International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Enhanced Data Reduction for Still Images by using Hybrid Compression Technique

Aqeel Kamil Kadim, Dr. Amin Babiker

Abstract: ***This paper present an image compression technique that utilize embedded wavelet based image coding with two types of compression algorithms for further compression. There are many types for lossy image compression algorithms available out of which EZW and SPIHT algorithms which are two separatetypes of mostsignificant compression techniques. EZW algorithm is depend oncumulative encoding in order to compress case image into a bit stream with high accuracy. Another efficient technique is SPIHT that utilized for image compression which based on the concept of coding set of wavelet coefficients as zero trees. The proposed hybrid image compression technique (HICT) that combined excellent featuresfrom each method, which then produce promising technique for still image compression, by reduce the number of bits required to represent the input image to the maximum extent possible, while maintaining the visual quality of the reconstructed image closer to the original image as much as possible. By using matlab software, the experimental results present that HICT improve the efficiency of image compression between 6.7 to 13.7%, and yields better performance of measurement values.***

Keywords: Hybrid compression, SPHIT, EZW

1. Introduction

Due to entering the digital age, the world has faced a huge quantity of information. The solution of this huge quantity of information can lead to many difficulties frequently, the digital information must be stored, retrieved, analyzed and processed in an effective manner, so as for putting it into practical use [1]. Considerable storage capacity and very high bandwidth are required to transfer uncompressed multimedia (image, video and audio) data. In order to transfer large data objects efficiently, these objects must be compressed to reduce the file size [2].

A common feature of most of the images is that "they contain repetitive information because of the neighboring pixels of the image are correlated". So, the essential task is to find less correlated representation of the image.

Two central basics of compression are ***redundancy*** and ***irrelevancy*** reduction [3]. Redundancy reduction aims "removing duplication from the signal source". Irrelevancy reduction drops parts of the signal that won't be seen by the signal receiver; namely for image signal it is "the Human Visual System (HVS)".

Image compression technique was, at first, most commonly used in the printing, telecommunications industries, and data storage. Also, the digital model of image compression is being put to work in industries such as satellite remote sensing transmission, fax, and high definition television. It has increased the efficiency of sharing and showing personal images [4].

Image compression playing a significant role in any organization is needed to display and store the images to be standardized, for example, a chain of retail stores. In the retail store example, the introduction of new and positioning of goods or the removal of broken items can be more easily finish when all employees obtain, display and process images in same manner [5].

In this paper, in order to increase the efficiency of performance in image compression, a simple hybrid technique will be suggested to compress still images. This technique based on using two separate compression methods, the wavelet transform with SPHIT method and the resulting data reduction file will be compressed again with LZW. The resulting compressed file will have a good quality, data reduction and there is large percentage in performance improving.

An important issue that occurs for digital data management is how to increase image quality and efficiency ratio of data through its storage and transmission. So, the problems encourage the researcher in image compression field to develop techniques that depends on several methods to improve the compression measurement [6].HICT is a technique that combining superior features from each group of methods. The aim of this paper is to identify how to develop a promising method that utilizes to improve the performance metrics of image compression. The effort of researchers in this field is focused on how to develop efficient images compressing method that reduce the number of bits required to represent the input image to the maximum extent possible, while maintaining the visual quality of the reconstructed image closer to the original image as much as possible.

2. Previous Work

Many techniques of image compression had been improved and developed specially through the past decade. SWETHA K P [7] present a new combined wavelet methods which introduced better image compression, in this paper new wavelet based bi-orthogonal filter coefficient that can give better result in case of PSNR and MSE comparison to wavelet 9/7 filter and wavelet 5/3 filter. Jurate Puniene et al [8] presented new concept for compression technique that improve the ultrasound and angio images through utilizing wavelet transform which give better results than discrete cosine transform. Hyung Jun Kim and Li, C, C [9] introduce image compression method by using bi-orthogonal wavelet transform, the results gives high compression performance and fast computational speed. Angelidis, P, A [10] presented a special method for MR image compression by utilizing a transform coding scheme based on wavelet transform and

vector quantization. Rehna V. J [11] present a summarized survey about some elected popular wavelet coding techniques for image compression and introduce recommendations for develop the algorithms to better implementation. Sure. Srikanth [12] present in his paper participate to the application of combining lossy image compression algorithms (EZW, SPIHT and Modified SPIHT method) with Huffman encoding, and also offered a discussion about advantages and disadvantages of these compression techniques.

Arhami et al. [13] present the efficiency of utilizing bi-orthogonal method over the performance of hybrid compression technique, also a comparison study for the performances of bi-orthogonal family filters by using run length coding, Huffman coding, and a conjunction of both. V.V. Yap [14] introduce a hybrid wavelet compression technique, that used a combination of three methods (bi-orthogonal filter, quantization and Huffman coding. This proposed method be able to retain about 20% of the time and at the same time maintain the reconstructed image quality. Sharadha and Bhanuprakash [15] carried out a comparative study for the performance of orthogonal and bi-orthogonal filters over DWT method. This method used dual types of wavelet families in order to show their performances, the extract of his conclusion indicates that the type of bi-orthogonal wavelet family has better performance as compared with orthogonal wavelet family. WimSwelden [16] utilize Lifting Wavelet Transform (LWT) method to improve the performance of combined compression methods over still images generated by digital camera. In this paper present that the implementation of LWT method is faster than classical wavelet.

3. Problem Statement

In the last two decades, demand of high speed data transfer and high level of data compression has increased and it has been a hot topic of research in the signal processing and communications area [17].

Many applications need large number of images for solving problems, and therefore a large quantity of digital data storage to archive the image(s) data. Though there is a technical advancement in storage space required storing data, but the requirement for storage capacities is, still, not satisfied by the availability [18].So, the storage and transfer of image data become more challenging task in the multimedia applications. Hence, an efficient compression system is required for imagery, which minimizes the requirement of storage medium and transmission bandwidth. Not only enhancement in performance, but also the compression techniques should be converged rapidly in order to utilize them for real time applications [19].Therefore, there is an ever increasing demand for a very potent and robust technique for compression of such images [18].

4. Image Compression

In people's life the images will carries the most important information. Because of the requirement to store and transmit images be continue to increase, the image compression field will also continue to increase. Each image will contain large amount of data, the redundant information mostly have occupies great storage space, which minimizes the bandwidth of transmission [20].

The art of representing image information in a compact form is called a data compression technique. The goal is to reduce the bits number required to represent a data series, so that data storing or transmitting is done with efficient manner. The main principle of compression is to decrease the data redundancy. The data may represent an image, audio or video, and in the current context, it is considered as an image. So, image compression is a data compression type, which encodes the original image with fewer bits. The major goal is to reduce the size of storage as much as possible, but we retrieve the original image from the compressed image, the gained image as much as possible be similar to the original image[20][21]. Normally, images taken from the camera are in the analog form. However, for transmitting, processing, and storage, images are transformed into digital form [21].

In the digital image, adjacent pixels are correlated so that these pixels contain redundant bits [22]. By applying the compression algorithms, redundant bits are removed from the image so that the image is compressed and the image size is reduced [21].

The image compression eventuates by taking advantage of redundant information in the image [10]. There are mainly three types of redundancy [21]:

- Inter pixel redundancy is produced from correlated pixels of an image.
- Psychovisual redundancy data is ignored by the HVS.
- Coding redundancy is demonstrated when a less number of code words needed instead of larger symbol.

Compression of image not only minimizes storage requirements, but also the transmission time [23, 24]. There are various image compression techniques that one can use. However, more popularly these techniques can be divided into two categories. ***Lossless*** and ***Lossy*** compression. Figure (1) shows the most popular compression techniques [25].

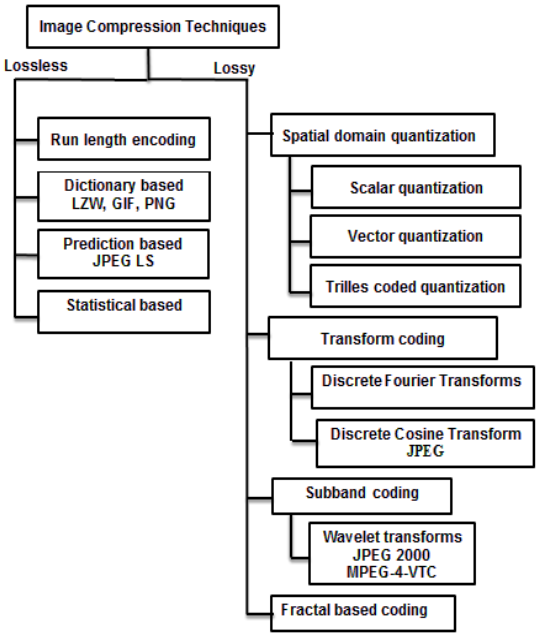


Figure 1: Taxonomy of compression techniques [25]

5. Discrete Wavelet Transform (DWT)

During the last several years, wavelet transformations have achieved a widespread acceptance, particularly within image compression research [22]. Wavelets permit complicated information such as speech, music, images, and patterns to be decomposed into elementary forms at various scales and positions, and then subsequently reconstructed with a high degree of accuracy [23].

DWT is a principle tool in image compression applications because of its ability to reduce their data. It permits uniform distribution of compression errors across the whole image. In a wavelet compression system, the entire image is converted and compressed as a single data object rather than block by block as in a DCT -based compression system [24].

The main idea of the wavelet transform is the representation of any arbitrary function as collection of given wavelets, or basis functions, these basis functions are obtained from a single prototype wavelet, called a mother wavelet, by shifting and scaling [22], according to that very large wavelets can recognize coarse details , while very small wavelets can be utilized to isolate very fine details in a signal [23].

Wavelet transform [26] attempt to isolate different of signal characteristic in way which collect the energy of signal into few component, mainly the utilizing of wavelet lies in the sub-band coding filters design [27, 28].

There are several reasons that make the wavelet transformations is constantly progress, and one of the most important reasons is obviously that wavelet coding scheme (often called sub-band coding) achieve better performance than other coding schemes like the one based on DCT in many applications. Since there is no need to block the input image, and its basis functions have variable length, wavelet based coding schemes can avoid blocking artifacts. Wavelet based coding also facilitates progressive transmission of images because it permits the rebuilding of an image starting with coarse quality and progressively improving to a higher quality and the DWT provides substantial improvements in the quality of the picture because of Multi Resolution Analysis (MRA) [29, 30] with which the signal is decomposed into several sub bands of high and low frequencies at different scales of wavelets [24].

In addition, wavelet transformations give a good localization in spatial, time and frequency domain, theses transformation robust against transmission and decoding errors, and well correspond to the HVS characteristics [22].

5.1 Bi-orthogonal Wavelet Transform

Bi-orthogonal wavelet transform is a part of the family of symmetric (encoding time is equal to decoding time) bi-orthogonal wavelet CDF, Daubechies 9/7 (as well as called Tap9/7 because the filter lengths are 9 and 7 for low and high pass filters, respectively) have risen to a particular occurrence because they were chosen to be the kernel transform in JPEG2000 standard [31].

In most of the cases, the filters utilized in this wavelet transform have floating point coefficients. Since the input images have integer entries, the filtered output no longer contains of integers, and losses will produce from rounding.

Symmetric extension is applied in order to handle filtering at the image boundaries by inserting mirror pixels to the outside of the boundaries so that substantial errors are not presented at the boundaries [32, 33].

The Bi-orthogonal wavelet transform is calculated by applying lifting steps follows by scaling steps, the lifting scheme is implemented through a sequence of phases, it can be identified in three phases: Split phase, Predict phase and Update phase [34].

5.2 Embedded Zerotrees of Wavelet transforms (EZW):

Is one of the powerful algorithms for lossy image compression . For pixel representation of low bit rates, which means, high compression ratios, major coefficients that generate by a sub-band transform (likewavelet transform) will be tend to zero, or close to zero. This is happen because very close in "real world" tend to consist of primary highly correlated low frequency information. In the edges of the image where the information of high frequency will exists, this is especially important in the terms of image quality for human perception, and thus must be carefully represented in each high quality coding platform.

5.3 Set partitioning in Hierarchical Trees (SPIHT):

Is hierarchical tree algorithm that used for lossy image compression algorithm. SPIHT will invest the inherent similarities through the sub-bands of image wavelet decomposition [35][36].

SPIHT algorithm is belongs to next generation for wavelet transform, which employing more advanced coding. In fact, SPIHT develop wavelet transformed images properties to

increase its efficiency. It has become a state-of-the-art method for image compression.

Nowadays SPIHT is one of the best powerful wavelet image compression techniques which used for lossless image compression. One of the most advantages of this method is it's capability to provide an output image with good quality, high PSNR and it is consider as the best method for continually Image transmission[36].

SPIHT technique merit special attention for it provides the following characteristics:
Highest Image Quality, Progressive image transmission, Fully embedded coded file, Simple quantization algorithm, Fast coding/decoding, Completely adaptive, Lossless compression, Exact bit rate coding and Error protection[36].

6. The Proposed Compression System

The algorithms of Image compression will have been main topic of researcher in both academic and commercial worlds for several years. Today, while an important enhancement was achieved in the performance of compression techniques, there is still scope for new algorithms. This research is directed to develop a compression scheme that based on using hybrid compression techniques. This type of data compression will have an excellent benefit to achieve significant data reduction in image size, conversely the image distortions was not affected on the image quality [26].

In order to utilize the proposed hybrid image compression technique, the following steps must be applied:
Step1: Load the input uncompressed image and read by particular MATLAB software, and store it in a file.
Step2: Compress original image component by using progressive compression method SPIHT (Set Partitioning in Hierarchical Trees) with Bior 4.4 wavelet method.
Step3: Load the stored compressed image and step through the uncompressing process.
Step4: Now we decompress the image retrieved from the step 2 file and compare it with the original image.
Step 5: Compute the performance metrics: CR, MSE, BPP and PSNR for the compressed image. We use these measures to quantify the error between original and compressed images.
Step 6: To improve the results we use another compression technique, by compress the resulted decoded image component through utilize a new progressive compression method.
Step 7: Compress the resulted decoded image from step 4, by utilizing a progressive compression method EZW (Embedded Zerotrees) with Bior4.4 wavelet method.
Step 8: Load the resulted dual compressed image and step through the dual uncompressing process.
Step 9: Dual decompress the image retrieved from the step 7 file and compare it with the original image.
Step 10: Compute the performance metrics: CR, MSE, BPP and PSNR for the dual compressed image. We use these performance measurements to quantify the difference between original and dual compressed images. The image we got must be convincing while maintaining a good visual perception.

7. System Performance Measures

The assessment of the performance of compression system is measured using some compression performance measures, the common used measures are:

a) Compression Ratio (CR)
Also known compression power utilized to measure the decrease in data representation size produced by a compression algorithm. CR is computed as the ratio of the original, uncompressed image file size to the compressed file size [37].

$$CR = \frac{Uncompressed\ File\ Size}{Compressed\ File\ Size} \quad (1)$$

b) Mean Square Error (MSE)
It is another measure for assessing the performance of image compression algorithms, utilized as an important evaluation parameter to measure the quality of compressed image. It compares the original data with reconstructed data and then produces the level of distortion [38]. Generally the variation between the original and compressed image is called as distortion. The error function Er is calculated as a difference between the original (input G(x,y)) and the reconstructed (output G'(x,y)) image [39]:

$$Er = G(x,y) - G'(x,y) \quad (2)$$

The MSE is defined as:

$$MSE = \frac{1}{W \times H} \sum_{x=0}^{W-1} \sum_{y=0}^{H-1} Er^2 \quad (3)$$

It is denoted using Mean Square Error (MSE) in dB. Where W, H is the width and height of the image respectively.

c) Peak Signal to Noise Ratio (PSNR)
It is the most popular tool for the evaluation of the compressed image and video. It is more informative than the MSE measure, and it is simple to calculate. It defines the resemblance between the original and reconstructed image. It can be measured using Peak Signal to Noise Ratio (PSNR) in dB.

The PSNR is measured in decibels (dB) unit and is defined as follows [40]:

$$PSNR(dB) = 10log_{10}[\frac{(R-1)^2}{MSE}] \quad (4)$$

Where R is the number of intensity level of the image.

d) Compression Gain (CG)
The compression gain is defined as:

$$CG = 100 \log_e \frac{ReferenceSize}{CompressedSize} \quad (5)$$

Where the reference size is the size of the input stream. The unit of the compression gain is called percent log ratio and is denoted by % [41].

e) Data Compression Rate
It is measured by the division of average number of bits that required representing a single element. It is described by the term of Bits per Pixel (bpp) [26].

Bits per pixel (bpp) =

$$\left(\frac{Number\ of\ bits}{Number\ of\ pixels}\right) \Rightarrow \left(\frac{8 * Number\ of\ bytes}{N * N}\right) \quad (6)$$

f) Speed of Compression

The speed of compression depends on the utilized compression method, as well as, the platform nature of the hosts that contain the compression process. Compression speed is affected by memory size and computational complexity [20].

g) Power Consumption

In image compression the power consumption is the most important performances metric. The multimedia nature requires large storage space and big bandwidth which consumes more power. The power of transmission that needed to manipulate for visual flows and energy-aware methods of compression used to minimize transmission time. Therefore, adjusting the processing complexity, minimize data size and transmission power reduction will save energy [26].

8. Experimental Result

In this paper, we have presented hybrid compression techniques to improve the data reduction of still color images. The test images which utilize in this work are selected from a dataset of JPEG images.

1) The proposed true color images are shown in Figure (2).
2) Table (1) The results of compression test images by using Hybrid (SPIHT & EZW) compression algorithms.
3) Table (2) present the results of compression test images by using Hybrid (SPIHT & EZW) compression algorithms based on some important of metric features.
4) Figure (3) shows the result of 1st compression by using SPHIT compression algorithm based onBior4.4 wavelet method.
5) Figure (4) shows the result of 2nd compression by using EZW compression algorithm based onBior4.4 wavelet method.
6) Figure (5) shows bar chart of the dataset test images before and after compression by using hybrid (SPHIT + EZW) compression algorithms based onBior4.4 wavelet method.
7) Figure (6) shows bar chart of the compression ratio after 1st and 2nd compression.

Figure 2: The original test color images.

Table 1: The results of compression test images by using Hybrid (SPIHT &EZW) compression algorithms.

Image title	File size in byte	File size after 1st compression	File size after 2nd compression
Friends	15087	11712	11135
Child	15803	12257	11566
Oldcar	10362	9595	9401
Battle	17329	13935	13405
Patrol	11559	9249	8993

Table 2: The results of compression test images by using Hybrid (SPIHT &EZW) compression algorithms based on four important metric features

	Performance Measures	Image Title				
		Friends	Child	Oldcar	battle	Patrol
1st compression	CR	6.230164	6.280518	3.274028	8.763123	4.859416
	BPP	1.495239	1.495239	0.785767	2.103149	1.166260
	MSE	10.089981	10.089981	17.406113	12.028411	7.063161
	PSNR	28.091900	28.091900	28.048731	27.328721	29.640813
2nd compression	CR	9.816996	9.790039	6.767273	13.758850	7.687887
	BPP	2.356079	2.356079	1.624146	3.302124	1.845093
	MSE	15.315167	15.315167	25.356031	20.402731	11.176706
	PSNR	26.279586	26.279586	24.089991	25.033921	27.647665

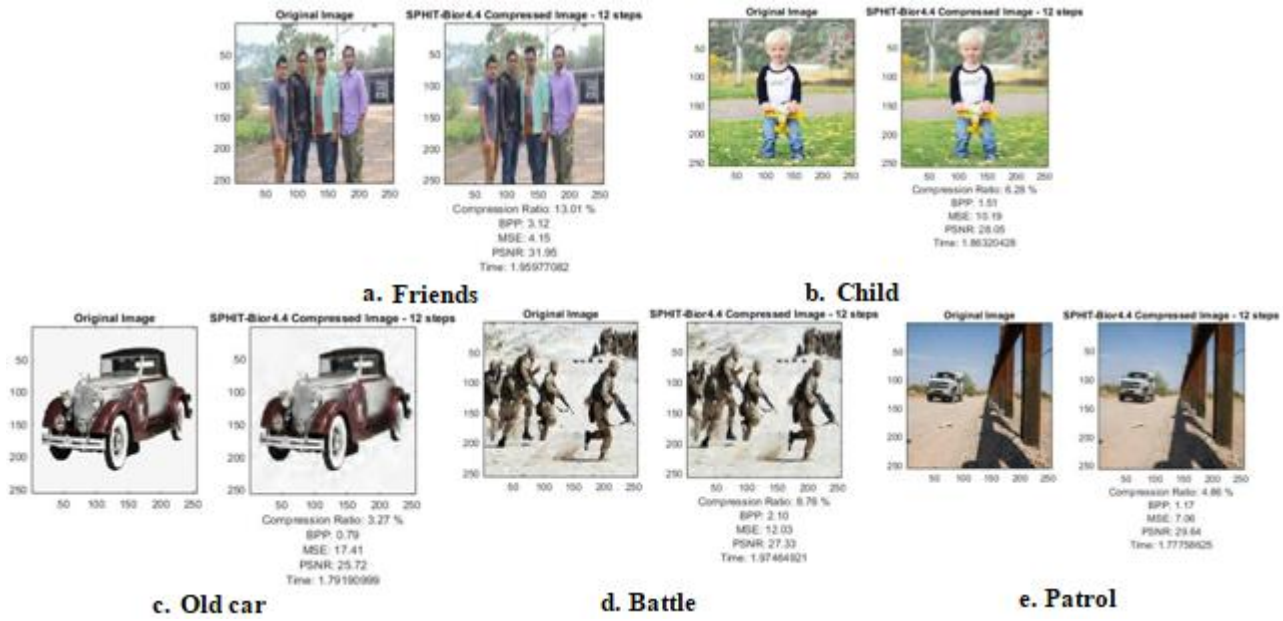
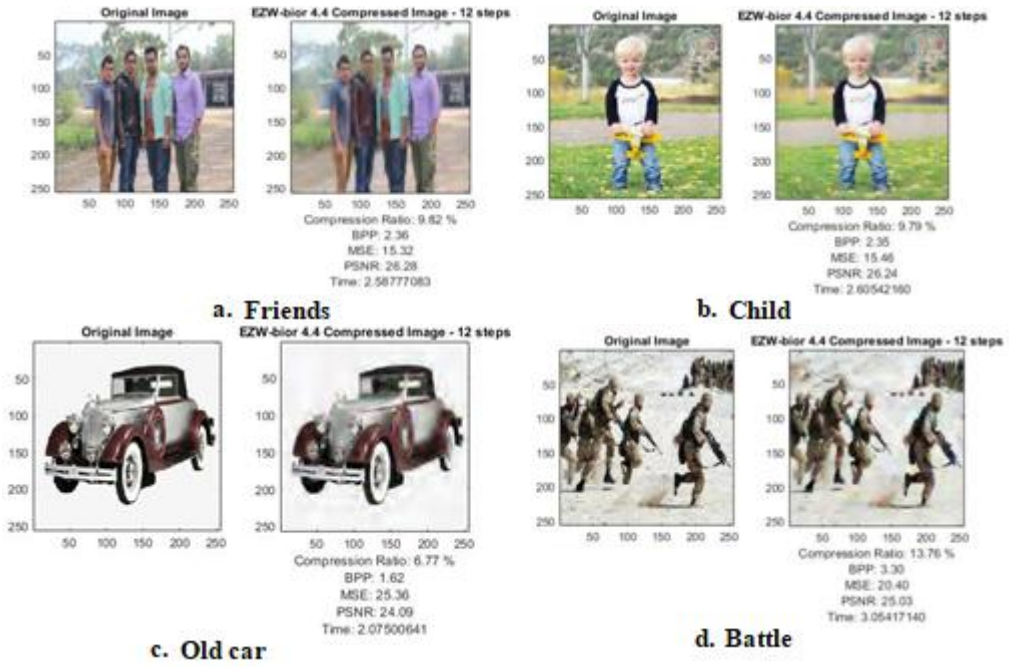


Figure 3: Shows the result of 1st compression by using SPHIT compression algorithm based onBior4.4 wavelet method



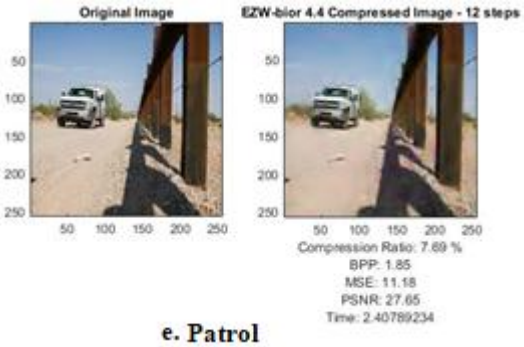


Figure 4: Shows the result of 2nd compression by using EZW compression algorithm based onBior4.4 wavelet method

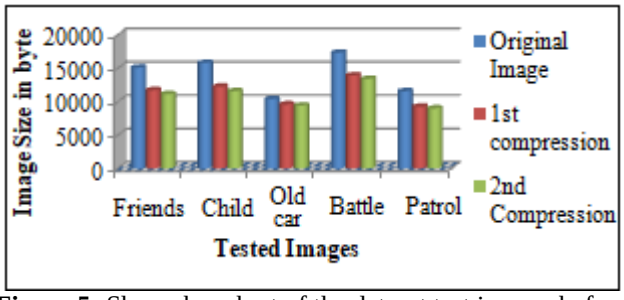


Figure 5: Shows bar chart of the dataset test images before and after compression by using hybrid (SPHIT + EZW) compression algorithm based onBior4.4 wavelet method.

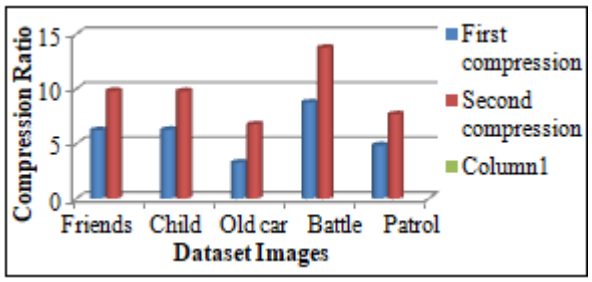


Figure 6: Shows bar chart of the compression ratio after 1st and 2nd compression.

9. Conclusion

In this paper we implemented the HICT which include (SPIHT and EZW) compression techniques, based on a bior4.4 wavelet method and then compare the performance metrics of five test color images. Among the different wavelet families, in the bi-orthogonal wavelet family the bior4.4 wavelet type have a good metrics performance (CR, BPP, MSE and PSNR) as compared with other types. SPIHT and EZW algorithms be tested on different elected color images, from practical results that obtained, we can see that the utilizing of HICT, have better performance on compression ratio as compared with other lossy techniques that used for still image compression. The results obtained from HICT was effectively improve the efficiency of image compression between 6.7 to 13.7%, and yields better performance measurement values.

References

[1] Raid, A. M.; Khedr, W. M.; El-dosuky, M. A.; and Ahmed, W.; "JPEG Image Compression Using Discrete Cosine Transform - A Survey", International Journal of Computer Science & Engineering Survey (IJCSES), Vol. 5, No. 2, pp. 39-47, April 2014.

[2] Tripathi, B.; "A Survey on Various Image Compression Techniques", Bachelor, Department of Computer Science & Engineering National Institute of Technology, India, 2014.

[3] Saha, S.; "Image Compression—from DCT to Wavelets: a Review", ACM Crossroads Student, Magazine, Vol. 6, No. 3, pp. 12-21, 2000.

[4] Subramanya, "Image Compression Technique", IEEE, Vol. 20, No. 1, pp. 19-23, Feb-March 2001.

[5] Shrikhande, R. N.; and Bairagi, V. K.; "Comparison of Different Methods for Lossless Medical Image Compression", Global Journal of Engineering, Design& Technology (GJEDT) , Vol. 2, No. 3, pp. 36-40, 2013.

[6] SWETHA K P; "Still Image Compression by Using New Wavelet Bi-Orthogonal Filter Coefficients"; Volume: 3 | Issue: 7 | July 2013 | ISSN - 2249-555X

[7] JuratePuniene., VytenisPunys and Jonas Punys "Ultrasound and angio image compression by cosine and wavelet transforms" International Journal of Medical Informatics, Vol. 64, Issues 2–3, (December 2011), pp 473–481. |

[8] Hyung Jun Kim and Li, C, C "Unified Image Compression Using Reversible and Fast Biorthogonal Wavelet Transform" Proceedings IWISP '96, 4–7 (November 2015), Manchester, United Kingdom, 2012, pp 263–266 |

[9] Angelidis, P, A "MR image compression using a wavelet transform coding algorithm" Magnetic Resonance Imaging, Vol. 12, Issue 7, (2014), pp 1111–1120

[10] Rehna V. J and Jeya Kumar M. K; "WAVELET BASED IMAGE CODING SCHEMES: A RECENT SURVEY"; International Journal on Soft Computing (IJSC) Vol.3, No.3, August 2012

[11] Sure. Srikanth, SukadevMeher; "Compression Efficiency for Combining Different Embedded Image Compression Techniques with Huffman Encoding"; International conference on Communication and Signal Processing, April 3-5, 2013, India

[12] M. Arhami, et al. "The Influence of Biorthogonal Wavelet Transform and Different Coding Method to Quality of Image Compression", International Conference on Mathematics, Statistics and Applications 2008 (ICMSA 08), Banda Aceh, Indonesia, pp. 157–163, 2008.

[13] V.V. Yap, and R. Comley, "A Hybrid Wavelet-Based Compression System", Proceedings of the Third International Conference on Information Technology and Applications (ICITA'05), IEEE, 2005.

[14] R. Sharadha, and C. Bhanuprakash, "Image Compression Technique for Color Images using Wavelets", International Journal of Advanced Research in Computer Science and Software Engineering, vol/issue: 3(11), pp. 322–327, 2013.

[15] C. Samson, and V.U. Sastry, "An RGB Image Encryption Supported by Wavelet- based Lossless Compression", International Journal of Advanced Computer and Aplications (IJACSA), vol/issue: 3(9), pp.36–41, 2012.

[16] Safdar, M.; Luo, M. R.; and Liu, X.; "Comparing CSI and PCA in Amalgamation with JPEG for Spectral Image Compression" Color Science Association of Japan, AIC2015 Tokyo, Japan, Vol. 2015, pp. 1253-1256, 2015.

[17] Goyal, R.; and Jaura, J.; "A Review of Various Image Compression Techniques", International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 4, No.7, pp. 708-710, July 2014.

[18] Thayammal, S.; and Selvathi, D.; "A Review on Transform Based Image Compression Techniques", International Journal of Engineering Research & Technology (IJERT), Vol. 2, No. 10, pp. 1589 - 1596, October 2013.

[19] RAJAKUMAR K ;'IMPLEMENTATION OF MULTIWAVELET TRANSFORM CODING FOR IMAGE COMPRESSION'; Engineering Sciences, Vol. 8, 2015, no. 6, 263 - 270 HIKARI Ltd, www.m-hikari.com; http://dx.doi.org/10.12988/ces.2015.519; A THESIS Submitted for Anand Nagar, Krishnankoil – 626 126 SEPTEMBER 2015

[20] Said, Amir; Pearlman, William A. (June 1996). "A new fast and efficient image codec based on set partitioning in hierarchical trees". IEEE Transactions on Circuits and Systems for Video Technology. 6 (3): 243–250. doi:10.1109/76.499834. ISSN 1051-8215.

[21] Johnsen, S. T.; and Standeren, M.; "Evaluate Multiple Description Coding as an Image Processing Method for Transferring Information in Error-Prone Networks with Low Transmission Rate, Related to Quality, Bit Rate

and File Size", M.Sc. Thesis, Faculty of Engineering and Science, Agder University College, Norway, 2005.
[22] Sifuzzaman, M.; Islam, M. R.; and Ali, M. Z.; "Application of Wavelet Transform and its Advantages Compared to Fourier Transform", Journal of Physical Sciences, Vol. 13, pp. 121-134, 2009.
[23] Joshi, M. A.; Raval, M. S.; Dandawate, Y. H.; Joshi, K. R.; and Metkar, S. P.; "Image and Video Compression Fundamentals, Techniques, and Applications", Chapman and Hall/CRC, 2015.
[24] Havaldar, P.; and Medioni, G.; "Multimedia Systems Algorithms Standards and Industry Practices", Cengage Learning, Boston, MA, USA, 2010.
[25] Dr. Ghadah Al-Khafaji *, Dr. Salah Al-iesawi&MahaAbdRajab;'A Hybrid Lossy Image Compression based on Wavelet Transform, Polynomial Approximation Model, Bit Plane Slicing and Absolute Moment Block Truncation';Dept. of Computer Science, Baghdad University, Dept. of Computer Science, Al-anbar University & Dept. of Computer Science Al-anbar University, Iraq IJCSMC, Vol. 4, Issue. 6, June 2015, pg.954 – 961
[26] Singh, P.; and Panda, S.;"A Survey of Image Compression Techniques", International Journal of Engineering and Innovative Technology (IJEIT), Vol. 4, No. 2, pp. 83-86, August 2014.
[27] Kumar, V. V. S.; and Reddy, M. I. S.; "Image Compression Techniques by using Wavelet Transform", Journal of Information Engineering and Applications, Vol. 2, No. 5, pp. 35-39, 2012.
[28] Parmar, C. K.; and Pancholi, K.; "A Review on Image Compression Techniques", Journal of Information, Knowledge and Research in Electrical Engineering, Vol. 2, No. 2, pp.281-284, 2015.
[29] Thyagarajan, K., S.; "Still Image and Video Compression with Matlab" , John Wiley & Sons, Inc., Hoboken, New Jersey, Canada, 2011.
[30] Unser, M.; and Blu, T.; "Mathematical Properties of the JPEG2000 Wavelet Filters ", IEEE Trans. Image Processing, vol. 12, No. 9, September 2003.
[31] Egger, O.; Fleury, P.; Ebrahimi, T.; and Kunt, M.; "High-Performance Compression of Visual Information-A Tutorial Review-Part I: Still Pictures", proceedings of the IEEE, Vol. 87, No. 6, June 1999.
[32] Odegard, J.E.; and Burrus, C.S.; "Smooth biorthogonal wavelets for applications in image compression", IEEE Conference: Digital Signal Processing Workshop
[33] Mahmoud, G. A. H.; "Robust Watermarking System Based on Wavelet Transform", M.Sc. thesis, University of Technology, 2005.
[34] http://reference.kfupm.edu.sa/content/n/e/a_new_fast_and_e_cient_image_codec_based_661859.pdf
[35] S. NirmalRaj ;'SPIHT: A Set Partitioning in Hierarchical Trees Algorithm for Image Compression'; EEE Department Sathyabama University, Chennai, India; Contemporary
[36] Scott E. U.; "Computer Vision and Image Processing A practical Approach Using CVIP tools", Prentice Hall PTR, 1998.
[37] Bannore, V.; "Iterative-Interpolation Super-Resolution Image Reconstruction", Springer-Verlag Berlin Heidelberg, South Australia, Vol. 95, 2009.
[38] Umbaugh, S.E.; "Computer Vision and Image Processing: A Practical Approach using CVIP Tools", Prentice Hall, Inc., 1998.
[39] Ibraheem, N. A.; Hasan, M. M.; Khan, R. Z.; and Mishra, P. K.; "Understanding Color Models: A Review ", ARPN Journal of Science and Technology, Vol. 2, No. 3, pp. 265-275, April 2012.
[40] Salomon, D.; "Data Compression: The Complete Reference", Springer, 4th Edition, London, 2007.