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Performance Analysis of Image Compression Standards with Reference to JPEG 2000

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Abstract: JPEG 2000 is the most widely used standard for still image coding. Some other well-known image coding techniques include JPEG, JPEG XR and WEBP. This paper provides performance evaluation of JPEG 2000 with reference to other image coding standards, such as JPEG, JPEG XR and WEBP. For the performance evaluation of JPEG 2000 with reference to JPEG, JPEG XR and WebP, we considered divers image coding scenarios such as continuous tome images, grey scale images, High Definition (HD) images, true color images and web images. Each of the considered algorithms are briefly explained followed by their performance evaluation using different quality metrics, such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Structure Similarity Index (SSIM), Bits Per Pixel (BPP), Compression Ratio (CR) and Encoding/ Decoding Complexity. The results obtained showed that choice of the each algorithm depends upon the imaging scenario and it was found that JPEG 2000 supports the widest set of features among the evaluated standards and better performance.

Keywords: Analysis, Standards JPEG 2000.

1. INTRODUCTION

There are different standards of image compression and decompression. Four of the very famous and widely used image compression standards include Joint Photographic Expert Group (JPEG), JPEG-XR (Extended Range), JPEG 2000 and WebP (Dufaux, *et al.* 2009). These standards have high compression performances and are widely used for images storage and transmission over wired and wireless networks. The comparison parameters used for performance evaluation are Structural Similarity Index (SSIM) (Yusra, *et al.* 2012), Bit per Pixel (BPP), Peak Signal to Noise Ratio (PSNR) (Ziguan, *et al.* 2014), Mean Square Error (MSE) (Ziguan, *et al.* 2014), Compression Ratio (Koli, *et al.* 2006) and Complexity (Shnayderman, *et al.* 2006)

In our experimental setup, we have used five set of images, each set with 10 images. These images are taken from various sources and are widely used in the streaming and storage scenarios. These images are encoded using different compression ratios and their encoding time is calculated. Furthermore, the performance of the encoding technique is evaluated using different quality evaluation metrics such as PSNR, SSIM, BPP, Compression Ratio and Complexity. This paper is organized as follows. Section 2 provides an overview of the considered encoding algorithms. In Section 3 we explain the test set that we used during our analysis. Section 4 explains our methodology that we employed for the performance evaluation of the considered coding schemes. Section 5 explains the system configuration setup for the performance analysis, followed by Section 6 with explanation of the considered performance analysis factors. Section 7 provides the results and discussions about the obtained performance. Finally the conclusion of the paper is provided in section 8.

2. OVERVIEW OF COMPRESSION ALGORITHMS

For our performance analysis study of the image encoding algorithms, we compared the performance of the most widely used compression algorithm –i.e. JPEG 2000 with the JPEG (basic algorithm mostly used in digital cameras), WEBP (commonly used on web) and JPEG XR (extended version of JPEG).

2.1 JPEG

This is well known standard developed in 1980's.The file name extensions for JPEG are .jpe, .jpeg and .jpg. JPEG is one of the image compression technique commonly used for lossy compression in digital images. It allows a trade-off between storage size and image quality (Tung Nguyen, *et al.* 2012)

2.2 JPEG-2000

JPEG 2000 is a continuation of JPEG standard. It was made standardized in year 2000. The reason behind its standardization was in order to super seed the JPEG Discrete Cosine Transform based version over Discrete Wavelet Transform. The filename extension is .JP2. JPEG 2000 has a unique feature of region of interest coding as well as it offers several mechanisms for spatial random access and region of interest access at varying degree of granularity (Dufaux, *et al.* 2009).

2.3 JPEG-XR

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JPEG XR is a still image coding technique. It is based on the technology develop by Microsoft under the name HD PHOTO. Microsoft initially named it as the window media photo and then they renamed it to HD photo. The file name extensions for JPEG XR are .jxr and .hdp. The joint expert group and Microsoft announced HD photo under their flag to make it a standard for JPEG and named it JPEG-XR.

2.4 WEBP

Image format WebP format supports both lossy and lossless compression with animation and alpha transparency of an image. WebP lossless images are 26% smaller as compared to PNGs, whereas their lossy images are 25-34% smaller in size as compared to JPEG images. WebP is an image format developed by Google Inc. WebP's algorithm is based on the intra-frame coding on VP8 video format and resource interchange file format.

3. TEST SET IMAGES

For the performance analysis of different compression algorithm, we considered five test set images. The description of the considered test set images is shown in **(Table 1)**. A brief description of the selected test set images is given below;

1- **Continuous Tone Images** are images in which colours and shades of grey smoothly merge into the neighbouring colours or shades, instead of producing distinct, sharply-outlined areas of colour or shade.

2- **Grey-Scale (or grey level) Images** is simply one in which the only colours are shades of grey.

3- **True Colour Images** is the specification of the colour of a pixel on a display screen using a 24-bit value.

4- **HD Images** refer to raster digital *images*, film *images*, and other types of images.

5- **Web images** are the 24 bit images used in web pages.

Table- 1: Test Images Set

Test Set Name	Symbol	#Images	Type
Continuous Tone Images (Shnayderman, *et al.* 2006)	A	10	24 bit Color
Normal Images and Grey Scale Images (MacKinnon, *et al.* 2005)	B	10	24 bit Color and 8 bit gray scale
HD Images (Licciardo, *et al)*	C	10	24 bit gray scale
True Color Images (Zhengmao, *et al.* 2008)	D	10	24 bit Color
Web Images (Zhengmao, *et al.* 2008)	E	10	24 bit Color

4. METHODOLOGY

For the performance evaluation of our selected coding standards, we followed a systematic procedure. The input image is compressed with compression ratio of 100 and the output format is adjusted according to the consider encoding standard, such as JPEG 2000, JPEG XR, WebP and JPEG. During the encoding process we employed C system programming to evaluate the compression time. Furthermore, the corresponding encoded stream for each standard, such as JPEG 2000, JPEG XR, WebP and JPEG is decoded using the standardized codec and its decompression time is noted. During this process the corresponding Bits Per Pixel (BPP) value of each coding standard is also noted. The corresponding performance curves, such as PSNR/ SSIM/MSE/BPP/ Complexity versus Test set images is drawn to evaluate the performance of each considered image coding standard. It is important to note that the different performance values of each curve, such as PSNR, SSIM, MSE, BPP and Complexity represents an average value obtained by dividing the total obtained value by the total number of test set images.

5. SYSTEM CONFIGURATION FOR ANALYSIS

For the precise measurement and analysis of the performance of the considered setup, one particular hardware systems has to be used. For reason **(Table 2)** shows our system configuration and the software specifications that we have used for the performance analysis of the different compression algorithms.

Table 2: System Configuration Parameters

OS	Windows 7
System Type	64-bit Based PC
RAM	6GB
Cache	L3,6MB
Processor	Inter Core-i5 @2.3 GHz,2301 MHz2,Core 4 logical Processors
Software	Matlab v.2011 Visual Studio v.2012

6. PERFORMANCE ANALYSIS FACTORS

The performance of image coding algorithm can be measured using different evaluation factors. These factors determine the feasibility of the choice of a particular coding algorithm for the selected application. An important factor that is applicable in most cases is *compression efficiency*. Compression efficiency shows the effectiveness of the coding algorithm to compress the original data in an effective way and is evaluated for both lossless and lossy compression. Furthermore, we measure the peak signal to noise ratio (PSNR) of the decoded image with respect to the original image. Beside these factors another important aspect of an image compression system is the complexity of the executed algorithm. A thorough complexity analysis of different algorithms is beyond scope of this article. However we have developed our own algorithm to find the complexity of each coding standard in terms of its execution time. The different performance evaluation

metrices that were utilize for the performance analysis of different codecs is listed below,

1. ***MSE*** measures the total squared error of the encoded image I_2 with respect to the original image I_1, as given below,

$$MSE = \frac{\sum_{MN}[I_1(m,n) - I_2(m,n)]^2}{M * N}$$

2. ***PSNR*** computers the peak signal to noise ratio between the encoded and original image is described. The higher PSNR values represent the better image quality. The computation of PSNR is given below,

$$PSNR = 10\log_1 10\left(\frac{255^2}{MSE}\right)$$

3. ***SSIM INDEX*** is a method to measure the extent of similarity between two images. This index is evaluated by considering the compressed image output with reference to the original image. The SSIM index measures the image degradation as a result of perceived change in structural information. The SSIM index on two images x and y with common size NxN is calculated on luma samples as follows,

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\delta_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\delta_x^2 + \delta_y^2 + C_2)}$$

with

μ_x *the average of* x; μ_y *the average of* y;
δ_x^2 *the variance of* x; δ_y^2 *the variance of* y;
δ_{xy} *the covariance of* x *and* y;
$c1 = (k_1 L)^2, c2 = (k_1 L)^2$
and L *the dynamic range of pixel values;*
$k_1 = 0.01$ *and* $k_2 = 0.03$ *by default.*

The output value of SSIM is in the range of -1 to 1, where 1 is only possible in case of identical data.

4. ***BPP*** –i.e. Bits Per Pixel is the number of bits of information stored per pixel of an image. It can be obtained by dividing the total number of bits in the final processed image file by the total number of pixels in the final decoded file.

5. ***Compression Ratio*** is the ratio of the total number of bits in the resultant processed image file to the total number of bits in the original image file.

6. ***Computational Complexity*** describes the resources required by the computing machine to solve the problem. In our case we have considered same machine with similar resources for all the image coding standards.

7. RESULTS AND DISCUSSIONS

Fig.1.1 show the conclusive results of the PSNR versus Test sets performance curves. These results were obtained while using the test set images given in (Table 3). From the results obtained in **(Fig. 1.1)** it is clearly shown that the PSNR value of JPEG 2000 is high as compared to the other considered algorithms. Furthermore, the PSNR value of WEBP is the lowest among the considered four coding algorithms and that of JPEG and JPEG-XR are almost similar and with reference to other coding algorithms they are better than WEBP but less the JPEG 2000.

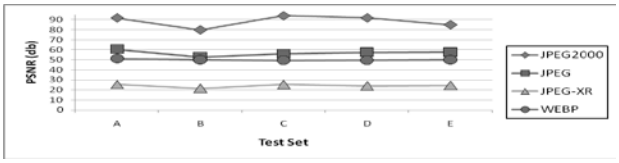


Fig 1.1 PSNR of the test set images

Fig. 1.2 shows the conclusive results of the SSIM INDEX versus Test set. From this figure it is clear that JPEG XR has the lowest SSIM values as compare to JPEG 2000, JPEG and WebP. Furthermore, all JPEG 2000, JPEG and WebP have similar SSIM INDEX values, as shown in **(Fig. 1.2).**

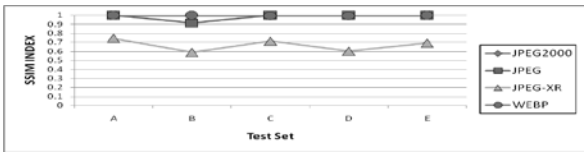


Fig 1.2 SSIM INDEX of the test set images

Fig. 1.3 shows the BPP versus Test Sets curves. It is clearly shown in **(Fig. 1.3)** that the values of JPEG 2000 are higher and that of WEBP is lowest. Furthermore, the BPP value off JPEG and JPEG XR is almost similar. Furthermore, the BPP values of JPEG and JPEG XR are lower than JPEG 2000 and are higher with reference to WEBP coding algorithm.

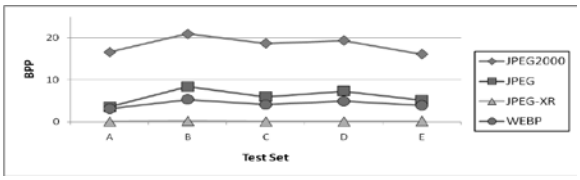


Fig 1.3 BPP of the test set images

Fig. 1.4 shows the MSE versus Test Sets performance curves. And it is clearly shown that value of the JPEG-XR is higher as compared to the other three algorithms such as JPEG 2000, JPEG and WEBP. Furthermore, the MSE versus Test Sets performance of JPEG 2000, JPEG and WEBP is almost same and they overlap as shown in **(Fig. 1.4) .**

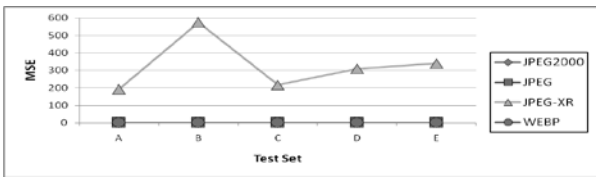


Fig 1.4 MSE of the considered image encoding algorithms

Furthermore, the compression ratio versus Test Sets performance results is shown in **(Fig. 1.5)**. it is clear

that the CR values of JPEG XR is higher as compared to the JPEG 2000, JPEG and WEBP algorithms and the Compression Ratio value of the JPEG, JPEG 2000 and WEBP is similar due to which the corresponding curves in **(Fig 1.5)** overlap on each other.

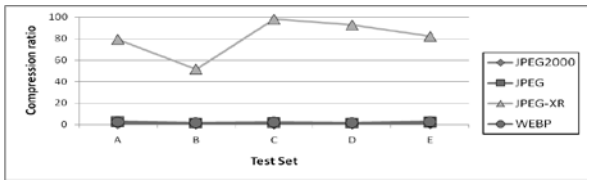


Fig 1.5 Compression Ratio of the test set images

Fig. 1.6(a) shows the conclusive result of the encoding time versus Test Sets and **(Fig. 1.6(b)**) shows the decompression time versus Test Sets performance curves. From both **(Figs. 1.6(a) and (b))**, it is clear that the complexity of the codec is dependent upon coded test set. This is because each codec employ different coding and decoding strategies and these strategies perform differently with respect to the considered image contents for encoding. Therefore, in some scenarios one of the algorithms may exploit in a better way the underlying correlated information, while the other algorithms may work better in some other scenarios preferable for their coding techniques. Therefore, no single codec can be exclusively declared as superior for all images.

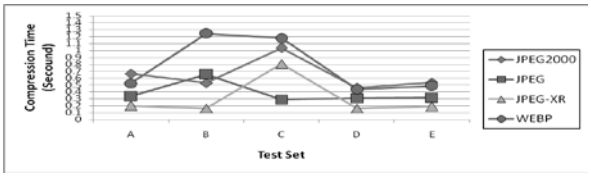


Fig 1.6(a) compression time of the test set images

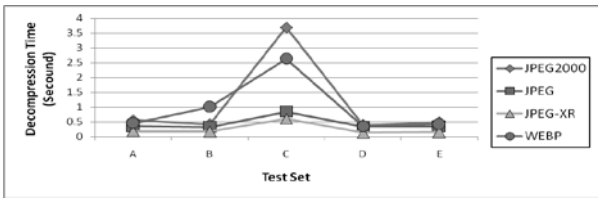


Fig 1.6(b) Decompression time of the test set images

8. CONCLUSION

The aim of this paper was to evaluate the performance of the JPEG 2000 standard with respect to the WEBP, JPEG and JPEG XR standards. The performance evaluation metrics considered for this purpose include PSNR, SNR, SSIM INDEX, BPP, CR and the encoding/decoding time. Simulation were perform on the five test set –i.e. Continuous tone images, HD images, Grayscale and normal images, true color images and web images. All the considered test set images were consist of 10 images with wide range of content scenarios and covering diverse resolutions. It was concluded that generally JPEG 2000 results in better image quality performance in terms of PSNR, MSE and SSIM quality metrics, while considering the same compression ratio.

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