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Significance of Image Compression and Its Upshots – A Survey

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ABSTRACT

In the recent years, digital imaging and multimedia are comprising a large growth. It comes to practice that huge amount of image has been utilizing and it probably demand the image compression methods. Image compression is mainly used for reduce the storage size and transmission cost of an image. Based on the quality requirement, it is classified as either lossy or lossless. In this paper, we explore the significance of image compression and the upshot of the survey conducted from the image compression literature. Additionally, we review the various evaluation metrics for image compression such as Compression Ratio, Bit per Pixel, Mean Square Error, Peak Signal to Noise Ratio and Structural Similarity Index.

Keywords : Image Compression, Digital Imaging, Multimedia, Lempel-Ziv-Welch, Vector Quantization, Block Truncation Coding

I. INTRODUCTION

Image compression is derived from the field of data compression, which encodes the actual image with fewer bits [1]. The fundamental objective of any image compression method is to reduce the storage size of an image when the limited storage space is only available. Image compression is naturally classified as lossless or near lossless and lossy methods (as shown in fig. 1). In lossless scenario, the decompress image is identical to the original image and so there is no loss of data [2]. Lossless methods itself again classified as statistical methods such as Huffman coding [3], Run length coding [4], Arithmetic coding [5] and Dictionary based techniques such as Lempel-Ziv-Welch (LZW) coding [6]. The hybridisation of those methods is also proposed in literature of image compression [7].

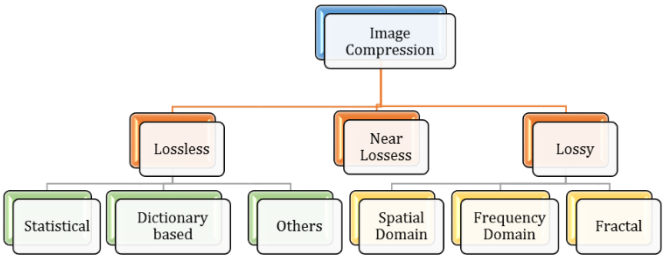

Fig.1: Classification of Image Compression Methods

While go through the lossy methods, it is irreversible method and may be a data loss can be occurred. It mainly classified as spatial and frequency domain methods. In spatial domain methods, only the spatial features of the image are taken into account and processed further. It includes vector quantization [8] and Block Truncation coding (BTC) [9]. Fractal coding [10] is also a lossy compression method which works on a fractal dimension. Frequency domain techniques transforms the image completely to the frequency domain instead using a spatial domain. Because computation is much easier with the frequency

component [11]. Transformation can be done by means of the various transforms such as Fourier transform [12], singular value decomposition based method [13], KL transform [14], Discrete Cosine Transform (DCT) [15] and Wavelet Transform [16]. The near lossless techniques also emerged for the purpose of attain more compression performance along with the high reconstruction quality of image [17]. Joint photographic Expert Group (JPEG) [18] is one of the compression standard that can be both lossy and lossless. The advancement of JPEG is implemented in JPEG2000 [19] and it comes with many variants such as ROI coding, high fidelity and JPEG2000 for high dimensional data. The further sections in this paper, explores the different types of image compression techniques exist in the past literature and the evaluation metrics for image compression Domain. Finally, we conclude our paper with the future work that should possess along the image compression domain.

II. LITERATURE REVIEW

Nadeem et al.,[2] implemented new lossy methods for compressing image. They performed a pre-processing namely smoothing followed by quantization in their proposed method. In this method image is partitioned as 4×4 non-overlapping sub blocks and iteratively implement the addition-based technique in each block separately. The distinct pixel table is produced and it can be used to decode the compressed file. This method performs well when compared to JPEG image quality is kept high. This proposed algorithm gave a very good result if the pixel value is closed to each other randomly they arranged.

A new compression technique which used principal component analysis is PCA and Huffman coding is presented in Ankita and Manoj, 2014 [3]. The dimension reduction is achieved by PCA and Huffman coding is used for reduce coding redundancy. It is naturally a lossy compression method because of PCA only tasks the principle component that are very significant. Their proposed method was compared with existing JPEG2000 and their method is observed with better quality in the terms of compression ratio and PSNR. It had also a drawback that it would perform well only when the PCA is applied block wise.

A modified Arithmetic Coding for still image compression was proposed in [5]. As a statistical coding, Arithmetic Coding is worked based on the updation of probabilities of pixels in the image. They modified as the probabilities of pixels are updated only after the detection of the final occurrence of each pixel. Moreover it depends on image block sorting and it outperforms the conventional Arithmetic Coding with evidence of high compression ratio of hundred tested images.

The modified Lempel-Ziv(LZ) coding is introduced in Vladimir et al.,[6]. They claimed that their method is used as a lossy compression method because of it reflected some minor distortion but with a higher compression ratio. The modification in traditional LZ algorithm is done using controlled deviation in the original image. Moreover it is an adaptive error controlled algorithm and the local variance is used to compute the maximum deviation should opted for current pixel. This method gave good result then the conventional LZ algorithm with high compression ratio and minimum distortion quality.

Cosman et al., [8]., gave a survey of vector quantization algorithm which discussed how the vector quantization is utilized in various image processing tasks. The fundamental ideas of vector quantization were explored in this paper and variety of image processing task such as enhancement, classification, half toning and edge detection are performed by using vector quantization. Moreover, this paper concluded as vector quantization is best choice of using mapping of pixel intensity into binary vector indexing. Seddeq et al., [9] proposed a

compression method for digital image using hybrid compression method based on block truncation coding (BTC) and Walsh Hadamard Transform (WHT). This hybridising gave better coding efficiency and better performance for the tested gray scale images.

Sharaboyko and Markov (2011) [10] implemented a fractal image compression with a base of quad tree image partition, block preparation, fisher block classification and multithread coding process. They derived three algorithms for colour images by the simple modifications of existing methods such as modified quad tree partitioning and the modified computation for finding block affine transform. They reported that their methods gave more compression ratio with good quality then the traditional fractal coding and it is comparable to JPEG.

An efficient still image compression method implemented by roumen and roumiana (2011) [14] based on the Karhunen-Loeve color transform (KLT) and the inverse pyramid decomposition. They presented approaches of flexible selection of the transform Co-efficient and corresponding quantization of their values. Restore the image of consecutive increasing quality. The use of the KLT when color image are processed, enhances the method efficiency to a high-degree for same quality of the restore image is obtained with much high compression ratio. A compression of DCT and DWT on the image compression field is done in Jaffar et al., [15]., they discussed about DCT and DWT in detail and performed an experimental on DCT and DWT which was incorporated in encoding method. Difference types of colour image were taken and the experimental results shown that DWT was better choice for the compression than the DCT. DWT gave better results in terms of high compression ratio and better PSNR values.

Rick et al., [18], proposed a customized JPEG encoder that inherited most of the aspects of JPEG and additionally, they have also done some novel customization. They proposed a new procedures for computation of the half toning error spectrum, computation of the desired error profile with the designing portion customization such as quantization table design and the optimization of Huffman tables. Their experimental results shown that it achieved bit rate of the range 0.13-0.25 for the tested grayscale image and effectively reduced the compression artifacts than the traditional JPEG.

Ping and Ricondo [19] reported that compression performance of the JPEG2000 behaves poorly when compressing an image with low colour depth such as graphics image. Their proposed techniques distinguish the true colour image from graphics image and to compress graphics image using a simplified JPEG2000 compression performance. Their improve compression performance significantly. Proposed method is easily adopted in mentioned JPEG2000 framework for video sequence compression.

Digital image Communication is being used in remote sensing, weather forecast, medical image satellite application. A research work presented by Balaka et al., [20] proposed parallel processing technique (PPT) in joint photographic expert Group (JPEG) compression using Discrete Cosine transformation (DCT) calculated by root mean square error (RMSE), peak signal to noise ratio (PSNR) and compression ratio (CR) values. In this work presents a novel framework for image compression by sequential and parallel processing techniques with different multi core processor.

Liu et al., [21] proposed a resolution progressing compression scheme for encrypted images. It worked based studying the local statistic of the decoded low resolution image and used this local statistic to get a next resolution level. Their proposed method reduces the computation complexity and produce good coding efficiency then the existing method namely context-based, adaptive, lossless image codec (CALIC) and

JPEG-LS. Moreover, context adaptive interpolation is implemented followed by the localized channel estimation to get the performance improvement then the conventional system. Finally, it reduces the 0.6BPP in average then the existing CALIC method with less computational cost.

Ayan et al., [22] implemented an image compression and decompression algorithms for almost dual-colour image using K-Means-clustering bit-map generation and run length coding. The experimental result show better on all the techniques and also worked as sharpens to remove colours. This method was tested with an input image having almost dual colour 24 bit, 32 bit or 8 bit image. It compress the image to very high degree and better compression than JPEG, block optimization and byte compression method (BOBC) and BOBC-RLE algorithms.

Dictionary learning based image compression has attracted a lot of research effort due to the internet sparsity of image contents. The entropy based orthogonal matching pursuit (EOMP) and quantization (KVSD) algorithm for dictionary learning based image compression [23] actives better performance than several state-of-the c0mpression techniques. This work achieves better image compression performance than the benchmark JPEG. JPEG 2000 and KSVD algorithm. Prasantha et al., [24]. implemented image compression is using Singular Value Decomposition (SVD) technique on the image matrix. SVD performed by arbitrary, squared, reversible and no reversible matrix of m*n size. This method used to reduce the storage space of the image. That perceptual quality of the textual image is better compared to the picture image even for the smaller rank.

A compression method which used fractal with variance and mean proposed in [25] claimed that their method overcome the conventional fractal coding by modified two algorithms. They utilized mean and variance value to classify image blocks and combined the transformation reduction method to the reduce the time. They show their experimental result that their method reduced the bit rate in 0.049 BPP to 0.0157 BPP range which is 480 times faster than the traditional fractal coding system. A segmentation based lossless image compression proposed in [26] employed a pre-compression segmentation and used the details of information through the segmentation process. To cover the spatial redundancies in the image data. They observed their novel contribution as the segmentation gave separate description of pixel in the edge portions and affront description on the interior portions. Also, they mentioned that the compression with conventional JPEG methods and CALIC has increased amount of compression ratio.

A gray image compression based on linear interpolation that using Hilbert scan described in [27] lies on a neighbourhood property, Hilbert curve is passed through all points in a quadrant and moved to neighbour quadrant. They concentrate on a lossy compression technique for the gray image using the Hilbert curve. Hilbert scan has a merit that clustering is much easier than another scanning method. Hilbert scanned one-dimensional data is divided into initial parts with the fixed length as initial segments. Finally, they confirmed that this method was easier to implement than JPEG and has almost the same compressibility as a JPEG.

Parikh et. al. [28] implemented a high bit depth medical image compression with high efficiency video coding (HEVC). Initially, they spotted the drawback of using JPEG200 in image series and 3D imagery. Then, they developed a HEVC based coding for high bit depth medical images which predominantly reduce the complexity and increase the compression ratio than the JPEG2000. Additionally, they reported their method increases the compression ratio by fifty four percentage than the existing JPEG2000 method.

A block-based Arithmetic Coding is proposed in [29]. Unlike the conventional method, they calculating the probability distribution as block by block rather than pixel by pixel calculation. Obviously, it is a lossless method and block based approach efficiently minimize the Kullback–Leibler distance (KL Distance). For the tested natural and synthetic images, it outperforms well than the conventional Arithmetic Encoder and other variants with sixteen percentage of bit rate reduction.

Singular Value Decomposition (SVD) based medical image compression is proposed by rufai et. al.[30]. It is a lossy method that tested with the medical images. Initially an image is decomposed using the SVD in which compression is perceived by ignoring the lowest singular values and Huffman coding is used as an entropy codes to encode the decomposed singular value and other details. It out performs the JPEG2000 compression standard with high PSNR value for the same amount of compression ratio.

III. EVALUATION METRICS FOR IMAGE COMPRESSION

3.1 Compression Ratio (CR):

Compression ratio is the ratio between original image size and the compressed image size. In other words, amount of bits needed for original image and the amount of bit needed represent the compressed image defines the compression ratio.

$$CR = \frac{Uncompressed\ Image\ Size}{Compressed\ Image\ Size} \quad (4)$$

3.2 Bit Per Pixel (BPP):

BPP indicates the amount of bit to represent a signal pixel in an image. It can be calculated as,

$$\text{BPP}= \frac{\text{Bits to represent compressed image}}{size\ of\ image} \quad (5)$$

For an instance, if an 8 bit image of size 256×256 is compressed, the total size of uncompressed/original image is 524288 bits (256×256×8), ie., it has 8 BPP.

3.3 Peak Signal to Noise Ratio (PSNR):

Peak Signal Noise Ratio (PSNR) is one of the accepted evaluation metric for image compression. It is a reference-based evaluation metric that compares the two images in terms of intensity variations in the image. Fundamentally, PSNR is a ratio between the high peak or maximum intensity value on an image and the intensity changes between the image. Logarithmic decibel scale is used to express the PSNR values. The intensity difference between the two images are computed using Mean Square Error (MSE) which uses Euclidean distance measure. The mathematical formula for compute the MSE is

$$MSE = 1/mn \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - J(i,j)]^2 \quad (1)$$

where,

m and n are dimension of image

I – original image

J – decompressed image (in compressed)

Moreover, the two images taken to compare must have same dimension. In other words, there should be a same number of rows and columns in both image. The mathematical formula for computing the PSNR is as follows

$$PSNR = 10log_{10}\,(max_i^2/MSE) \quad (2)$$

(or)

$$PSNR = 10log_{10}\,(max_i/\sqrt{MSE}) \quad (3)$$

where,

max_i– maximum intensity / high peak.

Indeed, PSNR value should be in range of 0 to ∞ high amount of PSNR in decimal indicates the more identical property between images. If MSE= 0, then there is no degradation between two images.

3.4 Structural Similarity Index (SSIM):

The structural similarity index is a perceptual metric that quantifies the image quality degradation caused by processing such as data compression or by losses in data transmission. SSIM actually measures the

perceptual difference between two similar images. It cannot judge which of the two is better, that must be inferred from knowing which is the "original" and which has been subjected to additional processing such as data compression. It is a fully reference based metric that requires two images from the same image namely a reference image and a processed image.

$$SSIM(\mathrm{x},\mathrm{y}) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[s(x,y)]^{\gamma} \quad (6)$$

where, $$l(x,y) = \frac{2\mu_x\mu_y + c_1}{\mu_x{}^2 + \mu_y{}^2 + c_1} \quad (7)$$

$$c(x,y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma_x{}^2 + \sigma_y{}^2 + c_2} \quad (8)$$

$$s(x,y) = \frac{2\sigma_{xy} + c_3}{\sigma_x\sigma_y + c_3} \quad (9)$$

where, μ_x and μ_y are the local means, σ_x and σ_y are the standard deviations and σ_{xy} is cross covariance for images x and$y$.

IV. CONCLUSIONS AND FUTURE ENHANCEMENT

In this paper, a survey was conducted for lossy and lossless image compression techniques. The significant of image compression and its literature study have been explored. The review was conducted on different types of evaluation metrics of image compression such as Compression Ratio, Bit per Pixel, Mean Square Error, Peak Signal to Noise Ratio and Structural Similarity Index. The research gap in image compression domain has identified as high compression performance with high fidelity of image is essential and it will be implemented in our future work.

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