Consolidating Literature for Images Compression and Its Techniques

N. S. A. M. Taujuddin[1], Rosziati Ibrahim[2], Suhaila Sari[1], Saima Anwar Lashari[2]
[1]*Faculty of Electrical and Electronic Engineering,*
[2]*Faculty of Computer Science and Information Technology,*
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
shahidah@uthm.edu.my

***Abstract*—With the proliferation of readily available image content, image compression has become a topic of considerable importance. As, rapidly increase of digital imaging demand, storage capability aspect should be considered. Therefore, image compression refers to reducing the size of image for minimizing storage without harming the image quality. Thus, an appropriate technique is needed for image compression for saving capacity as well as not losing valuable information. This paper consolidates literature whose characteristics have focused on image compression, thresholding algorithms, quantization algorithms. Later, related research on these areas are presented.**

***Index Terms*—Compression Techniques; Image Compression; Lossless Compression; Lossy Compression.**

I. INTRODUCTION

Compression is one of the promising algorithms that can reduce the storage requirements and network traffic, therefore improving system efficiency [1]. There are several approaches appeared in literature, mainly focusing on developing an algorithm able to compact as much as possible the original image in few coefficients. In the meantime, it is identified that wavelet is the most prominent tool used in compression as proved by the number of algorithms suggested [2].

This minimization in size enables more images storage in an available memory space and cut down the transmission duration that is demanded by an image to be downloaded over the internet [3]. Image compression can basically be achieved by eliminating wherever possible various redundancies in an image. An inverse process is called decompression (decoding) where it is applied to the compressed data to get the reconstructed image [4]. To demonstrate the compression result, compression ratio or rate distortions are used. Compression ratio is the size ratio of an original image compared to the size of its compressed image. Rate distortion is the required bit needed to achieve a certain point of desired performance in a compressed image. Besides that, the Peak Signal to Noise Ratio (PSNR) and Mean Structural SIMilarity (MSSIM) can be used to quantify the quality of the compressed images.

Even though, nearly all image processing applications can accept some lossless information, in numerous critical areas such as medical, satellite, and legal imaging, lossless compression algorithms are preferred. The Joint Photographic Expert Group (JPEG), Context Based, Adaptive, Lossless Image Codec (CALIC), JPEG-LS, and JPEG2000 are among outstanding lossless image compression algorithms that give high compression ratio in a practical time [5]. The compression ratio for a typical image is best offered by CALIC, while JPEG-LS provide a low complexity alternative and JPEG provides a unified approach to lossy to lossless compression.

Literature suggest that wavelet is the most prominent tool used in compression as proved by the amount of algorithms suggested [2][3][6]. Eliminating redundant information is a major aspect in compression. This can be achieved by performing a thresholding process [7-11]. While, some researchers are focusing on the quantization process [12-17].

The organization of this paper is as follows Section 2 provides a brief description of image compression. Section 3 discussed wavelet thresholding for image compression. Section 4 illustrates quantization algorithm for compression, Section 5 provides summarization of techniques used in compression algorithms. Lastly, Section 6 concludes this paper.

II. IMAGE COMPRESSION: AN OVERVIEW

Image compression is a process of reducing the amount of data in an image by removing the redundant data while keeping the resolution and visual quality of the reconstructed image as close to the original image. Image compression can be achieved by eliminating wherever possible various redundancies in an image. An inverse process is called decompression (decoding) where it is applied to the compressed data to get the reconstructed image. In general, compression algorithms consist of three basic steps: transformation, quantization and entropy coding as shown in Figure 1[18].

A. Transformation Process

The initial step in image compression is to transform the image from spatial domain to the transform domain using transform algorithm such as Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT) and many more. The reasons of having transformation are to compact the energy and decorrelation. Energy in an image is spread in the whole image. So, by transforming the image, a large portion of energy can be concentrated in a low frequency region of transform domain. Usually wavelet is implemented due to its great energy compaction and it is good for human visual. Transformation process also will produce many wavelet coefficients having a value of zero, or near zero and magnitude.

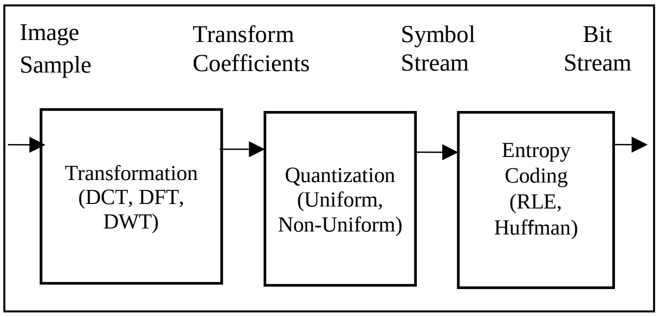

Figure 1: Typical compression basic steps

B. Transformation Process

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C. Quantization Process

At the quantization step, the loss of information is introduced by deliberately rejecting the less important data in the image. Quantizing refers to a reduction of the precision of the point values of the wavelet transform, which is typically either a 32 or 64 bit floating point numbers. To use less bits in the compressed transform which is necessary if compression of an image is to be achieved, these transform values must be conveyed with fewer bits of each value [14]. The wavelet transform will approximate the images when the inverse transform is performed. The human visualization is good at identifying small dissimilarity in brightness for a large area, but not so good at examining the exact strength of a high frequency (rapidly varying) brightness variation. In other words, the eye is most sensitive to low frequencies, (upper left corner) and less sensitive to high frequency (lower right corner).

D. Entropy Process

After the quantization process, entropy coding is performed to further compress the quantized to give extra compression values. It is a reversible yet lossless compression. Entropy is a measurement of unpredictability of a system. It is used to find a reversible mapping to the quantized values so that the average number of bits or symbols is minimized. Minimum entropy value will lead to optimal threshold. The most accepted entropy coding are Arithmetic Coding and Huffman Coding

III. COMPRESSION TECHNIQUES FOR IMAGES

Compression techniques are classified in two categories: lossless or lossy compression as shown in Figure 2. In lossless compression, the reconstructed image, after compression, is numerically identical to the original image. However, lossless compression can only achieve a modest amount of compression. An image reconstructed by using lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. This means lossy schemes can achieve much higher compression with some tolerance of corrupted data. However, under normal viewing conditions, no visible loss is perceived (visually lossless). Thus, it will produce a sufficient data size for transmission and storage purposes. Some of the prominent lossy image-coding algorithms are block truncations, transform coding and wavelet subband coding.

Algorithms used in lossless compression are Run Length Encoding, Huffman Encoding, Lempel-Ziv-Welch (LZW) Encoding and Area Coding as shown in Figure 2. For Lossy compression, the algorithms used are Transformation coding, Vector quantization, Fractal coding, Block Truncation coding and Subband coding. The compression ratio for lossless coding is not larger than 2:1 to 4:1 while lossy compression ranges from 4:1 to 100:1 or even higher.

Current compression algorithms present an excellent performance and many of them support the use of wavelet transformation [19-21]. Sreelekha, [19] proposed a model that detects threshold by using psychovisual experiment on each individual subbands. This manual experiment is done recursively until it reaches the highest possible value where the Human Visual System (HVS) cannot detect any changes or degradation of image quality. Then, each image coefficient is subject to this value, where coefficients with a higher value than the threshold will be retained while the rest will be discarded. Quantization is then done by mapping the coefficients to different clusters using the k-means algorithm. The number of clusters and hence the bit allocation are decided depending on the perceptual based root mean square error allowed for each sub-band.

Savic, [20] proposed a pixel value prediction threshold in the pre-processing stage. The correlation between adjacent pixels is exploited to improve the threshold decision. Dual mode quantization was done by using low and medium number of quantization levels and fixing the code word length by using pixel value prediction is done in the pre-processing stage. Prediction is done on blocks with m x m sizes. Linear prediction is performed by calculating the variance between original and predicted block, followed by fixed uniform or piecewise uniform quantization and differential encoding.

Srikanth & Meher [27] presents image compression technique that used different embedded wavelet based image coding with Huffman-encoder. The embedded zerotree wavelet *(*EZW*)* and the Set Partition in Hierarchical Tree *(*SPIHT) algorithms with Huffman encoding were deployed and it was observed that the obtained results have good quality and also provides high compression ratio as compared to the previous existing lossless image compression techniques.

Lately, Bartrina-rapesta and Aulí-llinàs [21] proposed a scheme that employs small cell coefficients magnitude threshold for more cognisant threshold value and extends the traditional Uniform Scalar Dead zone Quantization (USDQ) to a more sophisticated Two-Step Scalar Dead zone Quantization (2SDQ). Two different size of interval at valued coefficient range based on its magnitude. Coefficients with larger magnitude will have larger interval size compared to smaller coefficient magnitude. Besides, these algorithms depend on a small set of wavelet coefficient magnitudes called a cell [22] [23].

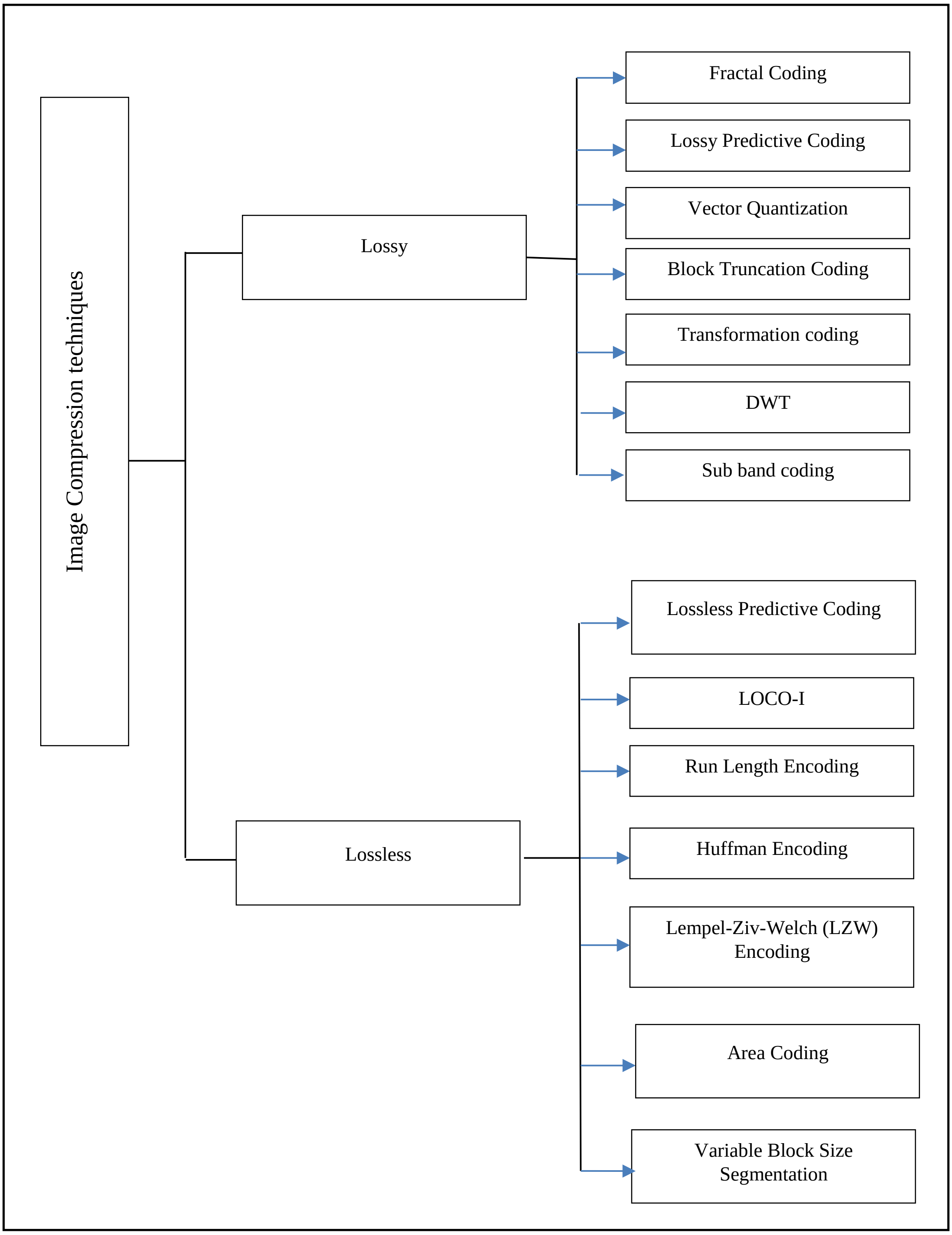

Figure 2: Image compression techniques

The entire above compression algorithm end up with encoding algorithm that typically uses statistical technique to minimize redundancy. At this stage, the symbol stream will be replaced by sequence of binary code word, which is the smallest possible number of bit per symbol. Due to high performance in achieving minimum code length, Huffman is the most commonly used technique. Another technique that usually used for encoding is RLE and Arithmetic Coding. To ease the understanding, Table 1 demonstrates the summary of techniques used in compression algorithm proposed by recent researchers.

The above quantization algorithms use conventional uniform or non-uniform based quantization and it basically concerns reducing the cost of compression parameter such as the length of the Code-word, quantization step as well as the quantization boundary without considering the importance of location of significant and non-significant coefficients. An image reconstructed by using lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. This means lossy schemes are capable of achieving much higher compression with some tolerance of corrupted data. However, under normal viewing conditions, no visible loss is perceived (visually lossless). Thus, it will produce a sufficient data size for transmission and storage purposes. Some of the prominent lossy image-coding algorithms are block truncations, transform coding and wavelet subband coding [19].

Although the forgoing algorithms can make an effective compression based on their proposed threshold estimation, most of them just considered the whole subband as equal (global subband threshold). Subsequently, just one threshold value is applied in general and it does not consider the different characteristics occurred in different subbands, leaving the individual subband's special representation unexploited. Besides, it suffers with time-consumption because of various steps introduced in the algorithm. Besides that, in the prediction part, manual examination is used.

Table 1
Summary of quantization algorithms used in compression algorithms

Author(s)/Year	Compression Algorithms	Transformation Algorithm	Threshold Setting	Quantization Algorithm	Encoding Algorithm
Savic *et al.*, 2015	Linear Threshold Prediction with Dual Mode Quantization	DWT	Pixel Prediction	Dual Mode Quantization	BTC & DPCM
Bartrina-rapesta & Aulí-llinàs , 2015	Cell Based Wavelet Coefficients Threshold with 2 Step Scalar Deadzone	DWT	Small Cell Wavelet Coefficient Thresholding	2 Step Scalar Dead zone Quantization	Huffman
Abu *et al.*, 2013	Generic Psychovisual Error Threshold for Modified JPEG Quantization Table	DCT	Psychovisual Test	Psychovisual-JPEG Quantization Table	Huffman
Arif *et al*, 2013	compression of pharynx and esophagus fluoroscopic images	DWT	Thresholding based on the peaks in the histogram	-	Run Length and Huffman coding
Hashemi-Berenjabad, 2011	Threshold based lossy compression using contourlet transform	contourlet transform	SPIHT	Vector quantization	Huffman coding
Sreelekha & Sathidevi , 2010	HSV Based Threshold and Adaptive Quantization	DWT	Psychovisual Test	Clustered Quantization	Huffman
Shen & Huang, 2010	adaptive image compression method based on vector quantization	Euclidean distance with code words	-	Vector Quantization	Arithmetic coding
Chandler & Hemami, 2005	Dynamic contrast-based quantization	DWT	near-threshold & supra threshold	DCQ	-
Liang *et al.*, 2005	a pre/post filtering framework	DCT	SPIHT	-	Video coding
Watson, 1994	Discrete cosine transform	DCT	-	Quantization	first-order entropy

Abbreviation:
Discrete Wavelet Transform (DWT)
Block Truncation Coding (BTC)
Different Pulse Code Modulation (DPCM)
Discrete Cosine Transform (DCT)
Set partitioning in hierarchical trees (SPIHT)
Dynamic Contrast-based Quantization (DCQ)
Correlation Coefficient (CC)

IV. Conclusion

Image compression refers to compressing the significant bits of an image such as quality of image does not get affected. In this paper, several compression techniques for lossless and lossy compression techniques have been presented. Current compression algorithms present an excellent performance and many of them support the use of wavelet transformation. The research trend is also more towards system perspective which is either using wavelet filter or sub-band coding. Besides, research on determining threshold value at wavelet domain gain its popularity because it offer a near optimal properties and can be perform well in simulation.

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