.5000	0.041	0.0439	16	8.2217 e-07	18.785
WWM	0.0313	0.0025	0.7022	256	4.1294 e-16	7.3111
WSW	0.5000	0.041	0.0439	16	4.6988 e-16	18.5797
WSS	2.0000	0.164	0.0219	4	7.9106 e-08	29.68
WSM	0.1250	0.0102	0.35	64	4.5054 e-16	11.8659
WMW	0.0313	0.0025	0.7	256	6.4163 e-16	7.7097
WMS	0.1250	0.0102	0.3498	64	1.5866 e-07	12.1462
WMM	0.0078	0.0006	5.507	1024	0.8968 e-15	4.5079

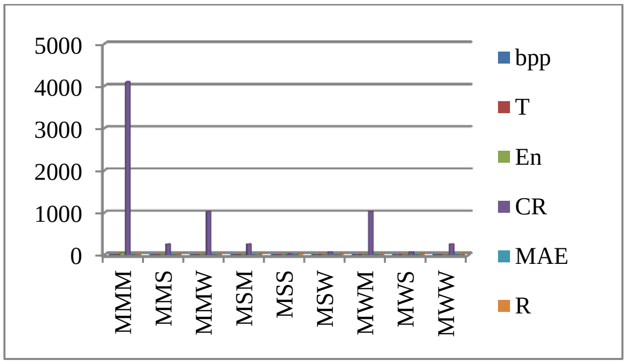

Figure 10. Chart of compression parameters for color GM_{av} technique.

Table 9. Compression parameters for color BW_{av} technique.

BW_{av}	bpp	T	En	CR	MAE	R(D)
WWW	0.1250	0.0102	0.0617	64	1.8531e-16	10.4572
WWS	0.5000	0.041	0.0308	16	7.353e-08	17.2218
WWM	0.0313	0.0025	0.4921	256	3.6406e-16	6.4897
WSW	0.5000	0.041	0.0308	16	4.1816e-16	17.1035
WSS	2.0000	0.164	0.0154	4	7.1514e-08	27.5995
WSM	0.1250	0.0102	0.2462	64	3.9946e-16	10.7752
WMW	0.0313	0.0025	0.492	256	5.1346e-16	6.5223
WMS	0.1250	0.0102	0.2458	64	1.418e-07	10.9722
WMM	0.0078	0.0006	3.8843	1024	7.9147e-16	3.9053

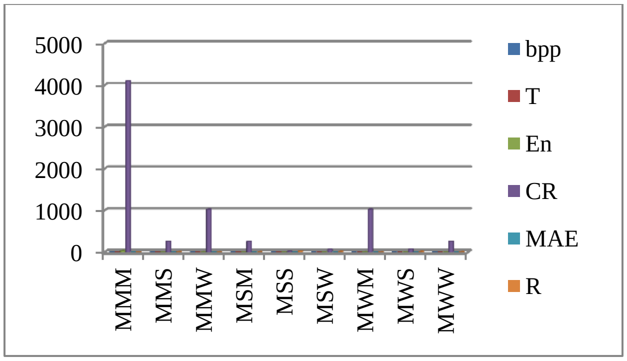

Figure11. Chart of compression parameters for BM_{av} technique.

Table 10. Compression parameters for color RM_{av} Technique.

RM_{av}	bpp	T	En	CR	MAE	R(D)
MMM	0.0020	0.0001	49.232	4096	1.9066e-15	2.5415
MMS	0.0313	0.0025	3.3834	256	3.3501e-07	7.3524
MMW	0.0078	0.0006	5.5971	1024	1.8049e-15	4.3016
MSM	0.0313	0.0025	2.797	256	2.8862e-15	7.1432
MSS	0.5000	0.041	0.1753	16	1.6591e-07	18.796
MSW	0.1250	0.0102	0.3506	64	4.0467e-15	11.5836
MWM	0.0078	0.0006	5.5188	1024	3.7747e-15	4.263
MWS	0.1250	0.0102	0.4252	64	1.7024e-07	11.7003
MWW	0.0313	0.0025	0.851	256	5.764e-16	7.0426

Table 11. Compression parameters for color GM_{av} Technique.

GMav	bpp	T	En	CR	MAE	R(D)
MMM	0.0020	0.0001	43.4204	4096	1.777e-15	2.7268
MMS	0.0313	0.0025	2.7974	256	3.212e-07	7.7344
MMW	0.0078	0.0006	5.5971	1024	1.7535e-15	4.5676
MSM	0.0313	0.0025	2.7970	256	0.8972e-15	7.4546
MSS	0.5000	0.041	0.1753	16	1.5205e-07	19.481
MSW	0.1250	0.0102	0.3506	64	0.9269e-15	11.9998
MWM	0.0078	0.0006	5.5188	1024	0.91e-15	4.5107
MWS	0.1250	0.0102	0.3503	64	1.5999e-07	12.1656
MWW	0.0313	0.0025	0.7011	256	6.4602e-16	7.3571

Table 12. Compression parameters for color BM_{av} Technique.

BM_{av}	bpp	T	En	CR	MAE	R(D)
MMM	0.0020	0.0001	30.9214	4096	1.6232e-15	2.2653
MMS	0.0313	0.0025	1.9564	256	2.854e-07	6.8441
MMW	0.0078	0.0006	3.9098	1024	1.5335e-15	3.9478
MSM	0.0313	0.0025	1.9632	256	7.8752e-16	6.6249
MSS	0.5000	0.041	0.1232	16	1.3692e-07	17.7745
MSW	0.1250	0.0102	0.2464	64	8.2669e-16	10.8593
MWM	0.0078	0.0006	3.8829	1024	8.0253e-16	3.9059
MWS	0.1250	0.0102	0.2459	64	1.4112e-7	10.9813
MWW	0.0313	0.0025	0.4923	256	5.1873e-16	6.5283

Figure 12. Samples of database images.