Evaluating Information Loss in Digital Image Compression Techniques

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Abstract*—Uncompressed multimedia (graphics, audio and video) data requires significant storage capacity and transmission bandwidth. Despite rapid progress in mass-storage density, processor speeds, and performance of digital communication systems, demand for data storage capacity and data-transmission bandwidth outperform the capabilities of available multimedia technologies. The recent developments of multimedia based applications have contributed not only for efficient ways of encoding signals but also in compression of signals. Therefore, the theory of data compression becomes more and more significant for reducing the data redundancy to save more hardware space and transmission bandwidth. In computer science and more specifically in information theory, data compression is the process of encoding information using fewer bits or other information bearing units than an unencoded representation. Data compression is useful because, it supports to reduce the consumption of expensive resources such as hard disk space or transmission bandwidth. Image compression is an application of data compression on digital images, as it reduces the computational time and consequently the cost of image storage and transmission. The fundamental concept about image compression is to remove redundant and unimportant data, and at the same time to keep the compressed image with acceptable quality. In this paper, a comparison of information losses caused by three different image compression techniques were performed. The information loss was measured using the entropy of the image after the compression. The first compression technique is the Joint Photographic Experts Group' or (JPEG) which is based on the block based Discrete Cosine Transform (DCT) method. The second technique, which is based on the wavelet transform, where the testing was carried out using three types of wavelet functions namely: Haar, Morlet and Meyer. The third and the last method which is called seam carving which is an image resizing algorithm by establishing a number of seams in an image and by removing the seams, the image can be downscaled. The experimental results verify the ability of the different compression techniques based on the post compressed image entropy value. MatLab™ was used for the comparisons.*

Keywords— JPEG, Seam Carving, Wavelet Transform and Entropy

I. INTRODUCTION

Digital images have become an important source of information in the modern world of communication systems. In the raw form, these images require an enormous amount of memory. In fact, according to a recent estimate, 90% of the total volume of traffic in the internet is composed of images or image related data. With the advent of multimedia computing, the demand for processing, storing and transmitting images has increased exponentially. A large amount of research has been devoted in the last two decades for an optimum image compression technique. There are mainly two different image compression categories exists: lossless and lossy. Lossless compression preserves the information in the image, thus an image could be compressed and decompressed without losing any information(Li. and Drew, 2005).Applications which use this kind of technique include medical images, images related to military and satellite photography. In lossy compression, information is lost but is tolerated as it gives a high compression ratio. If n_1 and n_2 denote the number of bits in original and encoded images respectively, then the compression ratio can be expressed by,

$$C_R = \frac{n_1}{n_2} \qquad (1)$$

Lossy compression is useful in areas such as video conferencing, fax or multimedia applications.

Digital image compression techniques are examined with various metrics. Among those the most important one is Peak Signal to Noise Ratio (PSNR) which will express the quality. There exists another property which expresses the quality, that is, Mean Square Error (MSE). PSNR is inversely proportional to MSE.

$$PSNR = 20log_{10}\left(255/\sqrt{MSE}\right) \qquad (2)$$

In this research the amount of information present with respect compression qualities was analysed.

II. METHODOLOGY

In this research three image compression techniques were tested such as JPEG (Joint Photographic Experts Group), Wavelet based image compression with three wavelet families (Haar, Meyer and Coiflet 2) and Seam Carving methods were tested.

2.0 Joint Photographic Experts Group

An important discovery of mid 1970's, DCT gives an approximate representation of DFT considering only the real part of the series. For a data of N values, DCT's time complexity is of order $Nlog_2N$ similar to DFT. But DCT has a better convergence with compared to DFT.

The block diagram of DCT based coding is shown in Figure 1. First a given image is divided into 8×8 blocks and forward discrete cosine transform (FDCT) is carried out over each block. This transformation concentrates most of the signal in the lower spatial frequencies whose coefficients are near zero. These coefficients are then quantized and encoded to get a compressed image(ITU, Std.; 1992; Gonzales et.al.; 2009).

2.1 Wavelet based image compression

The rapid advancement in wavelet technology has led to very advanced standards for image compression which is based on Discrete Wavelet Transform (DWT). It has brought a new surge of interest in wavelets and also towards advancement and faster computational algorithms for storing and transmission of images. In the second stage of image compression, the transformed wavelet coefficients will be quantified. Then the encoding of the quantized coefficients is done and after that the data is stored. To reconstruct the image, decoding is done and by inverting the quantized coefficients inverse wavelet transform was applied (Mallat; 1989).

Wavelet involves pair of transform: one to represent the high frequencies or detailed parts of an image and one for the low frequencies or smooth parts of an image.In this paper, three families of wavelets being used for the compression of images such as Haar, Meyer and Coiflet 2 wavelets (Goswami J.C. and Chan A.K.; 1999).

2.2 Haar

$$\phi(t) = \begin{cases} 1 & if \;\; 0 \le t \le 1 \\ 0 & otherwise \end{cases} \qquad (3)$$

The function $\emptyset(t)$ is called the Haar scaling function and $\psi(t)$ is called the Haar wavelet and is defined as

$$\psi(t) = \begin{cases} 1 & if \;\; 0 \le t \le 0.5 \\ -1 & 0.5 \le t \le 1.0 \end{cases} \qquad (4)$$

2.3 Meyer

The Fourier transform of $\Phi(\omega)$ of the scaling function $\phi(t)$ is defined as,

$$\Phi(\omega) = \begin{cases} 1 \\ \cos\left[\frac{\pi}{2} v(\frac{3}{4\pi}|\omega| - 1)\right] \\ 0 \end{cases}$$

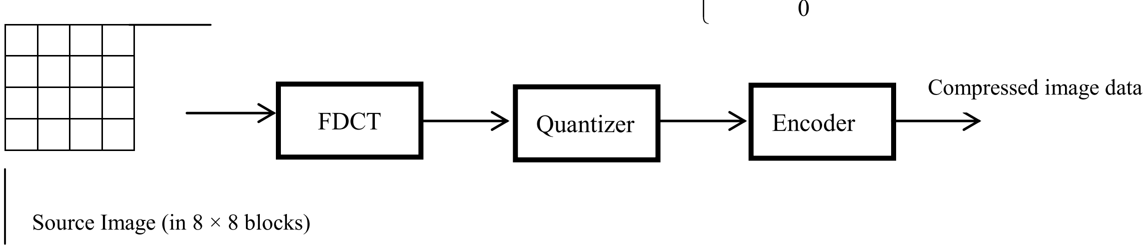


Figure 1: DCT based image compression

2.4 Coiflet 2

Coiflet wavelets are obtained by imposing vanishing moment conditions on both scaling and wavelet functions.

III. SEAM CARVING

Seam carving is a technique targeting image compression and resizing based on detection of seams from the energy function of the image. The method aims at finding seams of minimum energy and manipulating the image using them.

Effective resizing of images not only use geometric constraints, but consider the image content as well. Conventional image resizing consists of cropping or evenly down sampling that lead to loss of important features or distortion. This method enables us to remove pixel from uninteresting parts of the image while preserving important content without losing the quality.

The following steps show how the seam carving algorithm performs:

Generating an Energy Map which can be based on gradient maps, entropy or HoG (Histogram of Gaussian) method.

Then Dynamic Programming is used to find the cumulative energy of a path taken from the top and left till the pixel(i,j). The cumulative energy function is defined as:

$$M(i,j) = e(i,j) + \min\left(M(i-1,j-1), M(i-1,j+1)\right) \quad (7)$$

To detect the optimal seam the cumulative energy map was considered such that the Pixel with the lowest value of $M(i,j)$ in the last row or last column was picked and backtraced to obtain the optimal seam. Backtracing in x direction can be represented mathematically as follows:

$$S^x = \{S_i^x\}_{i=1}^n = \{x(i), i\}_{i=1}^n, where\ \forall i, |x(i) - x(i-1)| \leq 1 \quad (8)$$

Similarly, this can be extended to y direction.

Then the optimal seam was used to perform the resizing of an image. This was done by removing the optimal seams. To increase the image size we can insert the copy of optimal seams in the image at the appropriate positions (Avidan and Shamir; 2007).

IV. RESULTS AND DISCUSSION

The proposed method was used the amount of information loss with respect to level of compression of images. In this paper experiments were performed on still images using JPEG, DWT and Seam Carving methods at different quality levels such as 95%, 90%, 75% and 50%. For these experiments the following image was used.

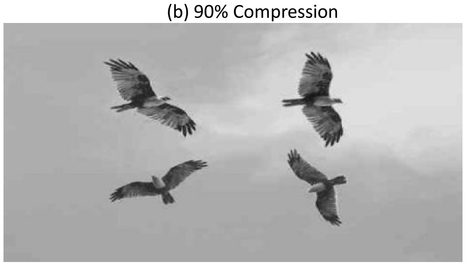
Figure 2: Test Image

In Figure 3, shows the compression of the image at various compression levels using JPEG. Figure 4 shows the different compression levels using the Haar wavelet, where Figure 5 and Figure 6 shows the compression using Meyer and Coiflet 2 wavelets respectively.

The compression quality levels are evaluated by PSNR (peak signal to noise ratio) and entropy measure was used to measure the amount of information present at different compression levels.


(a) 95% Compression


(b) 90% Compression


(c) 75% Compression


(d) 50% Compression


(a) 95% Compression


(b) 90% Compression


(c) 75% Compression


(d) 50% Compression

Figure 4: Two level Haar based Wavelet compression

Table 01: JPEG Compression

Compression Quality (%)	PSNR (dB)	Entropy
50	45.6	5.9847
75	41.7	5.5980
90	40.8	4.6453
95	40.1	3.7314

In this study according to Table 01-Table 04, it was found that for JPEG compression, with quality between (50%-95%) the PSNR was between 40dB to 46dB, whereas for Wavelet it was between 38dB to 45dB.


(a) 95% Compression


(b) 90% Compression

(c) 75% Compression

(d) 50% Compression

Figure 5: Two level image compressionbased on Meyer Wavelet

Table 02: Haar Wavelet Compression

Compression Quality (%)	PSNR (dB)	Entropy
50	44.4	6.2383
75	41.9	6.2263
90	41.2	6.2223
95	39.8	6.2165

JPEG images suffer from block-shaped pieces at higher compression ratio. The pieces result from the compression algorithm, which is to divide the image into smaller pixel blocks which are processed independently.

Wavelets are highly efficient for image compression because they organize the image data in a way that closely resembles the human visual system. Wavelet is better than JPEG compression in terms of compression ratio as it can achieve high compression by using Wavelets.

(a) 95% Compression

(b) 90% Compression

(c) 75% Compression

(d) 50% Compression

Figure 6: Two level image compression based on Coiflet 2 Wavelet

Table 03: Meyer Wavelet Compression

Compression Quality (%)	PSNR (dB)	Entropy
50	43.3	6.3516
75	41.6	6.3183
90	40.5	6.2527
95	39.9	6.2500

Table 04: Coiflet2 Wavelet Compression

Compression Quality (%)	PSNR (dB)	Entropy
50	42.4	6.2515
75	40.6	6.2528
90	39.2	6.2520
95	38.9	6.2529

We experimented 50%, 70% 90% seam carving resizing and obtained the following results. at 50% it showed better PSNRs and Entropy values than wavelet transformations objects were distorted as the compression or the size the ratio increased.

(a) 50% compression

(a)70% compression

(a) 90% compression

Table 05: Seam Carving Compression

Compression Quality (%)	PSNR (dB)	Entropy
50	44.5	6.4001
70	42.6	6.3502
90	40.2	6.2820

Based on our experiments, JPEG compression standard has obtained the worst level of entropy at all the compression levels. From the compression of wavelet families Meyer wavelet provides the best entropy levels.

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