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Integrated Shuffled Singular Value Decomposition and Wavelet Difference Reduction based Image Compression

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Abstract:

The paper presents a new lossy compression technique in which compression is achieved by combining two compression based algorithms. The first method is wavelet difference reduction (WDR) based image compression and the other is shuffled singular value decomposition (SSVD) based image compression. Both the methods are integrated in a way to achieve high compression with better image quality. WDR is a compression technique that involves applying DWT with differential reduction encoding. Shuffled Singular Value Decomposition (SSVD) is enhanced version of singular value decomposition (SVD) that gives high PSNR values for same rank.

DWT is applied on the image to be compressed at the encoder side and then WDR based compression is applied on low frequency sub-band. SSVD based compression is applied on high frequency sub-bands parallely. At the decoder side image quality enhancement is carried out. The proposed method is compared with other methods. It is seen that psnr values of proposed method are greater than other methods for same amount of compression.

Keywords **— Discrete Wavelet Transform, Wavelet Difference Reduction, Shuffled Singular Value Decomposition, Standing Wavelet Transform.**

I. INTRODUCTION

Compression plays a very important role in today's life. We store, transmit, share lots of images, especially over internet. Use of social media for uploading or downloading images has increased. Compression comes into picture in such areas. It is way of removing the redundant information present in an image, without much degrading its quality. This will reduce file size and allow more images to be stored in a given amount of memory space.[13]

Some images need not have to be reproduced exactly after compression. An approximation of original image is enough for most of the purpose, as long as the error between the original and compressed image is low. Such lossy compression techniques are used to lessen the amount of data in order to store, handle, and transmit the represented content in effective manner.

JPEG is a DCT based compression technique that is most commonly used. One major disadvantage of this method is the presence of blocking artifacts. The wavelet-based image compression has gained much popularity due to reduction in the blocking artifacts. Also multiresolution feature of wavelet based technique gives high quality reconstructed images.

JPEG2000 is a high performance image compression technique that is based on wavelet transform. However, other simple algorithms like the wavelet difference reduction (WDR) algorithm can be used as an alternative to JPEG2000 while achieving comparable performance. Performance of WDR based image compression can be increased by integrating another technique that is shuffled singular value decomposition (SSVD).[12]

SSVD is enhanced version of singular value decomposition (SVD) that gives better quality image at same rank.[2] WDR is wavelet based compression technique that applies difference reduction of the positions of significant transformed coefficients. [14]

Integrating SSVD and WDR will give higher PSNR values with higher compression.

II. PROPOSED SYSTEM

Figure below shows the block diagram of proposed work:

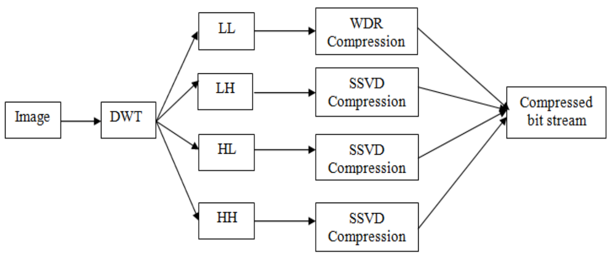


Fig. 1. Block diagram at encoder side

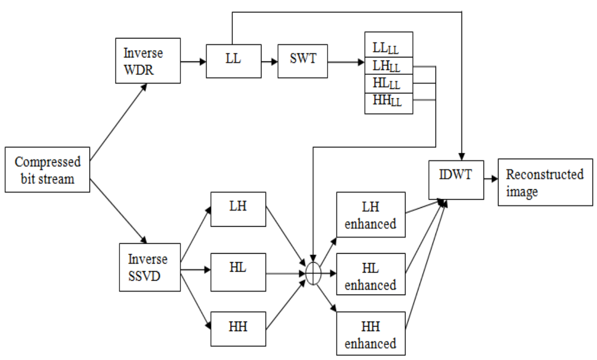


Fig. 2. Block diagram at decoder side

The proposed image compression technique is a lossy compression technique. First DWT is used to decompose the image into its frequency subbands. Among these, LL subband is compressed by using WDR; whereas the high-frequency subband images are compressed by using Shuffled SVD. In Shuffled SVD based compression the qualitative loss is not psychovisually noticeable up to some point.

Decompression is carried out by taking the inverse WDR (IWDR) of the bit streams in order to reconstruct the LL subband and in parallel LH, HL and HH subbands are also reconstructed using inverse SSVD. Due to the losses by ignoring low-valued singular values using shuffled SVD, high-frequency subbands need to be enhanced. So stationary wavelet transform (SWT) is applied to the LL subband image which will give new low and high frequency subbands. These high-frequency subbands will be added to the previously obtained respective high frequency sub-bands. Now, the LL subband image obtained by IWDR and the enhanced LH, HL and HH subbands are combined by using inverse DWT (IDWT) in order to reconstruct the decompressed image. The enhancement of high-frequency subbands by using SWT results in more sharpened decompressed image.

Compression ratio is calculated by dividing the total number of bits in input image by total number of bits in the compressed bit stream.

A. *Discrete Wavelet Transform*

The two dimensional wavelet decomposition of an image is performed that results in four decomposed subband images referred to Low-Low (LL), Low-High (LH), High-Low (HL), and High-High (HH). The frequency components of those subbands cover the full frequency spectrum of the original image. LL subband carries the most important information of the image while the other subbands carry details of an image.

B. *Wavelet Difference Reduction*

The WDR algorithm follows few simple steps for coding. A wavelet transform is applied to an image, and then WDR encoding algorithm for the wavelet coefficients is carried out. WDR encodes the positions of significant wavelet coefficients by difference reduction method. [14]

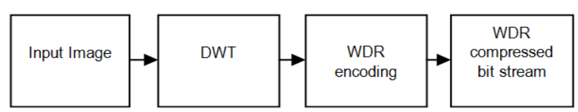


Fig. 3. Block diagram for WDR based compression

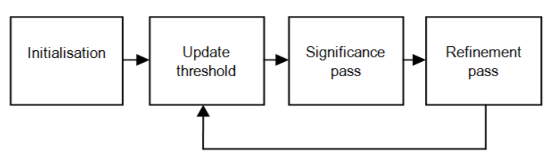


Fig. 4. WDR encoding

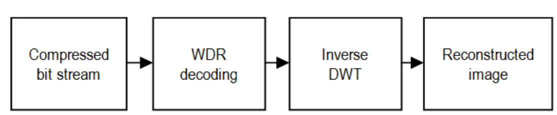


Fig. 5. Block diagram for WDR based decompression

WDR based encoding uses four steps for encoding: Initialisation, Thresholding, Significant pass and refinement pass.

1. Initialisation: In this the scan order is decided. The scan order goes through sub-bands from higher level to lower levels in zig-zag manner. A threshold T_0 is selected.
2. Update Threshold: Threshold is updated to $T_k=T_{k-1/2}$, for k=1, 2…p and 'p' is the number of pixels in an image.
3. Significance Pass: Here, values of wavelet transform are compared to a specific threshold value. A value is significant if it is greater than or equal to threshold value. If an index is found to be significant then it is removed from the scan order. Next, difference of these index values is taken and binary expansion of successive difference is done. Since the MSB in these expansions is always 1, we can ignore this bit and use the signs of the significant transform values in its place in the symbol stream. The stream consists of four symbols that can be encoded using probabilistic model.
4. Refinement Pass: In this, standard bit plane quantization is carried out to give refinement bit. Refined value gives better approximation of transform value.
5. Repeat steps (2) to (4) until you get desired bit budget.

To reconstruct the image, WDR decoding and inverse DWT is performed on compressed bit stream. [14]

The property of WDR is that it gives perceptually better image at high compression ratio while retaining the desirable features.

C. Shuffled singular Value Decomposition

It is a variant of singular value decomposition.

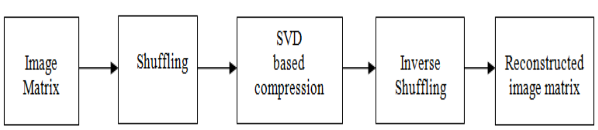


Fig. 6. Block diagram for SSVD based compression

The image matrix is shuffled and then SVD based compression is applied on it. Inverse shuffling is then applied to reconstruct the approximate image.[2]

1) Shuffling the image matrix

Let A again be $N * N$ matrix and $N = n2$. A shuffled image X is formed such that $X = S(A)$ and S is the shuffle operator. This is done by breaking A into blocks of size $n * n$, taking the ith block in row major order and arranging its pixels in row major order to produce the ith row of X. For example, if A is 4*4 matrix then it is broken into four blocks of size 2*2. All the pixels in 1st block (considering the rows from top to bottom in that block) are then arranged to form first row of a new matrix X. Similarly the pixels from second block will form the second row of new matrix and so on. This process gives a shuffled matrix.

The shuffling equation is given by:

$$X\left[\left[\frac{i}{n}\right]n + \left[\frac{j}{n}\right], (i \bmod n)n + j \bmod n\right] = A[i,j] \quad \ldots (1)$$

Each image in the column of X is built by taking one element from each block of A. Hence, each image in the column of X is a low resolution sample of A.

After shuffling the pixels to produce shuffled image X, SVD is carried out on it.

2) SVD based compression

SVD decomposes a matrix into three matrices- U, S and V. Singular value decomposition of matrix A is:

$$A = USV^T \quad \ldots (2)$$

where, A is a $m \times n$ matrix, S is a $m \times n$ diagonal matrix in which the entries along the diagonal of S are singular values of A, U is a $m \times m$ matrix containing left singular vectors of A and V is a $n \times n$ matrix containing right singular vectors of A. U and V are orthonormal matrices which means $UU^T = I$ and $VV^T = I$.

In matrix form the equation becomes:

$$A=[u_1, u_2, \ldots u_v]\begin{bmatrix} \sigma_1 & 0 & 0 & 0.....0 \\ 0 & \sigma_2 & 0 & 0.....0 \\ 0 & 0 & \sigma_3 & 0.....0 \\ . & . & & . \\ . & & . & . \\ . & & . & . \\ 0 & 0 & 0 & 0\ldots\sigma_z \end{bmatrix}\begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ . \\ . \\ . \\ v_z \end{bmatrix}$$

σ_i for $i = 1, 2, \ldots\ldots n$ are the singular values of matrix A. The singular values are arranged along the diagonal of S in such a way that $\sigma_1 \geq \sigma_2 \geq \sigma_3 \ldots \geq \sigma_n \geq 0$. Also, $\sigma_i = \sqrt{\lambda_i}$ where λ_i for $i = 1, 2, \ldots, n$ are the eigen values of image matrix A.

To compress an image, after applying SVD, only a few singular values are retained while other singular values are discarded. This follows from the fact that singular values are arranged in descending order on the diagonal of S and that first singular value contains the greatest amount of information and subsequent singular values contain decreasing amounts of image information. Thus, the lower singular values containing negligible or less important information can be discarded without significant image distortion.

Furthermore, the number of non-zero singular values is equal to the rank of A. But even if the lower order singular values after the rank of the matrix are not zero, they have negligible values and are treated as noise.

A matrix $\bar{S}_{p\times q}$ with smaller dimensions $p \leq m$ and $q \leq n$ can be used to approximate the diagonal matrix with the dimensions m and n:

$$S_{m*n} = \begin{bmatrix} \bar{S}_{p*q} & 0 \\ 0 & 0 \end{bmatrix}$$

Some columns of U and rows of V are then reduced in order to reconstruct the compressed image by multiplication as shown below.[1]

The compressed image is then obtained as shown in Eqn. (3):

$$A_{m*n} = \bar{U}_{m*p}\bar{S}_{p*q}(\bar{V}_{n*q})^T \qquad \ldots (3)$$

The image reconstructed using equation (3) above will reduce the storage space requirement to $k*(m+n+1)$ bytes as against the storage space requirement of $m*n$ bytes of the original uncompressed image.

3) Inverse shuffling

Inverse shuffling the compressed shuffled matrix X will give a matrix which is approximate of the original image. Inverse shuffling is carried out using the equation given below:

$$\tilde{A}[[i/n]n + [j/n], (i \bmod n)n + (j \bmod n)] = X[i,j] \qquad \ldots (4)$$

In the above equation, $\tilde{A}$ is approximate of original image A.

SSVD based compression gives better psnr values and good quality image as compared to svd based compression having same rank (k). Results of comparison between SVD and SSVD based image compression is shown below in result section.

D) Standing Wavelet Transform:

Stationary wavelet transform (SWT) is applied to the LL subband image which results in new low and high frequency subbands. These high-frequency subbands will have the same direction as the ones obtained by DWT (e.g., horizontal, vertical, and diagonal). The enhancement of high-frequency subbands by using SWT results in more sharpened reconstructed image.

Sharpening the image produces sharpness in the output image; however along with it there is appearance of some blockiness. This leads to reduction in image quality. Hence method of averagimg is performed between output image after applying SWT and the IDWT image produced before applying SWT.[1]

III. RESULT AND DISCUSSION

The experimental results for the two techniques are shown below. The codes of these algorithms are executed in matlab software. For this matlab version 2013a is used. Matlab provides hundreds of built-in functions for technical computation, graphics, etc.

For experimenting, a jpeg image is selected and it is resized into matrix size of 256x256.

A) Compression using SSVD

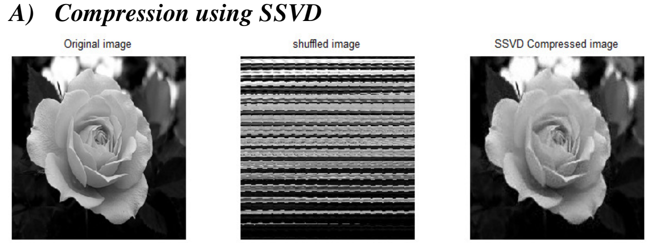
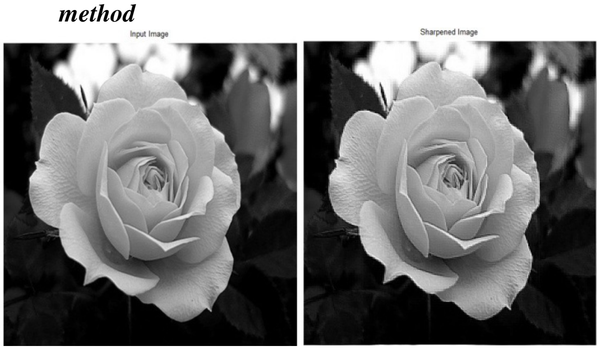


Fig. 7. Original image is compressed using SSVD at rank k=30. Figure shows original, shuffled and compressed image.

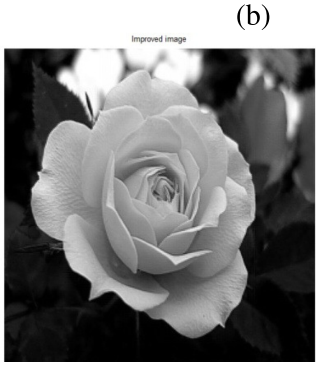
B) Compression using WDR

Fig. 8. Figure shows input image and WDR compressed image

C) Results of proposed(SSVD+WDR with averaging) method



(a) (b)



(c)

Fig. 9. (a) Input image (b) Sharpened image (c) Improved image after averaging

D) Comparison of proposed method with other methods

TABLE I
PSNR VALUES OF 40% COMPRESSED IMAGES

Compression method	PSNR
JPEG2000	46.17
WDR	39.195
WDR+SVD	41.57
WDR+SSVD	40.27
Improved WDR+SSVD	46.16

TABLE 2
PSNR VALUES OF 60% COMPRESSED IMAGES

Compression method	PSNR
JPEG2000	43.12
WDR	35.40
WDR+SVD	41.62
WDR+SSVD	40.47
Improved WDR+SSVD	45.37

TABLE 3
PSNR VALUES OF 80% COMPRESSED IMAGES

Compression method	PSNR
JPEG2000	38.21
WDR	34.06
WDR+SVD	41.08
WDR+SSVD	40.19
Improved WDR+SSVD	42.75

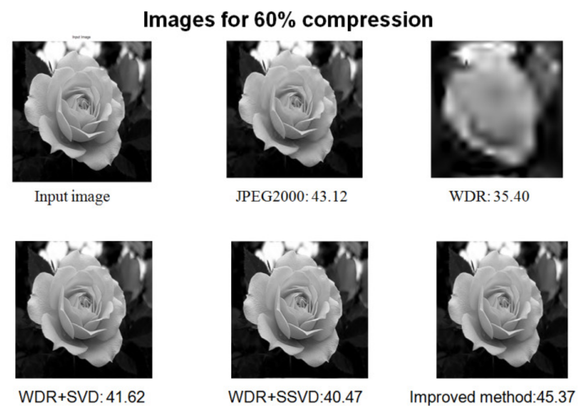


Fig. 10. Images for 60% compression

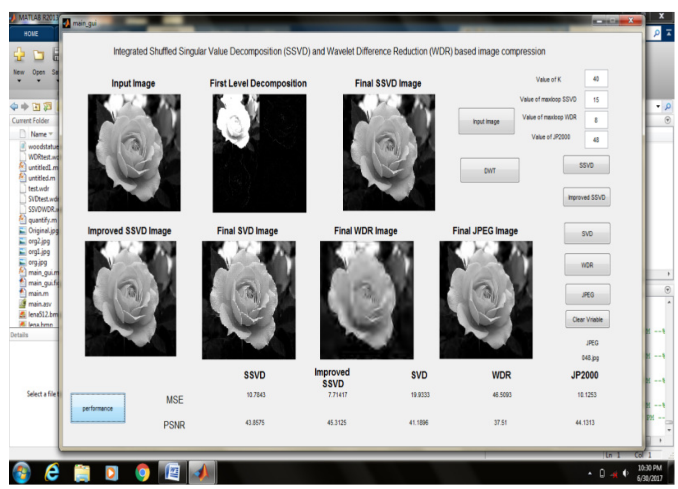


Fig 10. GUI of comparative work

IV. CONCLUSIONS

In this paper a lossy compression technique is presented. The method integrates WDR and SSVD for compressing the image. On comparing the method with other techniques it is seen that the psnr values of compressed image by proposed work are more than the psnr values of images compressed by other methods for same amount of compression.

Future scope of the proposed work is to use techniques like SPIHT, ASWDR, etc that gives better psnr values than WDR and study the application of the same on coloured images.

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