Analysis of Different Image Compression Techniques Using Transformation Method

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Abstract - *Digital image compression is a subfield of Image Processing that deals with various methods to reduce the total number of bits required for image representation. This objective is achieved by elimination of various types of redundancies that exist in an image. In this paper survey of different image compression techniques is done. It gives an overview of the various compression algorithms based on transform method. Firstly basic working of Discrete Cosine Transform based compression scheme is explained along with its advantages and limitations. After that analysis of Discrete Wavelet Transform image compression scheme is done. Finally performance of hybrid DCT-DWT compression method is compared with both methods.*

Key Words: Peak Signal to Noise Ratio, Mean Square Error, Discrete Cosine Transform , Discrete Wavelet Transform, Zerotree

1.INTRODUCTION

With the fast growth in digital technology field the requirement for new signal processing techniques goes on increasing. Digital Image processing forms the major part of signal processing. Digital Image Processing refers to changing any property of digital image. New techniques are being developed in field of image compression mainly to provide improved representation of pictorial information and an efficient storage and transmission of image data. Digital images are an important source of information in the modern communication systems. In their raw form, these images require an enormous memory for storage. To overcome this problem considerable amount of research has been devoted in the field of image compression. Research in image compression field started more than two decades ago. The major research work began in this field after Shannon entropy was introduced by C.E. Shannon. Advanced Image compression techniques are required in every field with the recent developments in digital technology. Image compression is imperative for web designers who desire to produce faster loading web pages. In a medical field, image compression is at an important key position as hospitals are moving towards filmless imaging and becoming totally digital.[1] Also large storage is required for storing these digital images which further emphasis on advancement in compression techniques. Other fields beneficial from the improved image compression techniques are multimedia, internet, satellite imaging, remote sensing etc.

Image compression is achieved by eliminating or reducing the redundancies present in an image. Redundancies are basically non-essential data which does not convey any information. There are mainly three types of redundancies present in an image which are as following:

1. Inter-pixel Redundancy: There is often correlation between adjacent pixels, i.e. the values of the neighbours of an observed pixel can often be predicted from the value of the observed pixel.

2. Coding redundancy: The quantized data is represented using codewords. If the size of the codeword is larger than necessary to represent all quantization levels, then it is coding redundancy.

3. Psycho-visual Redundancy: This redundancy occur as eyes have different sensitvity for different visual information. Some type of visual information is relatively less important.

1.1 Types of Compression

Image compression is divided into following two types:

- Lossless compression: With this type of compression every single bit of data that was originally present in an image remains after an image is uncompressed. All of the information is completely restored.Lossless Compression is useful for applications with precise requirements where even a little loss of information can cause significant error, such as in medical imaging.

- Lossy compression: This technique reduces an image size by permanently eliminating certain information. When an image is uncompressed some part of information is lost.[2] Lossy Compression is mainly suitable for applications where less significant losses are acceptable.

1.2 Performance Parameters

- Compression ratio: Compression ratio is defined as the ratio of an original image size to compressed image size.
- Compression Ratio = Original Image Size / Compressed Image Size
- The entropy measure conveys the information contained in the image and any compression scheme should retain the entropy measure while reducing the redundant information from the image.
  - Source Entropy - The entropy of original image.
  - Destination Entropy - The entropy of reconstructed image.
- Peak Signal to Noise Ratio (PSNR) = It is used to evaluate image quality.

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

$$= 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (1.1)$$

where Mean square error (MSE) is

$$MSE = \frac{1}{mn}\sum_0^{m-1}\sum_0^{n-1}\left(f(i,j) - g(i,j)\right)^2 \quad (1.2)$$

2. DIFFERENT IMAGE COMPRESSION TECHNIQUES

Image compression techniques consist of mainly three steps:

- Transformer/Mapper: It converts the input data from spatial domain to frequency domain to reduce the redundancies present in an image. Generally, it is a reversible process .
- Quantizer: It reduces the mapper's output accuracy according to some pre-established criteria. Elimination of psycho-visual redundancies is provided by this step. This operation is irreversible and must be skipped for achieving lossless compression.
- Symbol encoder: It generates varying or fixed length code words to represent the quantizer output. This operation is reversible.

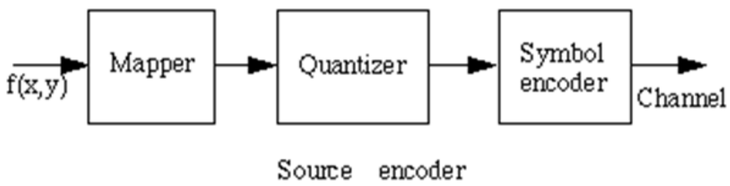

Figure 1. Source Encoder for Image Compression

2.1 Discrete Cosine Transform compression

Discrete Cosine Transform (DCT) is used to convert an image from spatial domain to frequency domain. The Discrete Cosine Transform is recognized as a more effective way to encode image information as compared to Discrete Fourier Transform. The DCT can gather all of the signal energy in low frequency, whereas it can not be achieved using DFT. According to Parseval's theorem, the amount of energy remains same in the spatial and frequency domain. Human eyes being less sensitive to the low frequency components, we can retain the low frequency components and reduce the contribution of the high frequency components after taking DCT. The DCT converts the spatial information into numeric values(coefficients) which provides data in quantative form and makes data manipulation easy for compression . DCT de-correlates the data being transformed so that most of its energy is packed in a few transform coefficients. The two dimensional Discrete Cosine Transform is represented as

$$DCT(i,j) = \frac{1}{\sqrt{2N}} c(i)c(j) \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} \text{pixel}(x,y) \cos\left[\frac{(2x+1)i\pi}{2N}\right] \cos\left[\frac{(2y+1)j\pi}{2N}\right] \quad (2.1)$$

$$C(x) = \frac{1}{\sqrt{2}} \quad \text{if } x = 0,$$

$$= 1 \quad \text{if } x > 0$$

The DCT is carried out on square matrix of pixel values of N x N size, and returns an N x N size square matrix of frequency coefficients (usually N is taken to be 8) as output. After transformation, the coefficient in the upper left corner is the “DC coefficient” and the rest of the coefficients are “AC coefficients”.

Quantization: Discrete cosine transform is a lossless procedure of conversion from spatial domain to frequency domain. The actual image compression occurs in quantization step where some of the data is removed. During Quantization every coefficients in the 8×8 DCT matrix is divided by a corresponding quantization value. The aim of quantization step is to make as many high frequency coefficients as possible to zero, the more zeros generated means better image compression can be achieved.[3] To make most high frequency components equal to zero, the quantization matrix generally has lower values in the top left corner increasing in the bottom right direction.

Image compression using DCT is obtained by reducing the bits per pixel (bpp). Lower the bits per pixel more will be the compression ratio. However the quality of image is affected by reducing the bits per pixel. The Mean Square Error is increased and subsequently Peak Signal to Noise Ratio is lowered when bpp is reduced below 0.25.[4] So a compromise between compression ratio and image quality is to be achieved. Another problem that occurs with DCT image compression is of blocking effect. Whenever higher compression ratio is required the block boundaries between adjacent blocks become visible at lower bits per pixel values. A technique to reduce this blocking effect has been invented in which the coefficients present on the block boundaries are modified while maintain the minimum error. The values of adjacent boundary coefficients of both blocks are altered so that the blocking effect is minimized.[5] Further post filtering methods are applied to reduce remaining blocking effect. With these limitations research was carried out to find another image compression technique. The new research led to the exploration of use of wavelets for image compression applications.

2.2 Discrete Wavelet Transform Compression

However the performance of DCT based image compression algorithm is satisfactory, still much more could be achieved. Therefore, the new Discrete Wavelet Transform (DWT) based image compression algorithms became popular. DWT image compression is an application of sub-band coding. In sub-band coding, the input frequency components are break down into set of band-limited components. First step is to distinguish between low and high frequency components using filters. After this filtering step, the amount of data of the low pass and high pass components will be doubled due to use of two filters; therefore, the low pass and high pass components must be down-sampled to obtain the original data quantity.[6]Sub-band coding uses the advantage of different sensitivities of human eyes to different frequency components. Once the less sensitive components are reduced, the objective of image compression is achieved. Image compression with DWT can be achieved in two ways. In one method , after decomposition of image into low and high frequency components using DWT all the high frequency components are ignored and image is then reconstructed. With this method high compression ratio is achieved but image is slightly blurred. Another method is to set a threshold level for high frequency components and ignoring components below threshold.[7] The image reconstructed using this method has good compression ratio and blurring of image is also reduced . The compression ratio achieved by DWT also depends on the wavelet used. The performance of DWT technique is better than DCT as it provides more compression ratio and higher Peak Signal to Noise Ratio. Also the problem of blocking effect is not present in DWT compression.

Another image compression technique base on wavelet transform ,known as Embedded Zerotree Wavelet technique, is developed in which encoding of the wavelet coefficients is done according to the coefficient values. In this method most important coefficients are encoded first and then less important coefficients are encoded. Thus bits are generated in an embedded bit stream.Using an embedded coding algorithm, an encoder can stop the encoding at any point, so allowing a target rate to be met exactly.[8] Also, given a bit stream, the decoder can cease decoding at any point in the bit stream and still produce exactly the same image that would have been encoded at the bit rate corresponding to the truncated stream.

2.3 Hybrid DWT-DCT Transform

A hybrid image compression technique uses advantages of both the transformations i.e. DCT and DWT. In this method image is transformed to frequency domain using Discrete wavelet transform with low and high frequency components. After this ,Discrete cosine transform is applied to low frequency components and different thresholds are used for low and highfrequency components. Hybrid technique performs better than DCT image compression technique in all cases. When number of coefficients are high (more than 20%), the DWT method is better than hybrid method. For lower number of coefficients (less than 20%) performance of hybrid method is better than DWT.**[9]** When image is compressed using DCT and hybrid compression technique to have same size at the ratio of 1:100 a better contrast of image is obtained with hybrid technique. Also the PSNR value for hybrid technique is higher than DCT method by 2-4 db at compression ratio of 70 and this difference in PSNR value keeps on increasing as the compression ratio is increased.**[10]** With the hybrid image compression technique the advantageous features of both DCT and DWT methods are utilised and the problem of blocking effect is removed. Image quality obtained with hybrid technique is also better. But the compression time is increased with this technique as both transformations are applied to image.

3. CONCLUSIONS

Image compression is the process to represent pictorial information using fewer bits to reduce the overall size of image. Image compression techniques using transform method has been studied. Performance parameters used to analyse these techniques are compression ratio, PSNR and MSE. Discrete cosine transform provides good energy compaction as compared to Fourier transform but problem of visible block boundaries exist in this technique. Discrete Wavelet Transform removes this problem with added advantage of improved compression ratio and PSNR. Hybrid technique using DCT and DWT provide better compression than DCT. At higher compression ratio it also outperforms DWT but compression time is increased with hybrid technique.

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