International Journal of Electrical and Computer Engineering (IJECE)
Vol. 7, No. 4, August 2017, pp. 2206~2214
ISSN: 2088-8708, DOI: 10.11591/ijece.v7i4.pp2206-2214

Survey of Hybrid Image Compression Techniques

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Article Info

Article history:

Received Dec 14, 2016
Revised May 30, 2017
Accepted Jun 14, 2017

Keyword:

Hybrid compression
Hybrid transformation
Image compression
Lossless compression
Lossy compression

ABSTRACT

A compression process is to reduce or compress the size of data while maintaining the quality of information contained therein. This paper presents a survey of research papers discussing improvement of various hybrid compression techniques during the last decade. A hybrid compression technique is a technique combining excellent properties of each group of methods as is performed in JPEG compression method. This technique combines lossy and lossless compression method to obtain a high-quality compression ratio while maintaining the quality of the reconstructed image. Lossy compression technique produces a relatively high compression ratio, whereas lossless compression brings about high-quality data reconstruction as the data can later be decompressed with the same results as before the compression. Discussions of the knowledge of and issues about the ongoing hybrid compression technique development indicate the possibility of conducting further researches to improve the performance of image compression method.

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1. INTRODUCTION

A compression technique is used for many purposes, such as data backup, data transfer and forming a part of data safety. The process of backing up data is performed by previously compressing the file to reduce the required storage capacity to a minimum or only to occupy a smaller space. File compression may also contribute to reducing the size of data before its transmission into network media like Internet. Based on types of data to compress, data compression technique can be grouped into compression method for (a) still image, (b) motion picture, (c) textual data and (d) speech signal data [1].

The Compression technique is used to reduce data redundancy. There are three kinds of data redundancy in the digital image compression [2], [3]:

1. Coding redundancy: this dismissal occurs when some bits used to represent an intensity value is redundant or superfluous.
2. Interpixel redundancy or spatial redundancy: that is, data redundancy that comes out of a correlation between a pixel with its neighboring pixels.
3. Psychovisual redundancy: data redundancy ignored by visual information perceptible to the eyes. That visual information can be eliminated because it will not impact significantly on the quality perception of the image. This compression process renders compressed image reconstruction incomplete, meaning that there is a difference between decompressed image and the original image.

Based on the information content of the reconstructed image, data compression technique can be classified into two, i.e., lossless and lossy. Lossless compression method does not rely on media with particular specifications and characteristics, but on the data sequence instead. Its advantages includ high quality of reconstructed data as the data can later be decompressed with the same results as before the compression. Examples of the method using this technique include Run Length Encoding (RLE), Entropy

Encoding, Huffman Encoding, Arithmetic Coding and Lempel–Ziv–Welch Coding(LZW). The Lossy compression technique is related to semantic data (i.e. the meaning of data) and media, hence the difference between decompressed data and data before compression. It discards optional, imperceptible and invisible parts of the data. Those dropped data are usually ones ignored or beyond the reach of human senses so that they will probably not affect those interacting with them. The advantage of this technique lies in its relatively high compression ratio, the examples of which include predictive coding, transform coding and quantization [4].

A pertinent issue that occurs in the management of digital data is how to increase efficiency ratio and quality of image data during its transmission and storage. These problems encourage the development of hybrid compression methods [5], [6]. A hybrid compression technique is a technique combining excellent properties of each group of methods [7] as is performed in the JPEG compression method. This paper aims at identifying the development of hybrid compression in the last decade and gaining knowledge of various compression techniques being worked out to improve their performances.

2. IMAGE COMPRESSION TECHNIQUE

A Common model of image compression consists of two significant parts, i.e., encoder and decoder [8]. Encoder works to produce a compressed image from the input image f (x,y), after being transmitted through a channel. This compressed image enters into a decoder system as is shown in Figure 1. In this system, the compressed image will be reconstructed to produce an output image f' (x,y).

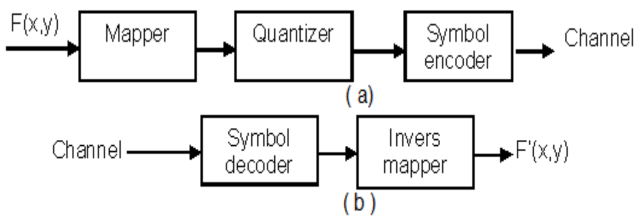

Figure 1. Image compression model: (a) Source encoder (b) Source decoder

Mapper works to transform the input image into a specified format to remove interpixel redundancy. This operation is reversible, meaning that information in the reconstructed image is the same as the original. Quantizer works to reduce psycho-visual data redundancy. This operation does the quantization process into the results of the previous stage. Its effect is irreversible which means that information in the reconstructed image is dissimilar to the original. Symbol encoder works to create codes representing quantizer outputs as well as mapping them into codes. The resultant can thus get rid of irrelevant data and are reversible.

Efforts to increase speed, ratio, and efficiency of compression and decompression process can be made using hybrid compression technique, that is, combining lossy and lossless compression technique [5] as is shown in Figure 2. In lossy compression technique, transformation process consists of three groups of the method, i.e., transform coding, Wavelet Base Coding and Embedded Zero Tree of Wavelet Coefficient (EZW). Quantification process stage consists of two groups of the method, i.e., scalar quantization and vector quantization.

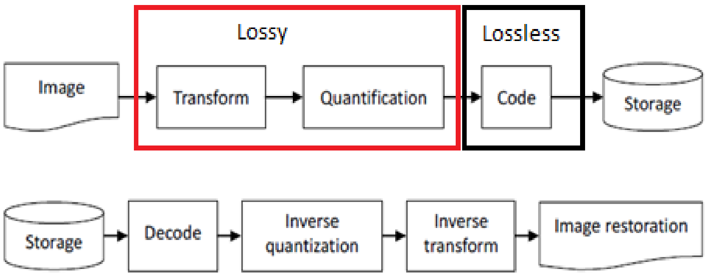

Figure 2. Hybrid compression technique.

3. PROCEDURE OF SORTING OUT LITERATURES

Articles used in this paper include journal papers and conference proceedings issued from 2005 up to 2016. The process of sorting out literature is as follows: first is to search for articles using ontology of hybrid image compression mapped and taken from several sources: IEEEXplore Digital Library (IEEEXplore), Science Direct(Direct), Springer, Scholar, and other (other journals and proceedings outside IEEEXplore, Direct, Springer, and Scopus). This procedure results in 92 articles with the following details: IEEEXplore (20 articles), Direct (8 articles), Springer (1 articles), Scholar (50 articles) and other that amounts to 13 articles. Second step: these 84 articles are subsequently classified into 3 (three) compression techniques, i.e., Lossy compression (26 articles), Lossless compression (19 articles), and hybrid compression (39 articles), as are shown in Figure 3.

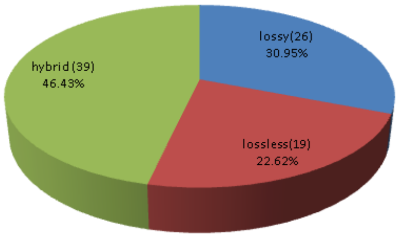

Figure 3. Articles sorted by classification of image compression techniques

Third step: in line with the purpose of this paper, which is to discuss the development of hybrid compression methods, 39 articles (46.43%) are then separated from those 84 articles. Table 1 presents the data source details of the 39 articles in question.

Table 1. Reports on data source

Data Source	Number of articles	Percentage of total (%)
IEEEXplore	15	38.46
Direct	4	10.26
Scholar	14	35.90
Journal/Conference (other)	6	15.38
Total	39	

4. CLASSIFICATION OF LITERATURE

The result of developmental analysis of the 39 articles, 20 articles (51.28%) discusses the methodical developments of hybrid compression technique, and 19 articles (48.72%) discusses the development of hybrid compression techniques wherein several transformation methods with different properties, or so-called hybrid transformations. Below is a discussion of the influence of proposed method developments on the performance of hybrid compression with a focus on the development of lossy compression technique, lossless compression technique, or both.

4.1. Wavelet Base Coding

Some researchers give attention to effects of wavelet transformation method on the performance of hybrid compression when orthogonal [9], or biorthogonal filters [10] are used. The technique proposed by Chouwdhury and Khatun [9] using DWT Daubechies filter tested over several threshold points. The testing result of grayscale image analysis using threshold point 30 is capable of providing up to 24.22 compression ratio. However, the quality of reconstructed images are relatively poorer, i.e., 19.86 dB below 30 dB.

The use of biorthogonal filter over the performance of hybrid compression technique is also effectual [10], [11]. A study by Arhami et al. [10] compares the performances of Bior1.1, Bior1.3, Bior1.5, Bior2.2, Bior2.4, Bior2.6, Bior2.8, Bior3.1, Bior3.3, Bior3.5, Bior3.7 and Bior3.9, Bior4.4, Bior5.5, Bior6.8 filters using RLE coding, Huffman coding, and a combination of both. A test is performed on three color images of 256x256 of varying details. The testing result indicates that the use of Biorthogonal wavelet families transformation does not significantly affect the compressed image as is observed from the image compression ratio difference between one type of wavelet and another. Type of image to be compressed significantly affects the wavelet filter used to improve the performance of compression. The testing result of the proposed method indicates that detail-classified images are very suitable for the utilization of the Bior2.2 filter, whereas non-detailed images are more appropriate to Bior1.1 filter. The ratio of compressed image is visually significant when a coding combination of RLE and Huffman is used, which is above 70% on average. The resultant quality of compression is relatively good for PSNR and MSE which, on average, are 42.007 dB and 16.94, respectively.

Hybrid Wavelet-based Compression System(HWCS) method [11] used a combination of biorthogonal filter Bior4.4 method, quantization and Huffman coding. This proposed method aims at smoothening compression by grabbing focus away from the background to reduce details. Reduction of picture details may increase the speed of compression. This proposed concept turns out to be able to save about 20% of the time while maintaining the quality of the reconstructed image.

A comparative study of orthogonal and biorthogonal performances over DWT method has also been carried out [12]. The Method proposed by Sharadha and Bhanuprakash [12] used two types of wavelet families to see their performances. Wavelet filters to be compared are orthogonal filters (Db40, Sym30, and Coif5) and biorthogonal wavelet filters (Bior 2.6). The testing result of 4 color images (Lenna, Peppers, Zedla, and Barbara) indicates that biorthogonal wavelet family type has performed relatively better compared to orthogonal wavelet family.

Improvement of the performance of hybrid compression over images produced by the digital camera is also made using Lifting Wavelet Transform (LWT) method. LWT is the second generation of DWT introduced by Wim Swelden. LWT implementation is faster than classical wavelet because it does not require additional memories and is easily reversible. Filter operation process of DWT is performed separately, whereas operation process of LWT is cut into halves and executed simultaneously [13]. LWT can be implemented in wireless sensor network (WSN), i.e., camera-supported network [14] and in a digital camera with Color Filter Array (CFA) [15]. Network WSN has problems with its picture size so that it requires compression technique to reduce memory capacity and communication cost. The proposed method to overcome them is a combination of LWT and SPIHT method [14], [15]. The testing result indicates that the quality of reconstructed images using LWT and wavelet filter db 9/7 and SPIHT method is better than that using LWT-EZW. The measurement result of Lena image of 512x512 indicates that the quality of the reconstructed image is fairly good (1-bit rate/bpp PSNR = 38.55).

4.2. Embedded Zero Tree of Wavelet Coefficient (EZW)

Embedded Zero-tree Wavelet (EZW) is a simple and very effective image compression algorithm characterized by its sequencing bits in a bit stream along their relevances and produces fully embedded codes. Performance improvement of EZW is made [16-20] to address emerging problems in the EZW method: how to minimize numbers of required bits to represent an image data.

The improvement of EZW performance is also made by integrating SPIHT method [16], [17]. Also, it also compares the effect of wavelet orthogonal and biorthogonal filter as an input to EZW method. The testing result of orthogonal db4, db10, coif4, coif5 filter and biorthogonal Bior4.4, Bior6.8 filter combined with SPIHT method [16] indicates that this proposed method produces a better result than adaptive arithmetic coding. The quality of a reconstructed image is better if the proposed method uses an orthogonal filter (average PSNR= 35.44 at a bit rate of 1 bpp) rather than Wavelet Biorthogonal filter (average PSNR=33.24). The testing result of the EZW method performance comparison between wavelet biorthogonal filter DWT 9/7 and DWT5/3[17] indicates that DWT 5/3 filter is relatively better. Filter DWT 5/3 is capable of improving the compression performance up to MSE=17.5 and PSNR=35.71 dB, whereas DWT 9/7 filter produces MSE=26.9 and PSNR=33.96. This result has proved that the use of SPIHT contributes to the improvement of compression performance and, based on this study, indicates that the use of orthogonal filter produces a slightly better result than that of biorthogonal filter [16], [17].

The testing result of Improved EZW (IEZW) [18] method indicates that compression ratio is capable of increasing EZW original performance to about 12.5%, although the quality of the reconstructed image is not so good, since it is still below 30 dB, i.e., 27.75 dB. Efforts to improve the performance of EZW are made, after DWT transformation, by using Orthogonal Polynomials Transform (OPT). Next, they are followed by quantization and entropy coding [19]. The testing result of 11 images of 256x256 at the level of Compression ratio 50% indicates that average PSNR value=39.89 dB. These results suggest that the proposed OPT provides a better compression ratio than DWT and EZW. The proposed Wavelet Difference Reduction (WDR) coding and prediction error quantization method to compress RGB image or picture [20] are used to reach a high compression performance so as to produce efficient compression output. The proposed scheme is to reduce correlation between RGB planes using RGB to YDbCr Transform. Next, each canal is decomposed into several sub-images. Sub-image of Y plane is compressed separately without reducing its color quality, whereas each canal of sub-image Cb and Cr is compressed using Quantization, WDR and

Huffman coding technique. The testing result of 7 color images indicates the quality of the reconstructed image is good (average PSNR=33.16 and 0.6061 bpp).

4.3. Quantization

Optimizing performance of hybrid compression is also made by developing quantization method [21-23]. In principle, quantization works to compute variances of transformation coefficient and produces more bits of bigger difference. The quantization table is developed to arrange optimum allocation of bits and visual threshold of human eyes. TMT quantization table generation [21] suggests a better quantization table for grayscale image compression. Also, it examines the effect of TMT coefficient on image reconstruction errors. The test results show that the psycho-visual threshold TMT function produces better compression performance in the picture and makes the average bit length of Huffman code lower. Improvement of compression performance through Hybrid quantization (Hy-Q) [22] is made by combining scalar and vector quantization into a compression framework. A proposed method uses different blocked sizes in each technique quantization strategy. An SPIHT compression algorithm, which is scalar-based quantization, is used to quantize flat areas of the image, whereas ModLVQ uses vector quantization to quantize specific areas of the image. The testing result of 3 images indicates that the quality of the reconstructed image, when using Hy-Q, is better than that obtained through SPIHT and ModLVQ, that is, 1 bit per pixel of average PSNR=35.47%, whereas the quality received through ModLVQ is average PSNR=35.36%, and SPIHT is average PSNR=35.32%.

Cuckoo Search (CS) quantization method [23] is capable of optimizing metaheuristic algorithm by optimizing Linde Buzo Gray(LBG) codebook with Levy flight distributional function based on Mentegna algorithm which does not use Gaussian distribution. LBG is a local design codebook for image compression used in Vector Quantization (VQ) method. Other than LBG, global design codebooks using Gaussian distribution function are Firefly Algorithm (FA), Particle Swarm Optimization (PSO) and Honey Bee Mating Optimization (HBMO). CS is developed to address the emerging problems of FA method, i.e. when applied to brighter images; the result is inversely blurred. CS would also solve problems of PSO method, that is, convergence instability when the speed of components combination is so high. CS algorithm possesses a high PSNR and a better fitness or accuracy point than LBG, PSO-LBG, Quantum PSO-LBG, HBMO-LBG and FA-LBG during high-cost convergence time..

4.4. Coding

The improvement of hybrid compression performance is also made by developing lossless compression technique in the coding method [24]-[28]. Hybrid compression using a combination of DWT, fractal method and SPIHT [24] works to reduce the informational deficit from human visual signal sensitivity by using low-frequency fractal coding method. Moreover, it also works to reduce the time required to do encoding by using SPIHT coding in a high-frequency sub-band. The testing result of 2 images of 256x256 at a bitrate of 0.25 shows that average PSNR=29.74 dB is slightly better if it only uses SPIHT method where PSNR is 29.63 dB, whereas processing time required to do a proposed algorithm of 1.27 second is little faster if it only uses SPIHT method of 1.31 second. A similar study has also been done by Rawat and Meher [25], the difference being that its transformation method uses DCT and quantization method, and the coding uses a combination of fractal and Huffman coding. The testing result indicates that the proposed method produces a relatively good reconstructed image, i.e., the highest PNSR of 30.06 dB compared to JPEG method with its PSNR value being 29.89 dB. Its compression ratio is also relatively good, i.e., 8.42 on average.

Improvement of hybrid compression performance in the coding method is also made by integrating Neural Network [5], [26] method, apart from combining it with the fractal method. The proposed method combines DWT transformation and neural network to increase the quality of image reconstruction. Computer simulation indicates that this proposed algorithm produces a better compression effect than that obtained through a traditional neural network or JPEG method. Adaptive significant DCT coefficients (ASDC) method is a refinement of coding method to improve the performance of hybrid compression [27]. It combines DCT method, quantization using Q50 quantizer, and zig-zag scanning followed by ASDC method before its final coding of Huffman method.The testing result of all images produces a compression ratio of about 89-96%, whereas the quality of image reconstruction in the average MSE is 9.53 and average PSNR is 39.22. The proposed hybrid compression method in the form of combining Block Truncation Coding (BTC) and Walsh-Hadamard Transform (WHT) [28] aims at reaching a higher compression ratio. The testing result indicates that the proposed method is capable of compressing the image in a compression ratio of about 87% and of maintaining the quality of image reconstruction.

4.5. Hybrid Transformation

A research proposal by Jassim [29] aims at improving the performance of JPEG method by refining the lossy method. It is carried out by adding Five Modulus Method (FMM) before embarking process stages over JPEG. FMM uses the concept of each matrix block 8x8. Each pixel intensity is combined with -1,-2,1 or 2 in the manner as follows: if pixel intensity is divided by 5 and equals 4, then pixel intensity is added with 1; if the result is 3, 2 is added; if the result is 2, 2 is subtracted; and if the result is 1, 1 is subtracted. In this way, all pixel intensities would be zero when divided by 5. The testing result indicates that, on average, the tested image compression ratio is better than that obtained through JPEG, whereas the quality of the reconstructed image is better when it is achieved through JPEG method. Other than adding FMM method [29], the improvement of hybrid compression performance is also made by combining several transformation methods (hybrid transformation). Of the combined transformation methods are transform coding technique and wavelet based [30-35]. Hybrid compression uses this hybrid transform combined with quantization and coding techniques like entropy coding [30], Huffman coding [31-33], or arithmetic coding [34], [35].The testing result indicates that hybrid transform is going to improve hybrid compression performance if it is combined with Huffman coding instead of arithmetic or entropy coding.

Some researchers have also examined the performances of hybrid transform to obtain the best possible compression performance. One such combination of the examined hybrid transform is Discrete Wavelet Transform. If it uses filter Db4 and LWT [36], it can maintain the quality of tested image (average PSNR=36.67dB). Examination of the performances of hybrid wavelet transform: Discrete Hartley Transform(DHT)- Discrete Cosine Transform(DCT), DCT-DHT, Discrete Walsh Transform(DWaT)-DCT, DCT-DWaT, DHT-DWaT, DWaT-DHT, Discrete Kekre Transform(DKT)-DCT, DCT-DKT [37] indicates that the use of hybrid transformation produces the best result if it is compared to single orthogonal transformation. Examination of hybrid transform using the combination of Discrete Walsh Transform(DWaT) and other: DCT, Discrete Sine Transform (DST), DKT, Real-DFT(Discrete Fourier Transform), Slant, DWT [38] produces the same result as well. DWT is used to represent global properties of a picture. DCT, Walsh, DST, Slant and Real-DFT are used independently to describe local properties of an image. The best performance of compression is obtained through a combination of DWT and DCT.

Examination of the performance of hybrid transform uses a combination of Haar transformation and nonsinusoidal transformations like Walsh, Kekre, and Slant to contribute to global features of a picture. They are however selected as local components by Kekre et al. [39]. The testing result indicates that the best compression is obtained through a combination of Haar-Slant. If Haar transformation is coupled with DCT, DST, Haar-Hartley and Real-DFT [40], then the best hybrid transform is obtained through a combination of Haar-DCT of RMSE 9.77.

Several researchers have also tested the performance of hybrid transform using a combination of DCT, acting as base transformation, and DWT, Kekre, DKT, DWT, DHT, Walsh, Haar, Sine, or Slant [41-45]. The testing result [41-43] indicates that the performance of hybrid compression can be increased using an improved hybrid transformation of DCT-Kekre. The proposed method [42] is even capable of maintaining a relatively good quality of the image (PSNR=63.4 dB, MSE=0.2). The testing result of hybrid transform, when applied to different color spaces [44], [45], indicates that DCT-Haar performance is capable of maintaining the quality of a picture.

Hybrid compression improvement not only develops hybrid transform that uses a combination of coding transform and wavelet-based method. A study by Afrose et al. [46] proposes a joint of 3 transformation methods: Singular Value Decomposition (SVD), Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT). Having used these three methods, the hybrid transform is then combined with Quantization factor and entropy encoding. The testing result indicates that the proposed method is capable of improving the quality of the reconstructed image of 20.61 dB in the average PSNR and 0.033 in the average MSE.

The development of hybrid compression includes KFCG (Kekre's Fast Codebook Generation) and KMCG (Kekre's Median Codebook Generation) [47] quantization method refinements as well. The performance of KFCG and KMCG quantization method is faster than that of LBG (Linde Buzu Gray) algorithm. The testing result indicates that combination of KFCG quantization and Hybrid Wavelet transformation produces the least distortion and a relatively good image quality as is reflected in the Structural Similarity Index (SSIM) of 0.974 nearly reaching 1, which shows the relatively good performance of compression method.

5. CONCLUSION

The improvement of image compression technique to get an optimal compression ratio and best quality of the image can be made by combining lossy and lossless compression technique known as a hybrid compression technique. This combination aims at optimizing the advantages of each compression method. An analytical review of the journals has revealed classifications of the development of hybrid compression technique, as are shown in Table 2.

Table 2. Classifications of the development of hybrid compression technique

Classification	Proposed Method	Paper
Wavelet Base Coding	DWT filter orthogonal, quantizer, coding	[9],[12]
Wavelet Base Coding	DWT filter biorthogonal, quantizer, coding	[10],[11],[12]
Wavelet Base Coding	LWT, SPIHT	[14],[15]
EZW	EZW, SPIHT	[16],[17]
EZW	IEZW	[18]
EZW	OPT	[19]
EZW	WDR	[20]
Quantization	TMT Quantization table generator	[21]
Quantization	Hybrid Quantization	[22]
Quantization	Cuckoo Search (CS)	[23]
Coding	Transformation, Fractal, coding	[24],[25]
Coding	DWT, Neural Network	[5],[26]
Coding	ASCD	[27]
Coding	BTC dan WHT	[28]
Hybrid Transformation	FMM	[29]
Hybrid Transformation	Combination of coding transform and wavelet-based, quantization, coding	[30]-[35]
Hybrid Transformation	Combination of coding transform and wavelet-based	[36]-[45]
Hybrid Transformation	SVD, DWT, DCT	[46]
Hybrid Transformation	Hybrid Wavelet, quantization (KFCG, KMCG)	[47]

Based on the analysis of the performance of various methods discussed above, there is a possibility of improving the performance of image compression. Future studies may be performed by developing an appropriate hybrid transformation method and quantization to increase the compression ratio and by combining the development of coding method using fractal and neural network to speed up the compression process time and maintain the quality of the image.

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