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THRESHOLDING AND QUANTIZATION ALGORITHMS FOR IMAGE COMPRESSION TECHNIQUES: A REVIEW

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ABSTRACT

With increasing demand on digital images, there is a need to compress the image to entertain the limited bandwidth and storage capacity. Recently, there is a growing interest among researchers focusing on compression of various types of images and data. Amongst various compression algorithms, transform-based compression is one of the promising algorithms. Despite the technological advances in transmission and storage, the demands placed on the bandwidth of communication and storage capacities by far outstrips its availability. This paper presents a review of image compression principle, compression techniques and various thresholding algorithms (pre-processing algorithms) and quantization algorithm (post-processing algorithms). This paper intends to give an overview to the relevant parties to choose the suitable image compression algorithms to suit with the need.

Keywords: Image compression, thresholding algorithm, quantization algorithm

INTRODUCTION

Image compression is a process of reducing the amount of data in an image by removing redundant data without affecting the quality of the image while keeping the resolution and Visual quality of the reconstructed image as close to the original image as possible. This minimization in size enables more image storage in an available memory space and reduces the transmission duration demanded by an image to be downloaded over the internet (Zhou et al., 2018). Image compression can basically be achieved by eliminating wherever possible various redundancies in an image. An inverse process is called decompression (decoding); applied to the compressed data to get the reconstructed image (Boujelbene et al., 2018).

Compression algorithms can be classified as either lossless or lossy compression. Lossy compression, in which the used algorithms are Fractal coding, Lossy predictive coding, vector quantization, Block Truncation coding, Transformation coding, Discrete Wavelet Transform (DWT) and subband coding. Lossless compression algorithms are Lossless Predictive Coding, Low Complexity Lossless Compression for Images (LOCO-I), Run Length Encoding, Huffman Encoding, Lempel–Ziv–Welch (LZW) encoding, area coding and variable block size segmentation. In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image (Taujuddin et al., 2015; Jiang, 1999).

The rest of the paper is organised as follows: Section 2 introduces thresholding algorithm for image compression whilst Section 3 discusses quantization algorithm for image compression in detail. Finally, the concluding remarks are given in Section 4.

THRESHOLDING ALGORITHM FOR IMAGE COMPRESSION

Thresholding is a process of shrinking the small absolute coefficients value while retaining the large absolute coefficient value. It will produce a finer reconstructed signal. Since this algorithm takes the condition that the amplitude of wavelet transform coefficients signals are much larger than noises, the unconsidered noise will be removed while holding the significant signal. Threshold can also be defined as the Peak Absolute Error (PAE) accepted for image reconstruction (Baligar, Patnaik, & Nagabhushana, 2006). Hard and soft threshold are the common operators used in conjunction with Discrete Wavelet Transform (DWT) (Zhen & Su, 2010; Lashari Ibrahim, & Senan. 2014). Furthermore, wavelets give superb compression ratio with the image quality maintained, which rivals Discrete Cosine Transform (DCT).

Donoho (1995) revealed that the best estimation error at its minimum is achieved through the Donoho universal threshold. Thresholding also eliminates noises and clean signals, creating some artifact. Hard threshold algorithm will preserve a good edge. However, the artifact appearance such as ringing and pseudo-Gibbs effect is irritated. The soft threshold is to lessen the gap between the remaining and discarded coefficients, giving better image recovery whereas soft threshold algorithm also produces a much better image quality over hard threshold because the end is linked, but it tends to produce an over-smoothing image (Chang, Yu & Vetterli, 2000).

The soft threshold image appears smoother but the image is distorted, leading to a blurred image. The hard threshold eliminates all coefficients that are lower than the threshold value and maintained the values of the rest. The soft threshold ascended the coefficients continually with the centre of zero (Jianmin & Shibo, 2009). Although there is a huge number of approaches proposed in literature, developing a threshold algorithm that reduces the image size without tolerating with the image quality is still a challenging task. Haar Wavelet, Embedded Zerotree Wavelet (EZW) and Set Partitioning in Hierarchical Tree (SPHIT) are three wavelet algorithms mostly utilised in the processing of images. Wavelet different reduction (WDR) and Adaptive Scanned Wavelet Different Reduction (ASWDR), on the other hand, are the advanced versions acknowledged in the committee. These are among the most outstanding compression algorithms which provide the smallest error per compression rate but transmitted the best perceptual quality image (Hashemi-Berenjabad, Mahloojifar & Akhavan, 2011; Bekhtin. 2011: Lashari, Ibrahim & Senan. 2015).

RELATED WORK IN THRESHOLDING ALGORITHMS

This section encompasses related work to wavelet threshold algorithms for image compression. Thresholding is a process of shrinking the small absolute coefficients value while retaining the large absolute coefficient value. The small absolute coefficients value is usually caused by noise while large absolute coefficients value is triggered by significant features. Generally, most of the wavelet coefficients are concentrated at near zero value with a small value. But the trend is differing at each particular subband as it associated to its resolution. Approximately 98% of coefficients in wavelet subband are smaller than 0.3W where W denoting the largest coefficients value (Auli-Llinas, 2013). A proper elimination of near zero coefficient will not harm the significant information. Besides, by performing thresholding process, many coefficients can be set to zero which resulting in a lesser space and reduce the image size (Sztyber & Pobocha, 2015). Threshold value estimation is very crucial in image compression. If the threshold value is set too small, it will adopt noise into data and compression ratio is not decreased. Whereas, if the threshold value is set too high, it will increase the compression ratio, but the important coefficients value will be screened out, leading to a destructive data condition (Zhen & Su 2010). The determination of threshold values can be done by defining it manually. The widely used technique are Psychovisual threshold technique or fixed threshold technique.

Psychovisual threshold is a threshold method used to obtain the threshold value based on human observation. Usually experiments are conducted to manually detect the threshold value based on Just Noticeable Different (JND) point in colour space, compressibility or visual distortion of compressed image compared to original image (Ernawan et al., 2013).

Sreelekha & Sathidevi, (2010) used the psychovisual threshold to detect the threshold on image subband. The experiment was done manually by recursively search the highest possible threshold value where the Human Visual System (HVS) cannot detect any changes or degradation of image quality. Then, each image coefficient is compared to this value, where coefficients with a higher value than the psychovisual threshold will be retained while the rest will be discarded. Although this algorithm can suggest a good threshold value below visual noticeable change, it suffer with time consuming because of manual testing. The similar approach was implemented by Abu et al. (2013), however, they implement it in DCT domain and the threshold is applied in a global condition. It then merged with the development of quantization stage. The threshold value is incremented one by one, manually, until it reaches a noticeable difference on color space (HSV). By using this threshold value, a new quantization table was developed. The resulting compressed image shows good quality, but still, it is time consuming.

Shanavaz & Mythili (2010) gave a different view in compressing the image using fixed threshold method. They suggest an algorithm of fixing the percentage of wavelet coefficients to be zeroed. Although this algorithm offer higher compression ratio, this algorithm cause low image quality for the threshold value set more than 50% coefficients to be zeroed. Tan & Tan, (2012) proposed another solution, where they suggested a method by fixing the reference points coding for thresholding. In this method, the threshold value is selected during compression process. Scanning was done until it meets the preferable compression ratio. This method is simple and the computational complexity is low, but compression ratio has to be compensated with degradation of image quality and error occurred during scanning will propagate threshold value. Some similar researches also have been done by (Palzer & Timo, 2016). To sum up, Table 1 present the summary of thresholding techniques as discussed in this section.

TABLE 1. Summary of Thresholding Techniques

Technique	Author	Types		Data sample	Advantage	Disadvantage
		Global	Local			
Psychovisual	Sreelekha & Sathidevi, 2010		√	RGB image	Threshold value is below noticeable change	Time consuming
	Abu *et al.*, 2013	√		Grey scale image	Good image quality	Manual increment on threshold value
Fixed	Baligar, 2006	√		Grey scale image	Low complexity	Fit on certain image category only
	Shanavaz & Mythili, 2010	√		Finger print image	High Compression Ratio (CR)	Quality degrade if threshold value zeroed >50% coefficients

Tan & Tan, 2012	√		Grey scale image	Various threshold value	Error during scanning will propagate threshold value
Abirami *et al.,* 2013		√	Grey scale image	Flexibility in choosing threshold value	No significant CR change after 4^{th} level decomposition
Palzer & Timo, 2016	√		Grey scale image	Multiple threshold value	High CR will cause low PSNR

While, fixed threshold is a very simple threshold method where the threshold value is predefined at the pre-processing stage. Formerly, Baligar suggested the use only one fixed threshold value to be apply globally to an image (Baligar, Patnaik & Nagabhushana, 2006) so it just can fit on certain image category only. While, Abirami et al., (2013) extend this work by suggesting the use of multiple threshold value then select the one that provide the highest Peak Signal-to-Noise Ratio (PSNR) value. These algorithms provide a manual suggestion to select the threshold value. Although it is fast, on the other hand it will limit the performance of compression because it creates a frontier where the coefficients cannot be reduced higher than the permanent limit.

QUANTIZATION ALGORITHM FOR IMAGE COMPRESSION

Quantization is a significant part in compression, charting the integer value of the quantized data to the tone value which is represented by some index value. High speed execution time is created but conversely, high quantization error is also produced because of the rounding process (Abu, Ernawan & Suryana, 2013). The precision of floating point value of wavelet coefficient is lessened by the quantization process. These approximated values are quantized, thus creating a lossy compressed image.

Defining the interval size for quantization process is very essential as it will provide compact signal representations with as little information loss as possible. Thus, the motivation of recent research is to define interval that gives good discrimination between significant and non-significant coefficient. By adaptively change the quantization interval size, original data used more than information. But the challenge is in formulating a virtuous quantization algorithm that can achieve high compression ratio without loss its reliability. Compression algorithm will end up with encoding algorithm which usually 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 (Abu, Ernawan, & Suryana, 2013) is the most commonly used technique. Another two techniques that usually used for encoding are RLE and Arithmetic Coding Savić, Perić & Simić (2015) in their research proposed dual mode quantization by using low and medium number of quantization levels and fixing the code word length by using pixel value prediction 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.

The Uniform Scalar Zero Zone Quantization (USZZQ) performs uniform quantization at valued coefficient range with same interval size, while double the interval size at zero coefficient range. Bartrina-rapesta & Auli-llinas (2015) proposed an extended version of USDQ named Two-Step Scalar Deadzone Quantization (2SDQ). The study used 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 cell.

Mahapatra & Jena (2013) presented a generalised fuzzy c-means clustering approach GIFP-FCM. This clustering approach, when applied to WQ based image compression, suitably demonstrates that the transition from fuzzy to crisp mode is more efficient compared to the known approaches. It is also independent of the choice of the initial codebook vector. The technique is fast, easy to implement and has rapid convergence. Bhattacharyya et al. 2007, proposed Hybrid DCT-VQ, the concept of energy compaction property of DCT to decrease the computational cost of codebook and to increase the VQ process. The simulation showed better results in terms of execution time and compression ratio as compared to that of conventional VQ process. Table 2 depicts the summary of the algorithms mentioned in this section.

TABLE 2. Quantization Algorithms Proposed By Recent Researchers

Authors	Technique	Advantage	Disadvantage
Savic *et al.*, 2015	Dual Mode Quantization	High Peak Signal to Quantization Noise Ratio (PSQNR)	High bit allocation needed for less correlated image
Manikandan & Dandapat, 2007	Uniform Scalar Zero Zone Quantizer	Provide energy packing efficiency	Suitable only on ECG signal
Bartrina-rapesta & Auli-Ilinas, 2015	Two-step Scalar Deadzone Quantizer	Produce high quality image	Auxiliary information transferred at low bit rate cause lower PSNR value at this rate
Mahapatra &Jena,2013	-	High speed performance	Difficult to implement
Bhattacharyya, 2007	Hybrid DCT-VQ	Better execution time and compression ratio	-

Although these algorithms produce good image quality, it suffers with time-consumption because of various steps introduced in the algorithm. Besides, in the prediction part, manual examination is used.

CONCLUSION

Nowadays, wavelet-based compression with its multi-resolution representation becomes a leading technology. In addition, it delivers impressive reconstruction image and more ideas can be developed for image compression. There are many generic wavelets being introduced currently. Sophisticated wavelets produce a smoother and more satisfactory compressed image. It makes no assumption concerning the periodicity of the data. Thus, wavelets are suitable for demonstrating sharp changes or even discontinuities. In this paper, several compression techniques for lossless and lossy compression techniques are presented. Current compression algorithms present an excellent performance, and many of them support the use of wavelet transformation. The previous researches show that thresholding ad quantization gives significant impact on the quality of the compressed image. Higher threshold value will give higher compression ratio but the image quality will tend to decrease, and vice-versa. Besides, appropriate decision on interval size in quantization is needed in reducing the quantization error because it also can affect the final reconstructed image. Despite the fact that great efforts are made to seek image compression at modest complexity and efficient performance, it still faces many challenges in achieving various degrees of scalability at different target bit rate based on users' individual requirements.

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