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A Survey on Performance of Various Image Compression Techniques

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***ABSRACT*--Image compression enables quite exciting solutions in many fields, such as image analysis, bio-medical image processing, wireless systems and seems to be a key application in today's digital and smart world. Image compression seems to be a powerful tool in case of transmission and storage of large data images in various applications such as big data, medical etc. However due to exclusive and quality soft tissue contrast, Dynamic Magnetic Resonance Imaging (MRI) has been a field of attraction with increasing attention in recent decades. Moreover, MRI is considered as one of the most effective and strongest diagnosis system making the extensive usage of magnetic and radio waves in order to diagnose the human organs. This diagnosis is capable of generating 3D images with detailed anatomical features without any X-ray radiations. The prime purpose of this survey is to provide a comprehensive report of different image compression schemes in order to design an efficient compression scheme for dynamic MRI images. In this paper, author has surveyed different image compression schemes which are either sole implementations or hybrid of two or more algorithms. The author has also presented a comparative analysis for the surveyed compression schemes. This survey paper finally makes inroads for further researches in the domain of image compression schemes for dynamic MRI images.**

Keywords--Dynamic MRI, Image Compression, Compression Ratio, Redundancy, PSNR, SSIM.

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) includes both the features of non-invasive for superior flexible tissue contrast and non-exposing nature with respect to the high ionizing radiation. Nowadays, MRI are becoming one of the key area of study in order to carry out computer aided diagnosis and clinical routine since they are the sources of prime and inevitable information about structure of tissue, such as size, shape, and localization. This is also one of the reasons for selection of domain by researcher too. Furthermore, medical imaging enables us to obtain the images of the inner organs, bones, tissues etc. in order to perform research and analysis work in medical domain. These images can further be utilized in order to perform the study of functions of few organs. These images are also used in radiology in order to visualize internal structures of the body and their functionalities. MRI images also provide the 3D image of the internal organisms of human body which further assist the doctors to analyze and cure the diseases as compared to the traditional techniques such as x-ray imaging which provide the 2D images.

From past few decades, Dynamic Magnetic Resonance Imaging (MRI) has been employed in order to extract all the related functional information corresponding to the peripheral vascular organism [1-3]. Here, multiphase MRI scanned images are in use along with the extensive use of intravenous injection of a contrast agent in order to perform the clinical practices. However, a lot of researchers have worked in the domain of the utility of the dynamic contrast enhancement (DCE) MRI in order to perform the various diagnosis schemes for salivary gland tumors [4]. There are lots of techniques which are used in order to fulfill these requirements. However, there are two important schemes which are used more frequently in order to measure the perfusion and energy consumption. These are known as arterial spin labeling (ASL) MRI and Blood Oxygen Level-Dependent (BOLD) MRI. While these techniques are limited to the stated criterion, they are further incapable to discover and provide the information for volume functions or vessel permeability [5-6].

Since the medical imaging technology is getting developed so rapidly along with the insertion of a variety of imaging modalities, the field of bio-medical image processing has further been renovated exceptionally. However, the image acquisition is performed with the extensive use of variety of devices using various types of modalities. Among all the modalities MRI was found to be the most dominant and probable tool in order to visualize all the comprehensive internal organisms to enable the precise and extraordinary measurement of human organ anatomy. The MRI medical imaging further presents a superior contrast among the various soft tissues of human body. Hence, this is extensively utilized in order to diagnosis and hence treatment of the diseases. However while these images are broadcasted, they are going to take up a great storage space, with inferior speed and larger bandwidth. Also, these images cannot be compressed with the use of common compression techniques [7].

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The rest of the paper is planned as follows. Section 2 presents the different image compression schemes. Section 3 presents the different performance parameters used for checking the quality and efficiency of compression schemes. Section 4 presents a comparison of different image compression schemes discussed in section 2 based on different performance parameters discussed in section 3. Section 5 presents the conclusion of the paper.

II. DIFFERENT IMAGE COMPRESSION TECHNIQUES

Image compression is a technique which deals with the issues related to the reduction of the amount of data or information required in order to represent any digital image. This image processing methodology is anticipated in order to capitulate an optimized and compact demonstration of any digital image while tumbling the huge requirements related to the image transmission and storage. There are two different classifications of compression schemes based on the data available after the reconstruction. These are lossy and lossless compressions. In lossy compression schemes, the image reconstructed after compression is composed of degradations with respect to the original image. Since these techniques enable us to obtain extremely high compressibility of data, the redundant data is completely rejected. However, in lossless compression techniques, the image reconstructed after compression is exactly similar to the original image. But these schemes are reserved in terms of compressibility and hence don't provide appreciable compression. Furthermore, the compression techniques with predictive coding are facilitated with prediction of the future values for transmitted data and hence the difference is going to be coded in order to achieve the compression. Here, the entire work is carried out in spatial domain and is easy to implement. Alternatively, the compression techniques with transformations are going to enhance the data compressibility while using various types of transforms in order to perform compression at the cost of increased complexity and computations. In this section we are going to discuss different researches conducted in domain of image compression in past decade.

A novel image compression technique based on the utilization of the reference points coding along with the computation of threshold values was presented in [8]. The key objective of this paper was to implement and lighten up the image compression technique which is proficient in order to perform both lossy and lossless types of image compression. In addition to this, a threshold value was also incorporated in the presented compression process. The variation of this threshold value enables to achieve various compression ratios. Hence, in order to perform lossless image compression, the threshold value is set to zero. However, in order to perform lossy image compression, the threshold value is set to positive value. Hence, the optimal threshold value can be achieved to perform desired level of compression to obtain the required compression ratio.

The implementation of multi-wavelet transform in order to perform lossless image compression was done in [9]. Here, the performance of the IMWT (Integer Multi-Wavelet Transform) was analyzed for lossless image compression. The IMWT enables to achieve good results during the reconstruction phase too. However, the performance of the Integer Multi-Wavelet Transform during the lossless compression was further improved with extensive use of magnitude set coding. In this work, the author coded the transform coefficient with the use of both magnitude set of coding and run length encoding scheme. Here, the bit rate of about 2.1 bpp (bits per pixel) was achieved when use of MS-VLI (Magnitude Set-Variable Length Integer Representation) with RLE scheme was taken into consideration. While the bit rate was further improved to about to 3.1 bpp was achieved when use of MS-VLI (Magnitude Set-Variable Length Integer Representation) without RLE scheme was implemented.

In [10] author proposed a hybrid technique for image compression. This technique used unique type of embedded Wavelet based image coding along with Huffman-encoder. Here, author implemented both EZW and SPIHT coding schemes along with the standard Huffman encoding while making the extensive use of various types of available wavelet families. For implanted various types of wavelet families author compared both bit rates and PSNR values for various types of images and proved to be efficient in term of image quality, compression ratio as compared to the existing schemes of image compression. A novel scheme of image compression along with the encryption was proposed in [11]. In this technique, the image compression was done using SPIHT scheme in order to achieve better compression ratios but before that the images were encrypted using stream cipher technique to obtain the better encryption before transmission. This enables us to obtain a highly confidential encryption along with the best compression rate enhance the security, which was the key objective of research.

A hybrid image compression (HIC) scheme based on the combination of discrete wavelet transform (DWT) and discrete cosine transform (DCT) was proposed in [12]. Here, author used the images of 256×256 resolution. The author employed two levels DWT on each sub band images of size 32×32. However out of four available sub bands (LL, LH, HL, HH), author used only LL sub band images. This in turn provides the 75% compression. Furthermore, the standard DWT was applied which avails 8x8 blocks. Other quantization schemes along with Huffman encoding technique may be employed in order to obtain higher compression ratios. These hybrid techniques provide better compression ratios along with superior values of bit rates and PSNR.

However, in preference to make use of spatial based, the techniques based on the histogram approaches can be used in order to compress the digital image. In this scheme, first the original image is sub-divided into brittle clusters of probabilistic divisions (threshold) base on the image histogram. Furthermore, for each division the threshold values are calculated using the famous Shannon's entropy theorem. This theorem enables us to measure the randomness of the brittle clusters. As we keep on increasing the number of thresholds, the image quality and compression ratios keep on improving. This occurs mainly because of precise accuracy of histogram values and hence the diminished compression errors at the cost of increased complexity and computations. In order to achieve the optimal results, the Shannon's entropy function was maximized and incorporated with new optimization scheme of differential evolution in [13].

Discrete Anamorphic Stretch Transform (DAST) based technique was proposed for image compression in order to achieve higher image space-bandwidth compression in [14]. This technique does not use feature detection which means the algorithm is carried out without the prior knowledge of the image. However, the Discrete Anamorphic transform is going to reshape the input image before performing the uniform sampling. This sampling is performed in such a manner that the sharp and fine features incorporate a higher sampling density than the coarse or generic features. The extensive use of this feature-selective stretching enables us to allocate the additional samples to available sharp features where they are mostly required and very few to the coarse features where they are redundant or not required. This scheme is non-iterative in nature and can be employed by itself. This scheme can further be combined with other types of compression schemes in order to improve the compression ratios further.

In [15] author presents a fast zonal DCT based technique in order to conserve energy in wireless image sensor networks. The algorithm was developed using combination of cardiac based DCT and zonal DCT. The cardiac based DCT is a standard multiplier less algorithm which is used in 1D-DCT domain. In cardiac based DCT, 8 × 8 blocks are obtained after performing the block level DCT coefficients. This operation is carried out by first applying algorithm eight times over the rows and then eight times similarly over the columns. However, cardiac DCT with 8x8 processing requires less number of shift and addition operations as compared to standalone cardiac - DCT. Hence, by reducing the number of operation with the extensive use of fewer DCT coefficients enables the technique for reduction in energy consumption too. The only disadvantage of this technique is inferior image quality and hence less PSNR value.

In [16] author proposed new scheme for image compression based on wavelet compression using entropy values. This technique uses DWT for compression. Here, the image is first sub divided into sub bands of 16. Further, the entropy of each sub band is calculated and priority is assigned to every sub band based on these entropy values. Based on this priority the compression is performed on the selective sub bands only instead of all sub bands. The sub bands with lower entropy values are highly intended for compression in order to make the technique energy efficient. However, as the distance increases the compression of more sub bands is needed. This technique was found to save the energy up to 28.26% as compared to the fully compressed scheme. The only limitation of this scheme is the requirement of ideal condition as after more distance, the fully compressed schemes are proficient.

In [17] author proposed a new cost effective, simple iterative threshold based scheme in order to perform segmentation of brain tumor and to isolation of tumor area from non region of interest in MRI images. Since MRI images are very large in size, hence storage is the critical task. Hence, non region of interest of image are going to be compressed using simple enhanced differential pulse code modulation transform (EDPCMT) along with the standard Huffman coding. Furthermore, the uncompressed tumor images along with the compressed non region of interest images are transmitted across the network which are going to reduce the storage space and hence bandwidth efficient. However, the complexity of the implemented compression scheme is found to be more than lossless JPEG. Furthermore, the implementation of iterative threshold scheme with the proposed scheme provides the improved segmentation results.

Along with these discussed compression techniques there are few more schemes which have been proposed and proven to be efficient in different aspects. These are hiding and compression with image inpainting [18], Side match vector quantization (SMVQ) [19], hardware compression scheme based on low complexity arithmetic encoding [20], DCT SVD and RLE based hybrid image compression [21], binary discrete cosine and Hartley transforms based compression [22] etc.

III. PERFORMANCE PARAMETERS

The performance parameters are used in order to justify the selection of the implemented image compression algorithm to be efficient and prolific. The selection of these parameters depends on the accuracy and types of compression schemes. In this section we will discuss various types of performance parameters which can be used accordingly in order to justify the efficiency of the implement compression technique. These parameters are as per following –

A. Compression Ratio (CR)

The compression ratio is defined as shown in equation (1). This is generally used in order to measure the capability of data compression. Here, comparison of size of compressed image is performed with respect to the original image. As compression ratio increases, superiority of compression technique enhances.

$$CR = \frac{Size\ of\ Uncompressed\ Image}{Size\ of\ Compressed\ Image} \quad (1)$$

B. Mean Square Error (MSE)

Mean Square Error (MSE) is defined as the cumulative squared error between the input image and the compressed image. It is calculated as shown in equation (2).

$$MSE = \frac{1}{M * N} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \| I_o(x, y) - I_1(x, y) \|^2 \quad (2)$$

Where, Where M and N are the number of rows (height) and number of columns (width) and hence M x N is the size of image and total number of pixels in image are M*N. $I_o(x, y)$ and $I_1(x, y)$ are the respective pixel values for initial uncompressed image and final compressed image respectively. If this mean square error is equal to zero then both the input uncompressed image and the compressed image are unerringly similar or identical.

C. Root Mean Square Error (RMSE)

The Root Mean Square Error (RMSE) is evaluated as shown in equation (3). This parameter is generally used in order to measure the differentiations between the sample and population data. On the whole, the RMSE is going to represent the sample standard deviation of the differences between the original input uncompressed image and the resulted output compressed image. Root mean square error parameter is generally a superior quantification of accuracy. The only limitation of this parameter is that it is used to compare only the forecasting errors of several models presented for any special type of variable rather than among the various types of variables due to its scale dependency.

$$RMSE = \sqrt{MSE} \quad (3)$$

D. Peak Signal to Noise Ratio (PSNR)

This parameter is used to measure the effects of the noise on the quality of the signal. It is defined as the ratio of the maximum possible value (power) of the signal with respect to the power of interfering noise which is going to affect the quality of signal representation. This parameter is generally expressed in terms of the logarithmic scale or decibel (dB) scale. This parameter is further used to measure the differences in quality between the original input image and the output or final image. Superior values of PSNR result in the superior quality of the output image. For any image this can be calculated as shown in equation (4) or (5).

$$PSNR = 10 \log_{10} \frac{(I_{max})^2}{MSE} \quad (4)$$

Where, $I_{max} = 255$ i.e. the maximum pixel value for any image. Hence equation (4) can be rewritten as –

$$PSNR = 10 \log_{10} \frac{(255)^2}{MSE} = 20 \log_{10} \frac{255}{RMSE} \quad (5)$$

E. Weighted Signal to Noise Ratio (WSNR)

This performance parameter is going to use a frequency domain transform function known as Contrast Sensitivity Function (CSF). This is generally used in order to filter spatially all irrelevant or inappropriate frequencies from the perspective of the human vision system. The computation of this parameter enables us to visualize and quantify the effects of image dimensions, their printing resolutions, screening or visual distance and the ambient lighting and visualization. This parameter is also generally expressed in terms of the logarithmic scale or decibel (dB) scale. In order to compute WSNR, first the error image is evaluated by taking the differences between original input image and the output noisy image. Next, the obtained error image is weighted with the extensive use of a linear and spatially invariant approximation to the respective frequency response of the human visual system given by CSF transformation. In the final step, the weighted signal to noise ratio parameter is going to be calculated as shown in equation (6).

$$WSNR = 10 \log_{10} \frac{\sum_{xy} |I(x, y) CSF\ (x, y)|^2}{\sum_{xy} |\omega(x, y) CSF\ (x, y)|^2} \quad (6)$$

F. Structural Similarity Index Measure (SSIM)

The structural similarity measure is used as an image quality parameter in order to evaluate the output compressed image. This parameter is a measure in two separate signal vectors in x and y dimensions respectively. This parameter attempts to measure the similarities between input and output images. This parameter is also known as full reference metric since this enables the measurement of image quality which is generally based on an initial input uncompressed or noise free image as reference image. This parameter is incorporated in order to improvise the conventional performance parameters such as MSE and PSNR too due to their inconsistencies in case of human visual system. This key concept behind this parameter is based on the inter-pixel dependencies in close spatial proximities or neighborhood. These inter-pixel dependencies are going to bring out the significant amount of information about the structure of the objects from visual perspectives. This parameter is generally being calculated as shown in equation (7)

$$SSIM = \frac{(2\mu_1\mu_2 + C_1)(2\sigma_{12} + C_2)}{(\mu_1^2 + \mu_2^2 + C_1)(\sigma_1^2 + \sigma_2^2 + C_2)} \quad (7)$$

G. Quality Index (QI)

Quality Index (QI) parameter is also defined very similar to SSIM. This can be calculated as shown in equation (8)

$$QI = \frac{(4\sigma_{12}\mu_1\mu_2)}{(\mu_1^2 + \mu_2^2)(\sigma_1^2 + \sigma_2^2)} \quad (8)$$

H. Other Parameters

In addition to the parameter discussed above few other parameters such as computational complexity, coding efficiency, power, entropy or randomness, bit rate, storage space, bandwidth, execution time etc.

IV. COMPARISON OF DIFFERENT COMPRESSION SCHEMES

Table-I presents a comparative analysis of various compression schemes discussed and surveyed in this paper. The different compression techniques along with their pros and cons are listed in this table. They are arranged in chronological order in this table. The selection of particular compression scheme depends on the choice of performance parameters such as MSE, RMSE, PSNR, WSNR, CR, SSIM, QI, entropy etc.

TABLE I COMPARISON OF DIFFERENT COMPRESSION SCHEMES

Compression Technique	Advantages	Disadvantages
Yi-Fei Tan et. al. [8]	Good CR Applicable for both lossy and lossless compression techniques Good PSNR	Extra calculation of threshold increases complexity Optimal threshold criterion limits the quality
K. Rajakumar et. al. [9]	Good CR Optimized bit rates in case of both with and without Run Length Encoding	Increased complexity Calculation of sub bands increases the coding overhead
C. Rengarajaswamy et. al. [11]	Better CR Better security due to encryption Very compact output bit stream with large bit variability	High complexity PSNR is not good Single bit error of SPIHT More execution time
Sujoy Paul et. al. [13]	Better PSNR Better SSIM Better CR Less MSE	Moderated Execution time Moderated Entropy Increased coding complexity
Mohammad H. Asghari et. al. [14]	Very less MSE Superior PSNR Less execution time Superior SSIM	Increased coding complexity Less CR
B. Heyne et. al. [15]	Low computational complexity High energy compaction Low processing power	Low CR Low PSNR High MSE Low SSIM
A. Mittal et. al. [16]	High CR Low processing power	High computational complexity Moderated PSNR Moderated SSIM Large memory requirements

V. CONCLUSION

This paper has presented a widespread and up to date survey on different image compression schemes. Since, quality of reconstructed image is the most challenging issue during the designing of compression techniques and especially in case of bio-medical images such as CT and MRI images. Moreover, the compression ratio and memory requirements are also equally significant in order to design an efficient and prolific compression scheme. In order to perform compression on dynamic MRI images different performance metrics are significant upon which the discussion has been carried out in respective sections. The summarized table presented in section 4 covers the different compression techniques along with their pros and cons. The enhanced values of PSNR, SSIM, compression ratio (CR) also create the issues like increased complexity, overhead, coding complexity and cost etc. This survey will enable the author to design an optimized and more efficient compression scheme for dynamic MRI imaging system.

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