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Analysis of Image Compression Techniques

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Abstract— Image compression addresses the problem of reducing the amount of data required to represent a digital image without degrading the quality of the image to an unacceptable level [14]. In image processing applications, the quality of compressed image and compression ratio plays an important role. This paper focuses on the subjective and objective quality measures for the lossy as well as lossless image compression techniques. It takes into consideration some of the image related parameters to analyze the performance of various compression techniques. The motive of the paper is to provide a comprehensive comparison of various existing image compression techniques so that one can understand which technique will be best suited for a given situation. Choosing one of the techniques for image compression among the various existing techniques is a challenging task which requires extensive study of all these techniques. Hence, in order to provide a quick solution to this problem the analysis was carried out.

Keywords*-DCT, DWT, Huffman, JPEG, JPEG2000*

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1. INTRODUCTION

Today we are living in a technologically driven world, where multimedia technology is used in almost every field. Since the advent of computers and digital cameras use of digital images in our day to day lives have increased phenomenally. Due to these reasons; it has been observed that the need for storage, manipulation, and transfer of digital images, has risen. Digital images can be bulky and sometimes may require huge amount of memory space for storage. Moreover transferring such huge images via internet may pose to be a hindrance since it will consume considerable amount of bandwidth. Downloading these types of huge images will entail a lot of time as well. Therefore, we can see that the size of an image directly affects storage space, bandwidth, and transmission time and transmission rate. By compressing an image its size is reduced, consequently it will require less storage space thus allowing more number of images to be stored in a given amount of storage space. Ultimately transmission of such images after compression will consume less bandwidth. Also; less time will be required to download these images. Due to these intrinsic worth image compression is considered as a necessity for multimedia technology. Higher performance of the image compression techniques is a major concern nowadays. There exist various image compression techniques like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), and Huffman Technique etc. and people are already aware of their existence. However, people struggle when a choice is to be made from among the available alternatives. They fail to identify the best compression techniques for a given situation. Every compression techniques have their merits and de-merit which cannot be overlooked. So in order to provide a clear picture of these techniques an analysis and comparison of the existing techniques is necessary. Sometimes situation may arise where the best compression technique need to be chosen which can cater to various needs. In such cases comparison and analysis of these techniques prove to be beneficial and helpful. It gives a clear vision of whether the technique is suitable for a given situation or not. Though the need for image compression is at its peak, yet it suffers due to the demand for higher performance at every stage. As pointed out earlier, image compression is a technique whereby size of an existing image is reduced without losing vital information to an unacceptable level. Compression techniques can either be lossy or lossless or both. If substantial amount of information is lost compared to an original image then it is known as lossy technique. If negligible amount of information is lost then it is known as lossless technique. An image can be compressed by the removal of data redundancies. There are three broad categories of redundancies viz. (A) Coding redundancies- when less than optimal code words are used. (B) Interpixel redundancies- when the neighbouring pixels are correlated. (C) Psychovisual redundancies- when some data is overlooked by the human visual system.

In this paper, quality factors of the compressed images are analysed, obtained as a result of various image compression techniques like: Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Huffman Technique, Joint Photographic Expert Group(JPEG) and Joint Photographic Expert Group 2000(JPEG 2000).

2. BACKGROUNG STUDY

2.1 DCT: This technique has three key properties firstly, finite sequence of data points are articulated by this technique. Secondly, these finite sequences of data points are oscillated in terms of cosine functions. Lastly, these data points are all oscillating at different frequencies. In this case cosine function has been used instead of sine function for image compression. Approximating a typical signal requires fewer cosine functions whereas on the other hand when boundary conditions need to be expressed; this technique uses cosines for differential equations.

2.2 DWT: This technique basically has two main parts numerical analysis and functional analysis. In both types of analysis the wavelets are sampled as a separate autonomous unit. Wavelet transformation is the key concept which is used for signal processing and image compression. When signals are broken down into set of basic functions they are termed as wavelets.

2.3 Huffman Technique: "Entropy encoding algorithm" and Huffman technique is like two sides of a coin. This technique is one of the popular compression techniques which compress images to an acceptable amount of degradation after compression. Due to this unique property it is categorized as a lossless compression technique. It efficiently removes the redundancies from images. In this technique a table known as variable length code table is maintained. This table is derived by estimating probability of occurrence for each value of source symbol that is to be encoded. Frequency of occurrence of a data item is what this technique works upon.

2.4 JPEG: This technique is popular for its efficient compressing ability of either full-colour or greyscale digital images. This technique is considered as both lossless and lossy technique. This is due to the fact that the baseline mode of JPEG is a lossy image compression technique i.e. there is a continuous loss of information. It also incorporates lossless mode, but lossless mode is not very popular.

2.5 JPEG 2000: If the main aim of compressing an image is to attain a better rate-distortion trade-off and improved subjective image quality, then JPEG 2000 technique is the ultimatum. This technique has an exceptional property of storing different parts of the same picture using different quality since it possesses varying degrees of granularity. The improvised version of JPEG is known as JPEG 2000.In addition to the features of JPEG it has two more features scalability and editability.

3. QUALITY MEASURES

There are two sides of quality metrics which are categorized as subjective measures and objective measures. The quality metrics which are human viewer oriented fall under subjective measures. Human visual interpretation plays an important role for measuring image qualities in this case. Those quality metrics which are totally computational oriented, fall under the category of objective measures. A particular method cannot be justified to attain a better quality image. Hence it becomes needful to set up quantitative measures to analyze the result of image enhancement algorithms on image quality. Using the same set of tests images, various image enhancement algorithms can be compared in order to identify whether a particular algorithm produces better results. In order to analyze and compare the various existing compression techniques the following parameters were used:-

Compression Ratio (CR): The compression ratio is used to measure the ability of data compression by comparing the size of the image being compressed to the size of the original image.

The greater the compression ratio means lesser the compressed image size.

$$CR = \frac{f'(i,j)}{f(i,j)}$$

[14]

Mean Opinion Score (MOS): A large number of people can rate their quality of compressed image by their surveillance after being exposed to the group and the type of scrutiny they performed. This rating can be on a scale of (1) bad; (2) poor; (3) fair; (4) good; (5) excellent. The average of the scores is called a mean opinion score (MOS).

$$MOS = \sum_{i=1}^{5} i.p(i)$$

[18]

Computational Complexity (CC): In computer science computational complexity can be considered as the combined study of analysis of algorithms and computability theory. It tries to classify problems that can or cannot be solved with approximately restricted resources.

Peak Signal to Noise Ratio (PSNR): It is the ratio between the maximum power of a signal to the power of distorting noise that hampers the quality of the image. The PSNR is usually expressed in terms of the logarithmic decibel scale i.e. as the ratio between the largest and smallest possible values of a changeable quantity.

Smaller the value of PSNR means the image is of poor quality.

$$PSNR = 20\log_{10}\left(\frac{N}{RMSE}\right) dB$$

[18]

Mean Square Error (MSE): MSE of an estimator measures the average of the difference between the estimator and what is estimated. The difference is noticed because the property of all possible outcomes being equally likely or because the estimator does not consider information that could produce a more accurate result.

Larger the value of MSE means the image is of poor quality.

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j) - f'(i,j))^2$$

[18]

Structural Content (SC): It calculates the closeness of appearance or the relation sharing properties of the structure of two signals. This measure conclusively analyses the overall weight of an original signal to that of compressed one. Since localized distortions are absent on that account it is a global metric. *Larger the value of SC means the image is of poor quality.*

$$SC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j)]^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}f'(i,j)^2}$$

[18]

Normalized Absolute Error (NAE): It is the calculation of the difference of decompressed image from the original image with the value of zero fitting perfectly. *Larger the value of NAE means the image is of poor quality.*

$$NAE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|[f(i,j) - f'(i,j)]|}{\sum_{i=1}^{M}\sum_{j=1}^{N}|f(i,j)|}$$

[18]

Average Difference (AD): It is the average of the difference between the original image pixels to the compressed image pixels. It is used to find out how clean an image is since lower the value of AD, the cleaner the image is, which means lesser presence of noise in the image.
Larger the value of AD means the image is of poor quality.

$$AD = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j) - f'(i,j)]$$ [18]

Maximum Difference (MD): It has a good connection with MOS for all tested compression techniques. It is a measure of compressed picture quality in different compression systems.

Larger the value of MD means the image is of poor quality.

$$MD = Max(|f(i,j) - f'(i,j)|)$$ [18]

In order to demonstrate which compression technique will be more efficient and prove to be the best among various other techniques in a given situation, the above mentioned parameters were chosen. Keeping in mind the end application area of the compressed image if we look closely at the above mentioned parameters after computation for various techniques it will give us a hint as to which technique can be qualified as the best technique.

The authors here were involved in finding and/ or computing the above mentioned parameters for five compression techniques. A comparative table for these parameters with respect to DCT, DWT, Huffman technique, JPEG and JPEG200 was obtained as demonstrated in Table 4.1.

4. RESULTS AND DISCUSSIONS

The table below shows the analysis of various image compression techniques based on the above discussed parameters.

Parameters/ Compression Techniques	DCT Image Compression	DWT Image Compression	Huffman Image Compression	JPEG Image Compression	JPEG 2000 Image Compression
Lossy /Lossless	Lossy	Lossy	Lossless	Both	Both
Size of Image (Original-Compressed)	288KB - 22.6KB	288KB-72.4KB	288KB-20.9KB	288KB - 16.6KB	288KB-18.4KB
Compression Ratio	4.2374	4.5757	4.5795	5.6756	5.2822
Mean Opinion Square	Average	Average	Good	Good	Good
Image Formats	.gif , .png, .tiff , .bmp , .jpg	.gif , .png, .tiff , .bmp , .jpg	.png, .bmp , .jpg	.png, .bmp , .jpg	.png, .bmp , .jpg
Computational Complexity	O(nlogn)	O(n)	O(nlogn)	$O(n^2)$	$O(n^2)$
Peak Signal to Noise Ratio	1.3711	1.4599	2.2602	2.3386	2.8724
Mean Square Error	2.7668e+03	2.8414e+03	357.2000	430.1538	8.7232e+03
Structural Content	0.9959	1.327	1.2657	0.9469	0.9202
Normalized Absolute Error	0.4353	0.4311	0.1324	0.1311	0.9202
Average Difference	-22.5000	-19.5500	11.4000	-2	-87.4615
Maximum Difference	63	55	41	61	11

Table 4.1: Comparison table for image compression techniques on the basis of various parameters.

On the basis of results obtained from compression ratio JPEG has compressed more than its counterparts, whereas the computational complexity of DWT is better. The obtained PSNR values suggest JPEG 2000 to be an efficient one. Huffman is better in terms of MSE. SC of JPEG 2000 is optimal. NAE values obtained favours JPEG to be remarkably good. AD and MD is observed to be marginally better in case of JPEG 2000. Hence as already discussed MOS may vary from observer to observer.

5. CONCLUSIONS

The DCT technique is computationally expensive i.e. they can overlap the blocks. DWT technique is very good for texture classification. Huffman technique reads only greyscale images and it takes longer compression time. JPEG technique works for continuous tone images but not for animated images. JPEG 2000 technique does not work for internet images. Thus we can clearly see that every technique have their advantages and disadvantages. We cannot certify that a technique is the best compression technique because it totally depends upon the environment where these images will be used or applied after compression. For example if we require a technique which can perform compression without being computationally expensive then DCT will not be the right choice.

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