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A Novel Lossless Image Compression Technique Using Singular Value Truncating Method

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Abstract- With the growth of multimedia and internet, compression techniques have become the thrust area in the fields of computers, such as digital imaging, videophone and medical field, etc. The objective of image compression is to reduce the amount of digital images information and therefore reduce the storage capacity, price as well as transmission cost. For latest applications we are using images for which enormous amount of storage space is required. So image compression technique can be efficiently used by adopting lossless compression method which is to reconstruct the image from the original image without falling original data. Singular Value Truncating (SVT) is an attractive algebraic transform for image processing applications. In this paper singular value truncating algorithm is proposed and compared with different algorithms such as Lempel-Ziv-Welch (LZW), Run length coding process (RLE) and Huffman coding. This technique has been applied to the original input image and then the original image is compressed using MATLAB platform. This proposed technique is used to increase the compression ratio (CR), Peak signal to Noise Ratio (PSNR) and decreasing Mean Square Error (MSE) which can be used to measure the quality of the compressed images.

keywords: Lossless compression, Lempel-Ziv-Welch coding, Run length coding, Huffman coding, Singular value truncating method.

Introduction

Image applications are widely used, driven by recent advances in the technology and breakthroughs in the price and performance of the hardware and the firmware. This leads to an enormous increase in the storage space and the transmitting time required for images. This emphasizes the need to provide efficient and effective image compression techniques.

Image compression techniques fall into two categories namely lossless and lossy image compression techniques. Choosing which of these two categories depends on the application and on the compression degree required [1,2]. Lossless image compression is used to compress images in critical applications as it allows the exact original image to be reconstructed from the compressed one without any loss of the image data. Loss image compression, on the other hand, suffers from the loss of some data. Thus, repeatedly compressing and decompressing an image results in poor quality of image. An advantage of this technique is that it allows for higher compression ratio than the lossless [3,4].

In [5] compression technique using the two lossless methodologies such as Huffman coding and Lempel Ziv Welch coding are used to compress image. In the first stage, the image is compressed with Huffman coding resulting the Huffman tree and Huffman Code words. In the second stage, all Huffman code words are concatenated together and then compressed by using Lempel Ziv Welch coding. In the third stage the Retinex algorithm is used on compressed image to enhance the contrast of image and improve the quality of image.

Hence, image compression becomes a solution to many imaging applications that require a vast amount of data to represent the images, such as document imaging management systems, facsimile transmission, image archiving, remote sensing, medical imaging, entertainment, HDTV, broadcasting, education and video teleconferencing [6]. One major difficulty that faces lossless image compression is how to protect the quality of the image in a way that the decompressed image appears identical to the original one.

In [7] the authors proposed a lossless method of image compression and decompression. It uses a simple coding technique called Huffman coding. A software algorithm has been developed and implemented to compress and decompress the given image using Huffman coding techniques in a MATLAB platform. They concerned with compressing images by reducing the number of bits per pixel required to represent it, and to decrease the transmission time for images transmission. The image is reconstructed back by decoding it using Huffman codes.

In [8], the two-dimensional Lempel-Ziv image compression scheme (denoted GS-2D-LZ) is proposed. This scheme is designed to take advantage of the two-dimensional correlations in the image data. It relies on three different compression strategies namely two-dimensional block matching, prediction, and statistical encoding. LZW is a simple lossless compression method. It is based on dictionary coding. In this technique, every data can be represented as image and it is saved in a single value of data. It places the longer and longer again entries into a dictionary and the algorithm emits the codes for a string element. Source alphabet provides a string of symbols for LZW. The algorithm is designed so that string table can be reconstructed by the decoder which is based on information in the encoded stream.

In [9] the authors present a new compression technique based on Run-Length Encoding scheme (RLE). The technique is semi-lossless and utilizes pixel value rather than bit value. The encoding process starts by mapping the colors of an image to a vector where each value of the vector is decimal ranging from 0 to 255. The decoding process reverses the encoding process steps to obtain the original image.

A number of already existing techniques are combined in [10] which work as follows: first, they apply the well-known Lempel-Ziv-Welch (LZW) algorithm on the image in hand. What comes out of the first step is forward to the second step where the Bose, Chaudhuri and Hocquenghem (BCH) error correction and detected algorithm is used. To improve the compression ratio, the proposed approach applies the BCH algorithms repeatedly until "inflation" is detected.

In this paper lossless image compression based on singular value truncating method is proposed, which compresses different types of image formats. The proposed method repeats the compression three times in order to increase the compression ratio.

Singular Value Truncation (SVT) Algorithm

In this work, the objective of the proposed method is to design the efficient and valuable lossless image compression. Traditionally, lossless compression technique such as Huffman coding, LZW, RLE, Area encoding and arithmetic coding are used to compress the images [11]. The proposed method is based on the singular value truncating algorithm which is used to reduce storage space required in the corresponding image.

The proposed work is focused on singular value decomposition method which is a way of matrices into a linear approximation that discloses the image structure of the matrix to obtain the further compression of original images. This works is generally used in many practical and theoretical applications such as signal processing, satellite images and used to improve the quality of images [12]. The compressing image *mxn* pixel value is following the truncation A into U, V and S orthogonal and diagonal matrices are expressed by, $A=USV^T$.

$$U = [u_1, u_2, \ldots u_m], \quad V = [V_1 V_2, \ldots V_n]$$

$$S = \begin{bmatrix} \sigma_1 & & & \\ & \sigma_2 & & \\ & & 0 & \\ & & & \sigma_n \end{bmatrix}$$

In the above equations, U and V are represented as u_i and v_i respectively, and S is denoted by s_i which are called singular values. We have to form an orthogonal basis as found below,

$$AV_i = s_i u_i \qquad (1)$$

Equation (1) denote that right singular vector is mapped on the particular left singular vector which is formed in the order of diagonal as shown below,

$$\sigma_1 \geq \sigma_2 \geq \ldots\ldots\ldots\ldots \sigma_r = 0 \qquad (2)$$

where r is mentioned for the rank of the matrix, the dimension m or n is represented by $(_p)$. Rank is considered as the number of rows and columns of the input matrix. The original image is designed as a matrix and it has a low rank. The singular value truncating method can be used to detect the low rank approximation. It represents more compatible than the original image and it is choosing the matrix A which has m rows and n columns.

The matrix V gives the below steps:

We have to multiply both sides USV^T by A^T yields,

$$A = USV^T$$

$$A^T A = (USV^T)(USV^T) = USV^T VS^T U^T$$

$$A^T A = VS^2 V^T \qquad (3)$$

In the above $S^T S=S^2$ and $U^T U$ gives the identity matrix values and $A^T A$ is the eigenvalues and eigenvectors of matrix is desired to calculate the V and S matrices. The eigenvectors of a matrix are the non zero vectors that, after multiplying by a matrix, other can be proportional to the original vector. The eigenvalue is the factor when multiplied by the square matrix by changing the eigenvector.

Assume A is a square matrix of size nxn and λ is an eigenvalue. Such that it is denoted,

$$Avi = \lambda Ivi, \text{wher}, i = 1,2,3\ldots,n, n+1.$$

The eigenvector of a matrix A is called V, which associated with is eigenvalue λ. The equation can be written as:

$$\begin{aligned} Avi &= \lambda Ivi \\ Avi - \lambda Ivi &= 0 \\ (A - \lambda I)vi &= 0 \end{aligned} \qquad \textbf{(4)}$$

where I is the size of identity matrix nxn. The identity matrix has to be the same for eigenvector and eigenvalue vectors have to be calculated. Equation (4) has a non-zero solution and coefficient matrix is noninvertible, if its determination value is equal to zero.

$$|A - I\lambda| = 0$$

The equation is defined as the characteristic equation of the matrix A. In our proposed method, the square of the eigenvalues are S and matrix V is the eigenvector of columns. The next step is calculating the U value so we have to take an equation (2).

$$A^T A = (USV^T)(USV^T) = USV^T VS^T U^T$$

In the above equation V^TV gives identity matrix and $S^TS=S^2$. Here S is the diagonal matrix of singular values. So the equation gives,

$$AA^T = US^2U^T \qquad \textbf{(5)}$$

This time for the matrix AA^T again the eigenvalues are calculated. U is the column on the left singular value. The determination process of matrix V is same as the process of calculating the eigenvalues and eigenvectors. If U, V and S matrices are calculated, the matrix A can be generated. U, V and S are the mxn matrices.

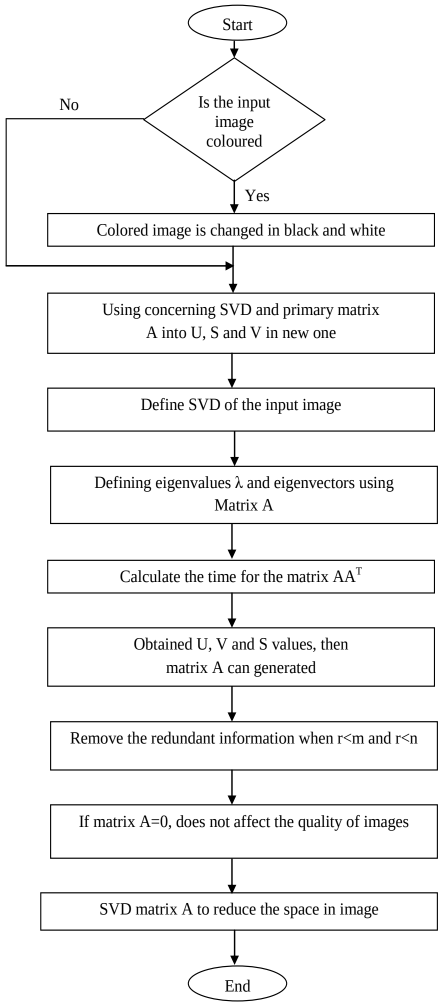

Figure .1 Block diagram of proposed image compression method

$$A = [u_1..u_2..u_r]\begin{bmatrix} \sigma_1 & \cdots & \sigma_3 \\ : & \sigma_5 & : \\ \sigma_r & \cdots & \sigma_{r+1} \end{bmatrix}\begin{bmatrix} v_1^T \\ v_2^T \\ v_3^T \end{bmatrix}$$

$$A = \sigma_1 u_1 v_1^T + \sigma_2 u_2 v_2^T + ...+ \sigma_r u_r v_r^T \qquad \textbf{(6)}$$

$$A = \sum_{i=1}^{r} \sigma_i u_i v_i^T + ...+ \sum_{i=n}^{r+1} \sigma_{i+1} u_{i+!} v_{i+1}^T$$

Finally, the redundant information is removed when r is less than either m or n of the original matrix and r is the total number of non-zero diagonal elements of the original S matrix which is called singular values and it is arranged in descending order. If singular matrix values are equal to zero, it does not affect the quality of images [13] [14]. In equation (6) mentioned reduce the more terms of the original matrix A. This method reduces the amount of storage space in an image on a computer and disc space. The flowchart of the proposed technique is given in Fig. 1.

Performance Evaluation and results

In order to evaluate the compression performance of this proposed SVD method it is compared with other standard lossless image compression schemes such as LZW, RLE and Huffman method. Generally two quality measures such as Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) [15] are used to evaluate the compression performance. The MSE is used to calculate the error between the original image and the processed image that is given by

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}[f(x, y) - g(x, y)]^2$$

where, x and y denote the coordinate values in the image, N is defined as the total number of pixels and f is the original image and g is the reconstructed image. PSNR provides measurement of signal fidelity metrics and it contains the quality of the images [16]. The PSNR is expressed by

$$PSNR = 10\log_{10}\left[\frac{255^2}{MSE}\right]$$

In lossless compression, no data is lost during the process and also protects the quality of the processed image. In the proposed method commonly used

(Lena) image is taken as test image which is of size 256x256. The proposed method has been tested at different compression ratios. The simulation result is compared with LZW , RLE and Huffman method.

Table 1 show the MSE and PSNR values for various algorithms. It is clearly illustrated from the table that the proposed algorithm gives lower MSE value and higher PSNR value than the other existing algorithms such as RLE, LZW and Huffman. By using this quality metrics it is proved that the proposed method will not affect the quality of original image.

Figure 2 illustrates the PSNR values between the proposed algorithm and standard image compression algorithms such as RLE, LZW and Huffman which can be distinguished by color. **Figure 3** explain the MSE value of the proposed method compared with other image compression algorithms. It is observed that proposed SVD method gives low MSE value then the other existing methods.

Table 2 and 3 show the compression ratio and compression based on bit per pixel respectively. The below results show that the compression by proposed SVD method is best compared with the result of compressing the image by using other existing methods. The aim of the image compression is to reduce the size as much as possible without degrading image quality. It will lead to reduce the storage space so it is better to have fewer bits need to represent each pixel in an image. The compression based on bit per pixel result shows averagely RLE-6.869, LZW-5.5754 and Huffman-6.6438. The proposed SVD method gives averagely low bits per pixel value (4.942 bit/pixel) to represent each pixel compared with standard existing methods.

The compression based on compression ratio between the proposed method and the other image compression methods are shown in **Figure4** which is distinguished by color and **Figure5** shows the result of the compression based on the bit per pixel rate for the proposed method and the other existing methods.

MATLAB simulation result of image with different compression factors are shown in **Figure 6.** It is observed from the figure that it has the less image size and utilizes less storage need to store image and therefore reduces the time for transmission.

Table 1. MSE and PSNR values compared with proposed algorithm

	MSE				PSNR			
Original Image	**RLE**	**LZW**	**Huffman**	**Proposed SVD**	**RLE**	**LZW**	**Huffman**	**Proposed SVD**
Lena1-CF=2	**297.99**	**409.13**	**502.44**	**155.74**	**23.3888**	**22.0122**	**21.1200**	**26.2068**
Lena2-CF=4	**162.33**	**98.01**	**45.15**	**36.7977**	**26.0268**	**28.2181**	**31.5842**	**32.4726**
Lena3-CF=6	**119.4**	**54.05**	**33.2**	**25.5647**	**27.3608**	**30.8028**	**32.9194**	**34.0544**
Lena4-CF=8	**95**	**41.39**	**27.13**	**15.9765**	**28.3536**	**31.9618**	**33.7963**	**36.0960**
Lena5-CF=10	**55.42**	**32.9**	**16.77**	**10.6758**	**30.6941**	**32.9588**	**35.8855**	**37.8468**
Lena6-CF=12	**42.62**	**25.87**	**13.53**	**10.1515**	**31.8347**	**34.0028**	**36.8178**	**38.0655**
Lena7-CF=20	**31.08**	**21.44**	**9.21**	**6.5294**	**33.2060**	**34.8186**	**38.4882**	**39.9821**

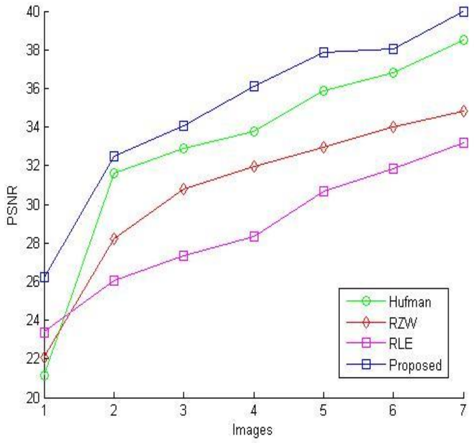

Figure 2. PSNR values compared with proposed method.

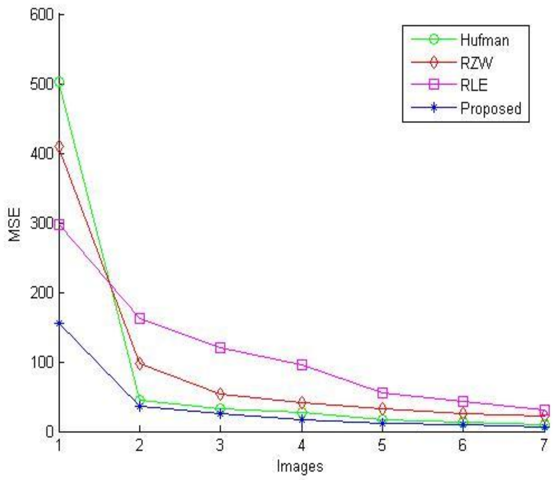

Figure 3. MSE values compared with proposed method.

Table 3. Bit per pixel for different techniques compared with proposed method.

Image Name	RLE	LZW	Huffman	Proposed SVT
Lena1	7.5891	5.6658	7.2241	5.0697
Lena2	7.0897	5.4658	6.8989	4.7892
Lena3	5.7389	6.0101	7.3938	5.0032
Lena 4	7.2482	5.0018	6.7413	4.8226
Lena5	7.5241	5.7923	7.1772	5.0083
Lena6	7.2667	7.9223	7.9861	7.0032
Lena7	5.6263	3.1702	3.0852	2.9001

Table 2. Compression ratio for different techniques compared with proposed method.

Original Image	Compression Ratio (%)			
	RLE	LZW	Huffman	Proposed SVD
Lena 1	1.262	1.511	1.870	2.012
Lena 2	2.564	2.521	3.451	4.217
Lena 3	4.963	5.063	7.621	8.431
Lena 4	7.283	8.820	10.243	12.118
Lena 5	11.296	12.465	15.220	16.395
Lena 6	14.235	16.577	18.559	20.520
Lena 7	17.604	20.319	22.047	24.531

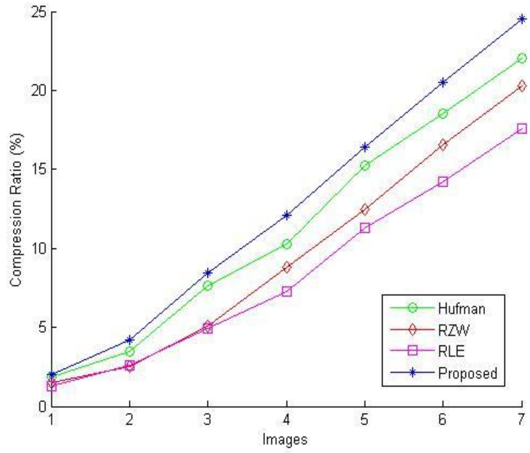

Figure 4. Compression ratio for various images compared with proposed algorithm

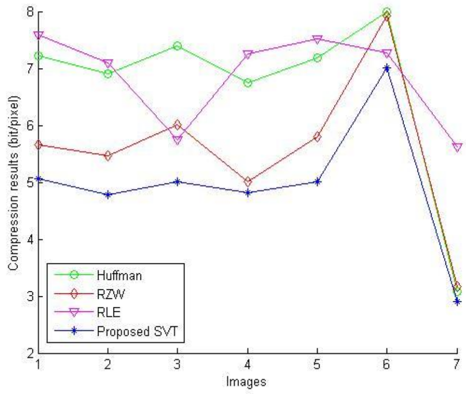

Figure 5. Compression with bit per pixel results for various images compared with proposed algorithm.

Original Image CF=8

Figure 6: Matlab Simulation Results.

CONCLUSION:

In this work an efficient algorithm, singular value truncating method (SVT) is proposed for lossless image compression technique. The ultimate goal of the propose method is to give a relatively good compression ratio and keep the time and space complexity minimum. Lena image is taken as the test image with the size of 256x256. To analyze the performance of the proposed algorithm the results are compared with other existing algorithms such as LZW, RLE and Huffman using PSNR, MSE, compression ratio and bits per pixel. The simulation results show that the proposed algorithm gives better compression ratio compared with existing algorithms and also the proposed method gives averagely low bits per pixel value (4.942 bit/pixel) to represent each pixel compared with standard existing method.

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