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An Overview to Various Image Compression Techniques

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ABSTRACT

The area of image compression is applicable to various fields of image processing. On the basis of analyzing the current image compression Techniques this paper presents the hybrid technique using the discrete cosine Transform (DCT) and the discrete wavelet transform (DWT) is presented. We observe evaluation and comparative results for DCT, DWT and hybrid DWT-DCT compression techniques. Using the Power Signal to Noise Ratio (PSNR) as a measure of quality, we observe that DWT with a two-threshold method named "improved-DWT" provides a better quality of image compared to DCT and to DWT with a one-threshold method. Finally, we observe that the combination of the two techniques, named improved-DWT-DCT compression technique, showing that it yields a better performance than DCT –based JPEG in terms of PSNR.

General Terms

Image Compression.

Keywords

Discrete Cosine Transform (DCT), discrete wavelets transform (DWT), DPCM Differential Pulse code modulation.

1. INTRODUCTION

The goal of data compression is to minimize the information redundancy with the objective of reducing archiving costs and data transmission bandwidth Image compression takes advantage of spatial and temporal redundancies in an image as well as perceived nonlinearities of human vision to represent an image with as few bits as possible. There exist two types of compression:

1. Lossless technique
2. Lossy technique

Lossless compression where the reconstructed image is identical to the original one but the compression ratio is very low and lossy compression where the compression ratio is very high but incurring appreciable data loss [2]. in lossy compression. The use of transform techniques is recommended for this type of compression [3]. The transform is able to concentrate the signal energy in the smallest No. of parameters and which does not require excessive computational complexity. The fast algorithm significantly reduces the no. of arithmetic operations to find forward transform and its inverse. Several transforms [4] are used in the domain of data compression, discrete Walsh-Hadamard transform (DWHT), discrete Walsh generalized transform, discrete cosine transform (DCT), discrete Fourier transform (DFT) and discrete wavelet transform (DWT). All of these transforms are symmetric, unitary and reversible [1][2]. And the total energy before and after transformation remain the same. Here the aim is to overview image compression systems based on transform techniques for data transmission and efficient data storage, with a good tradeoff between the compression rates and signal to noise ratio. The transform techniques chosen include discrete cosine transform (DCT) and discrete wavelets transform (DWT) [1], [2], [3]. The application of DCT is in image coding (JPEG) and video coding (MPEG2, H263, H264) .Moreover, the DWT transform is used in image and video coding (JPEG2000) with embedded zero-tree wavelet (EZW) and set partitioning in hierarchical trees (SPIRT) coder [4] In order to get both advantages of DCT and DWT, a hybrid scheme based on DCT and DWT schemes has been presented in [5] and [6]. In [5], the application of DWT-DCT compression for medical images such as X-ray and ultrasound images has been presented and evaluated, showing the benefits of the hybrid method. The authors considered all the decomposed images obtained from DWT analysis (i.e., approximation and details images) and applied DCT transform technique on those images. In [6], the authors considered two iterations for the DWT image analysis stage and for an efficient compression they applied a two dimensional DCT of size 4x4 on only the approximation image, without considering the details images from the moment that they claim that details coefficients are not important information. To develop a compression system with a DWT transform, four parameters are important to take into the consideration: image test, wavelet function (and the order of filter), number of iterations, and finally calculation complexity. Image with high spectral activity are not recommended for test image compression. High number of iterations provides more details information on the image or signal. However, the calculation complexity becomes high. Hence, we have fixed the number of iterations equal to three in our work. Also, unlike the works in [5] and [6], In [4] a two-dimensional DCT of size 8x8 on only the third approximation image is applied. And on all the details images which are obtained from DWT analysis, they have applied a threshold to keep the important information existing in those details images. In addition, due to the use of different entropy coding methods in DCT and DWT (DCT uses Huffman coding while DWT uses SPIRT) and in order to obtain a better comparison for efficiency and the performance of the DCT and DWT transforms, they compare those transform techniques without considering entropy coding.

2. Image compression technique

. There exist two types of compression:

1. Lossless technique

2. Lossy technique

2.1 Lossless compression technique

In lossless compression techniques, the original image can be perfectly recovered from the compressed (encoded) image. These are also called noiseless since they do not add noise to the signal (image).It is also known as entropy coding since it use statistics/decomposition techniques to eliminate/minimize redundancy. Lossless compression is used only for a few applications with stringent requirements such as medical imaging. Following techniques are included in lossless compression:

1. Run length encoding
2. Huffman encoding
3. LZW coding
4. Area coding

2.2 Lossy compression technique

Lossy schemes provide much higher compression ratios than lossless schemes. Lossy schemes are widely used since the quality of the reconstructed images is adequate for most applications .By this scheme, the decompressed image is not identical to the original image, but reasonably close to it. Figure: Outline of lossy image compression As shown above the outline of lossy compression techniques .In this prediction transformation decomposition process is completely reversible .The quantization process results in loss of information. The entropy coding after the quantization step, however, is lossless. The decoding is a reverse process. Firstly, entropy decoding is applied to compressed data to get the quantized data. Secondly, dequantization is applied to it & finally the inverse transformation to get the reconstructed image.Major performance considerations of a lossy compression scheme include:[4]

1. Compression ratio
2. Signal - to – noise ratio
3. Speed of encoding & decoding.

Lossy compression techniques includes following schemes:

1. Transformation coding
2. Vector quantization
3. Fractal coding
4. Block Truncation Coding
5. Subband coding

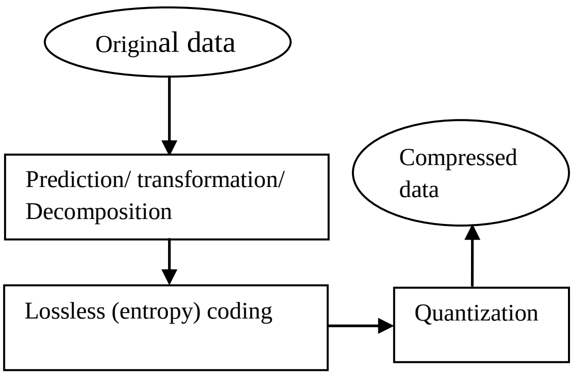

Fig a. lossy image compression

3 Transformation Techniques [9]

Basically there are two transformation technique DCT and DWT transforms. And combination of both is hybrid DCT-DWT algorithm. Discrete cosine transform and discrete wavelet transform have been used in many digital signals processing application and specifically in data compression

3.1 Discrete cosine transforms (DCT)

DCT transform used in JPEG standard [4], as shown in Fig. b.

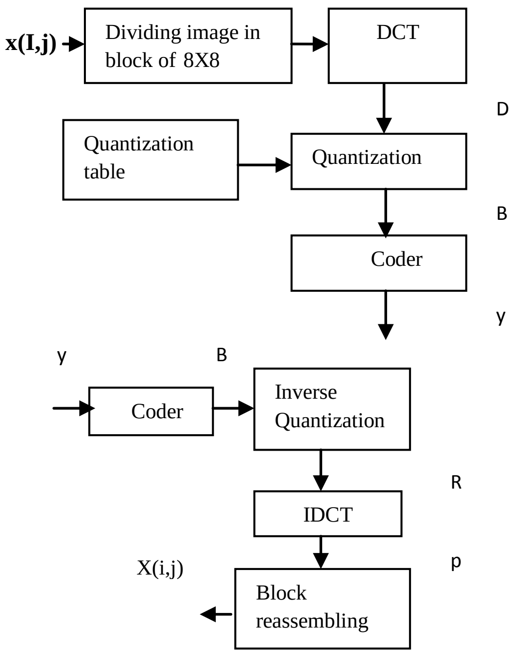

Fig b. JPEG diagram block

The JPEG process is as follows: first, the image is broken into 8x8 blocks. Second, DCT is applied on each block from the left to the right and from the top to the bottom. Then, quantization is applied for compression process, and data are stored following a specific process to reduce the information in the memory. And to reconstruct the compressed image we apply IDCT transform. The coefficients of DCT transform are computed using

$$D(i,j) = \frac{1}{\sqrt{2N}} c(i)c(j) \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} p(x,y) \times \cos\left(\frac{(2x+1)i\pi}{2N}\right) \cos\left(\frac{(2y+1)j\pi}{2N}\right) \ldots.1$$

where, p(x,y) is an input matrix image NxN, (x,y) are the coordinate of matrix elements and (I,j) are the coordinate of coefficients, and

$$c(u) = \begin{cases} \frac{1}{\sqrt{2}} & if\ u = 0 \\ 1 & if\ u > 0 \end{cases} \ldots\ldots..2$$

The reconstructed image is computed by using the inverse DCT (IDCT) according to

$$x,y) = \frac{1}{\sqrt{2N}} \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} c(i)c(j) D(i,j) \times \cos\left(\frac{(2x+1)i\pi}{2N}\right) \cos\left(\frac{(2y+1)j\pi}{2N}\right) \ldots.3$$

The pixels in black and white image are arranged from 0 to 255 with the step of 1, where 0 corresponds to a pure black And 255 correspond to a pure white. Since DCT is used for pixels arranged from -128 to 127, then for each input pixel we subtract 128. DCT could be accomplished by **D=TMT**^{t} , where **M** is theoriginal matrix leveled, T(I,j) is computed according to

$$T(i,j) = \begin{cases} \frac{1}{\sqrt{N}} & if\ i = 0 \\ \sqrt{\frac{2}{N}} \cos\left(\frac{(2j+1)i\pi}{2N}\right) & if\ i > 0 \end{cases} \quad \ldots\ldots.4$$

Since human eyes are sensible to low frequency therefore, high frequency information is usually removed in compression through quantization. This operation is achieved by dividing each component of D (i.e., D(I,j))by the corresponding element in the quantization matrix according to

$$B(i,j) = round\left(\frac{Di,j)}{Q(i,j)}\right) \ldots.5$$

As explained earlier, DCT is applied on each 8x8 block, hence, from each block we get 64 DCT coefficients. Each element of the matrix B (i.e., B(I,j)) is coded as a binary data. The first coefficient (i.e., the DC term) is coded differently from the other 63 coefficients (i.e., the AC terms) which follow a zigzag line. Note that the most part of the information of the block image is concentrated in DC term. In this work, we do not consider the entropy coder as explained in Section 1. For the reconstruction of the signal we use,

$$R(i,j) = Q(i,j) \times B(i,j) \ldots.6$$

where, each element of matrix B is multiplied by the corresponding element in quantization matrix Q. Finally, IDCT is applied for each block and then each coefficient of IDCT is added by 128. Also, to control the quality of DCT compression, we choose a matrix quantization using the following expression,

$$Q(i,j) = \frac{1}{4}[1 - \mu + (1 + i + j)(100 - fq)] \ldots.7$$

where, fq is quality factor, i,j=0…..7 and $i < u < i + j$

3.2. Discrete Wavelets Transform (DWT)

As the basis functions of Fourier transform are sinusoids, basis functions of Wavelets transform are small waves (i.e. wavelets), in which the waves are varying in frequency but have limited duration . The implementation of wavelets transform is equivalent to implement a filter with its impulse response that is a wavelet function. For one-dimensional signals and one iteration, two filters bank are required for analysis stage and two other filters bank for synthesis stage Analysis of a signal by DWT for a first iteration provides one approximation signal (AI) and one detail signal (D1). If there is a need for more precision, the decomposition is used on the approximated signal (AI) to provide A2 and D2 and so on as seen in Fig.b. In this figure, we can see the sequence is decomposed into high frequency and low frequency using filters $g_{\varphi}(-n)$ and $h\psi(-n)$ respectively, followed by down-sampling in the first and the second iterations.

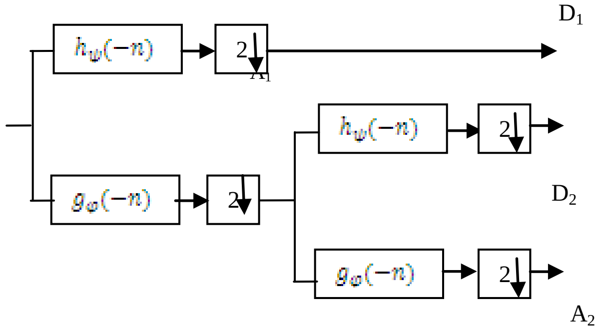

Fig.c: Analysis stage for two iterations

For signal reconstruction, we apply the up-sampling to all approximations and details signals and we apply a complementary filters $h\psi(-n)$ and $g_{\varphi}(-n)$ as shown in Fig.d

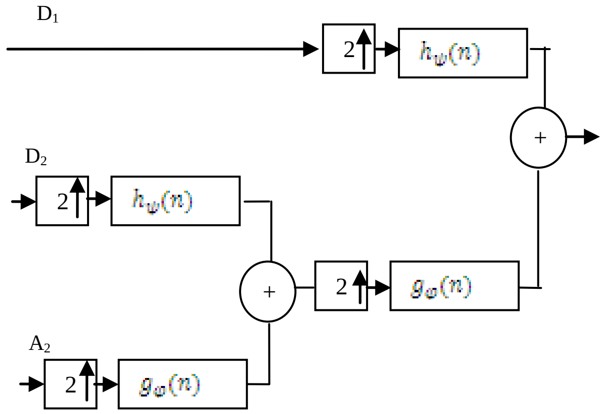

Fig.d: Synthesis stage for two iterations

For two dimensional signals (e.g., image), given by a matrix of size nxm, the processes of analysis and synthesis are the same as for one dimensional signals but applied first for rows and then for columns of that matrix. In image analysis and for one iteration, we need three similar banks of two filters. The image is filtered by a first two filters bank using high filter $h\psi(-n)$ and a low filter $g_{\varphi}(-n)$, each filter is followed by down sampled. Each output of this two filters bank is crossing another filter-bank similar to the first one. The results are four images, approximation (A), horizontal detail (HD), vertical detail (VD) and diagonal detail (DD), as seen in Fig. For more number of iterations, the same analysis process is applied only on approximation image of the last iteration that is the iteration of level 3.

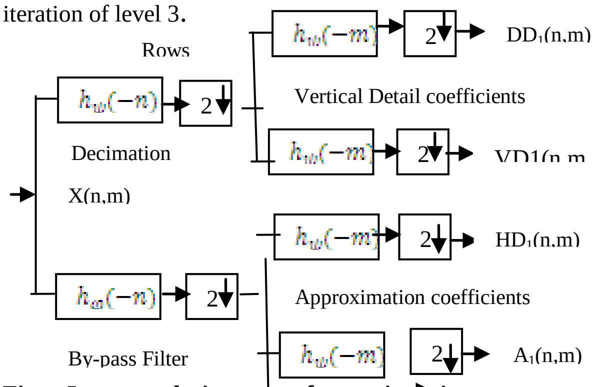

Fig.e: Image analysis process for one iteration

In synthesis process, up-sampling is used for all the outputs of the image analysis process (A, HD, VD and DD) before

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applying to filter. For one iteration, three banks of two filters are applied on synthesis process as seen in Fig.f. We see that the four images are added two by two, approximation with horizontal detail and diagonal detail with vertical detail. For more number of iterations, we start applying the same process with images from the same iteration. As the number of iterations in DWT algorithm becomes high, the details information becomes high too. However, to avoid high complexity of calculation, we fix a number of iterations equal to 3. Also, to come to a best compromise between Peak Signal to Noise Ratio (PSNR) and compression ratio in DWT algorithm, we select a bi-orthogonal wavelet 'bior4.4' to use in filters analysis and synthesis. Then to improve the DWT compression we choose the threshold equal or less than the smallest coefficient in approximation coefficients. We apply this threshold on all details coefficients resulting from iterations 1 and 2. In order to improve the quality of compression, we use two thresholds in DWT algorithm. The first threshold is applied on details coefficients resulting from iterations 1 and 2, and the second threshold is applied only for details coefficients resulting from iteration 3. We call this method improved DWT

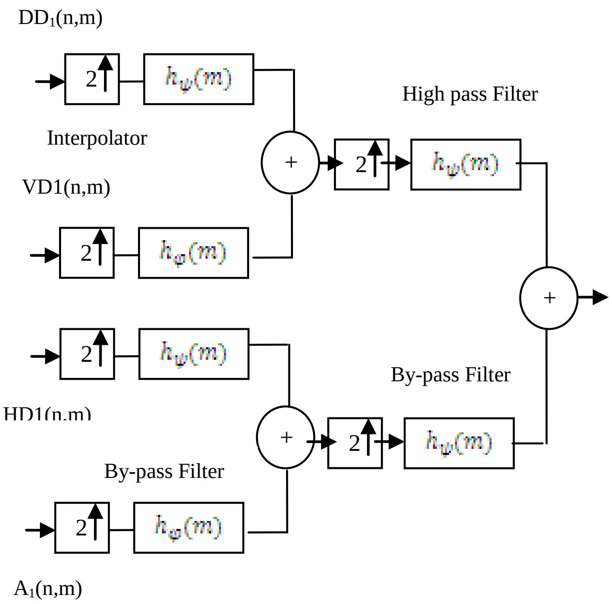

Fig.f: Image synthesis process for one iteration.

3.2 Hybrid DCT -DWT Compression Technique

The high quality of reconstruction and low distortion level is obtained by Hybrid DCT-DWT compression technique which uses advantages of both DCT and DWT transforms and remove drawback of each. It is also called improved-WTDCT shown in fig g. In Fig.g, the image X is analyzed by DWT for three iterations, as a results, we get one approximation image of size N/8xN/8 and nine details images of ifferent size (3 images of size N/8xN/8, 3 images of size N/4xN/4and 3 images of size Nl2xN/2). The two-dimensional DCT is applied only on approximation image resulting from iteration 3. The quality factor used is equal to 80. For the nine detail images, we apply two thresholds for compression as described in improved-DWT method. The results from the two ways are supposed to be coded and transmitted. For the reason presented in section 1 the entropy coded is not considered in this work.

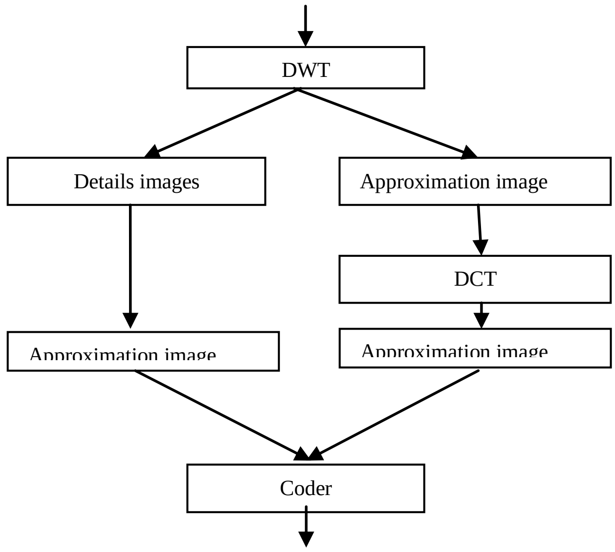

Fig.g Hybrid DCT –DWT

The performance evaluation of DWT, DCT, and the combined Wavelet-DCT compressions can be performed using two images of size 256x256: In image compression, we generally use two metrics to evaluate the quality of image compression: objective and subjective evaluations. As an objective metric, we use Peak signal to noise ratio (PSNR) which characterizes the amount of distortion in lossy compression [4],. It is defined by

$$PSNR = 10\log_{10}\frac{Pic^2}{MSE} \ldots\ldots 8$$

Where MSE refers to mean square error between the original image and the reconstructed image and is defined by

$$MSE = \frac{1}{n\times m}\sum_{i=1}^{n}\sum_{j=1}^{m}(x(i,j)-y(i,j))^2 \ldots\ldots 9$$

and Pic is equal to 255, the high input pixel in the image of size n x m . As a subjective metric, we use evaluations by human eyes as described in [7].

4 Lossless Compression scheme

The comparative table for different lossless compression technique is shown In Table-1. Comparing the performance of compression technique is difficult unless identical data sets and performance measures are used [8]

Image Comparison Approaches Approach	Compression Ratio	Comments

DPCM	1.66:1	Header data not included in Compression lculation. Huffman code uniquely generated for each image.
Pyramid Coding	1.73:1	Header data not included in compression calculation. Huffman code uniquely generated for each image. Approach supports progressive transmission.
Bit Plane	1.65:1	DPCM gray scale pre-processing followed by bit-plane processing
Adaptive Quad tree Segmentation	1.81:1	Exploits both local and global redundancies. Header data included in compression calculation
S+P Transform	1.92:1	Approach supports progressive transmission.
Universal Context Modeling	1.93:1	Context algorithm with binary tree and conditional autoregressive prediction
SCAN Bit-plane	1.72:1	
JPEG-2000	1.91:1	
SCAN Context	1.91:1	

Conclusion

In this paper we have analyzed three transforms techniques DCT, DWT and hybrid DCT-DWT method for image compression technique which uses the advantages of both DCT and DWT techniques. We observed that DWT yield a better PSNR compared with that of DCT in image compression, when coefficients used for image reconstruction is more. But when small No. of coefficients are there then DCT is better as DWT. Finally we observed that Improved-DWT presents better PSNR than DCT and DWT. Which is obtained by combining improved-DWT and DCT, presents better PSNR comparing to DCT technique for all transform coefficients used in image reconstruction but comparing to DWT-improved, this technique presents better PSNR only when transform coefficients are below 20%. For lossless digital image compression technique comparing the performance of compression technique is Difficult unless identical data sets and performance measures are used Comparing the performance of compression technique is difficult unless identical data sets and performance measures are used. Some techniques perform well for certain classes of data and poorly for others. Nowadays, since practical adaptive entropy coders are nearly optimal, future research in lossless signal coding is expected to concentrate on the decor relation stage. Significant improvements are likely to require much more complex and computationally demanding source models.

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