Performance Analysis of a Hybrid Method for Medical Image Compression

M.Laxmi Prasanna Rani[a], V.Lavanya[b], G. SasibhushanaRao[c]

Assistant Professor, Dept.of ECE, MVGR College of Engineering, VIZIANAGARAM, AP, INDIA
Assistant Professor, Dept.of ECE, MVGR College of Engineering, VIZIANAGARAM, AP, INDIA
Senior Professor, Dept. of ECE, Andhra University, Visakhapatnam, AP, INDIA

Abstract: A hybrid approach of image compression using Singular value decomposition (SVD) and Set Partition in Hierarchical Trees (SPIHT) is proposed in this paper. SVD provides less image quality with more compression rate; SPIHT offers high quality of image with more compression. In the proposed method, image is compressed using SVD and reconstructed image is given to SPIHT technique. This method is tested on MRI and X-ray images and provides an improvement in Peak Signal to Noise ratio (PSNR) of 5dB compared to SPIHT, reduced Mean Squared Error (MSE) and significant improvement in compression ratio compared to SVD and SPIHT alone.

Keywords: Medical Image Compression; SVD; SPIHT; PSNR; MSE

1. Introduction

Compression of images is an important step in the fields of communication, satellite, and medical for efficient storage and transmission. In bio-medical imaging, this compression of medical images becomes essential to scale back the cupboard space for transferring the patient's images from one place to other place for accurate diagnosis with different experts [1]. Generally, medical images contain large amount of data with more storage space. So, the compression of these medical images is required to get less storage space and faster transmission with less loss of image quality in telemedicine applications. Lossy and lossless are the two methods to compress the images. Lossy techniques produce the reconstructed images with some loss of image quality. Lossless techniques are preferred for medical images in telemedicine applications with no loss of image quality. Generally, lossy methods with acceptable quality have used in many applications [2]. Different compression techniques are used to reduce space to store images based on spatial domain and transform domain. The Discrete Fourier Transform is a transform technique used to convert an image from the spatial into frequency domain. It separates the transform coefficients into high frequency and low frequency and neglect specific frequencies with less information of an image with an acceptable quality [2]. Hence, image compression based on transform domain becomes more popular [3].

Discrete Cosine Transform (DCT) is the popular technique and it has been used for image compression over several years. It has fixed basis function. It has the property of high Energy Compaction for better image compression. Singular Value Decomposition (SVD) is another transformation method based on singular values is used to compress the images. Discrete Wavelet Transform (DWT) has become popular compression technique for images due to its multi-resolution property. Set Partition In Hierarchical Trees (SPIHT) technique becomes paradigm and highly developed algorithm for compression of images due to progressive structure with wavelet transform. This technique is taken as the best among other compression techniques due to fast encoding and decoding [7]. The SPIHT process represents a very effective form of entropy-coding. After the SPIHT encoding, the compressed output is transmitted through the channel. The encoded bit stream is decoded at receiver using the process of decoding. This process is exactly identical to encoding. The only difference is the output from the encoder is given as input to the decoder. The processing time of both decoding and encoding processes are almost equal. Therefore, SPIHT algorithm is nearly symmetric.

This paper is arranged such that introduction to medical image compression with different transforms is described in section 1. SVD and SPIHT techniques are discussed in section 2. Section 3 explains the proposed methodology of compression. The experimental results of proposed technique and also its comparison with stare of art techniques are tabulated in section 4 and conclusions are given in section 5.

2.Significance ofthe Study

In this paper, a hybrid approach for compression and decompression of medical images is proposed. In this method, the input image is transformed using SVD and reconstruct the image with less singular values as the first singular values have more information. The reconstructed image of SVD is then given to SPIHT technique to obtain more compression with high PSNR. This property of SVD i.e. an image can be reconstructed by less number of singular values, which makes SVD suitable for compression. After reconstruction of the image the ignored singular values cannot be recovered, the compression by SVD is lossy. The proposed compression technique is benefiting from cascading SVD based compression followed by SPIHT based compression. This is due to the fact that SVD compression technique offers very good PSNR values but low compression ratios and SPIHT compression technique offers high compression ratios.

3. Proposed Methodology of Image Compression

The techniques of SVD and SPIHT algorithms explained below.

3.1 Image Compression using SVD

SVD was discovered by Beltrami and Jordan for square matrices in 1873 and 1874 respectively. It was improved in 1930 by Eckart and Young for rectangular matrices. The image matrix is split into product of three matrices using SVD [5].

The SVD of a rectangular matrix L of can be represented by

$$L = MDN^T \tag{1}$$

M and N are the rectangular matrices of orthonormal. D is the diagonal matrix contains singular values.

The singular values of $\sigma_1, \sigma_2, \sigma_3, \ldots\ldots \sigma_N$ are along the main diagonal of D. Eq.1 can be rewritten as

$$L_{PXQ} = \begin{bmatrix} M_1 & M_2 & M_3 \ldots\ldots & M_P \end{bmatrix} \begin{bmatrix} \sigma_1 & 0 \ldots\ldots\ldots & 0 \\ 0 & \sigma_2 \ldots\ldots\ldots & 0 \\ 0 & 0 \ldots\ldots\ldots\ldots & \sigma_P \end{bmatrix} \begin{bmatrix} N_1{}^T \\ N_2{}^T \\ \ldots \\ N_Q{}^T \end{bmatrix} \tag{2}$$

The square roots of the Eigen values of matrices LL^T and $L^T L$ are taken as singular values. These two matrices are given in Eq. (3) & (4).

$$LL^T = \left(MDN^T\right)\left(MDN^T\right)^T = MDN^T NDM^T = MD^2 M^T \tag{3}$$

$$L^T L = \left(MDN^T\right)^T \left(MDN^T\right) = NDM^T MDN^T = ND^2 N^T \tag{4}$$

The values of M and N are as the Eigen vectors of LL^T and $L^T L$ respectively. The input image can be expressed by the Eq. 5

$$L = MDN^T = \sum_{i=1}^{r} \sigma_i m_i n_i{}^T = \sigma_1 m_1 n_1{}^T + \sigma_2 m_2 n_2{}^T + \ldots + \sigma_r m_r n_r{}^T \tag{5}$$

The singular values in the diagonal matrix are arranged in the descending manner. The large amount of data is in the first singular values and subsequent singular values contain reducing amounts of information [6]. The reconstructed image using first k singular values is represented in Eq. 6.

$$L = MDN^T = \sigma_1 m_1 n_1{}^T + \sigma_2 m_2 n_2{}^T + \ldots + \sigma_k m_k n_k{}^T \tag{6}$$

Thus, the compression of images can be obtained by discarding lower singular values as these values contain negligible information and with less number of singular values the image is reconstructed at the receiver.

The algorithm of image compression using SVD is explained below.

Step 1: Read the input image.
Step 2: Decompose the image intodiagonal and orthonormal matrices using SVD.
Step 3: Diagonal matrix contains singular values as diagonal elements.
Step 4: Remove the singular values, which contain negligible information
Step 5: Reconstruct the image with less number of k singular values as these contain large amount of data.

3.2 SPIHT Algorithm for compression of images

DWT based progressive SPIHT method is widely used in many applications. Initially, the image is decomposed by Daubechies wavelet. Using wavelet decomposition, the image is split into four sub-bands. In these, horizontal, vertical, diagonal coefficients are high frequency and coefficients with approximation are low frequency. The low frequency components are further divided into sub bands depending on the level of decomposition. Fig.1 (a) demonstrates the wavelet decomposition structure with 3 levels. In SPIHT algorithm, the coefficients of sub bands are associated with similar characteristics in the structure like pyramid.The spatial relationship of the hierarchical structure of tree is called spatial orientation tree (SOT) [5]. Fig.1 (b) gives Parent-children relation in SOT. The process of SPIHT algorithm is explained below.

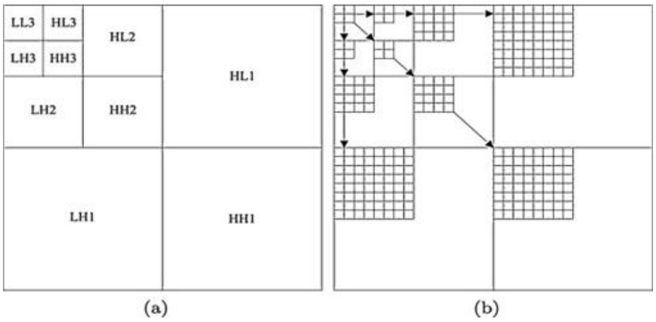


Figure 1.(a) 3- level Wavelet Decomposition Structure
(b) Parent-children relation in SOT

SPIHT algorithm has mainly three steps for the arrangement of transformed coefficients according to their magnitudes. They are initialization/sorting, refinement, and quantization. These wavelet-transformed coefficients are divided into list of 3 sets. These sets contain the List of Significant Pixels (LSP), List of Insignificant Pixels (LIP), and List of Insignificant Set (LIS). Firstly, the no. of bits required to represent largest value among all wavelet-transformed coefficients is given in Eq. 7.

$$P = \left[\log\left(\max_{i,j}\left(\left|B_{i,j}\right|\right)\right)\right] \qquad (7)$$

$B_{i,j}$ is largest value of pixel is in spatial tree. All transformed coefficients in the sorting list of LIP and LSP are compared by threshold T. At the start, all the pixels are considered as insignificant. The threshold value is given in Eq.8 below [10].

$$Threshold\,(T) = \begin{cases} 1, & \max(\left|B_{i,j}\right|) \geq 2^P \\ 0, & otherwise \end{cases} \qquad (8)$$

The encoding and decoding process of SPIHT algorithm is explained in steps below.

i Initially, all the transformed coefficients are taken as insignificant and are in LIP.
ii Determine the threshold value T. Depending on the threshold value; a significant test has done on the coefficients of LIP to decide whether the coefficients are insignificant or significant.
iii If the magnitudes of coefficients in LIP are more than T, then output is '1'. These are considered as significant and shifted to LSP. If the magnitude coefficients are lesser than T, then output is zero and remaining coefficients in spatial tree except the immediate off springs are shifted to the end of LIS. This method of significant test is termed as sorting and it repeats until all the coefficients of direct off springs are completed [4].
iv All the bits (n) in LSP at same threshold are taken as refinement bits. In the refinement pass, the threshold becomes half of the value i.e. $T = T/2$ and P becomes P-1.
v This process repeats until all the coefficients in LIP, LIS become empty, and the bitrate compliance requirements of encoder are called as quantization. These steps are shown Fig2.

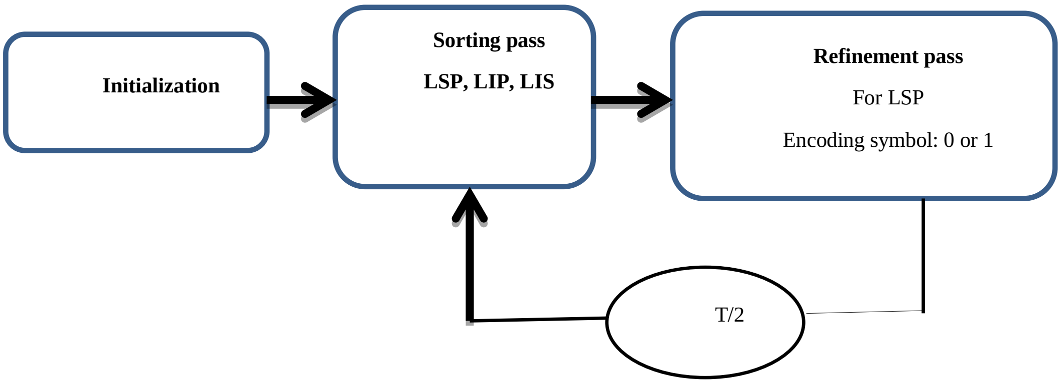


Figure 2. Implementation of SPIHT Technique.

After the SPIHT encoding, the compressed output is transmitted through the channel.The encoded bit stream is decoded at receiver using the process of decoding. This process is exactly identical to encoding. The only difference is the output from the encoder is given as input to the decoder. The processing time of both decoding and encoding processes are almost equal. The efficiency of the SPIHT algorithm is more compared to other algorithms [15]. Finally, the output image is decompressed using inverse DWT.

3.3 Image Compression using Proposed Method

The proposed technique for the compression and decompression of images is explained below.The input image is decomposed using SVD and get diagonal and orthonormal matrices in which the diagonal matrix consists of '*r*'singular values as diagonal components are organized in descending order shown in Eq.5. The greatest amount of information is in the first singular values and the subsequent values contain image information in decreasing order [8]. Thus, the lower singular values can be discarded without significant change in the quality as these values contain negligible information. The less number of '*k*' singular values are used to reconstruct the output image is shown in Eq.6. With less number of singular values, the reconstructed image provides low PSNR value with high compression ratio. Hence, the reconstructed image from SVD produces high MSE and there is a loss in the reconstructed image with respect to input image. As the number of singular values increases, PSNR increases but compression ratio reduces. But SPIHT technique provides more PSNR with high compression rate.SVD provides low image quality with high compression rate; SPIHT offers high quality of image with more compression. In the proposed method, the image is compressed using SVD and reconstructed image is given to SPIHT technique to get better quality output with high compression rate. Hence, the proposed compression technique is benefiting from cascading SVD followed by SPIHT technique [9].

In the proposed method, the reconstructed image from SVD is then given to SPIHT technique [8]. This technique gives more PSNR value and reasonable compression ratio compared to individual SVD and SPIHT. The encoding process, which is discussed in section 2, is carried out through the entire transformed coefficients obtained from wavelet decomposition using DWT of image. SPIHT coding consists of sorting, refinement and quantization. After the SPIHT encoding, the compressed bit stream is transmitted through the channel. At the receiver, encoded bit stream is decoded using the decoding method and the output image is decompressed using inverse DWT. The performance metrics of this proposed technique are evaluated and compared to SVD and SPIHT techniques individually [10-11]. This proposed hybrid technique of image compression and decompression is shown in Fig.3

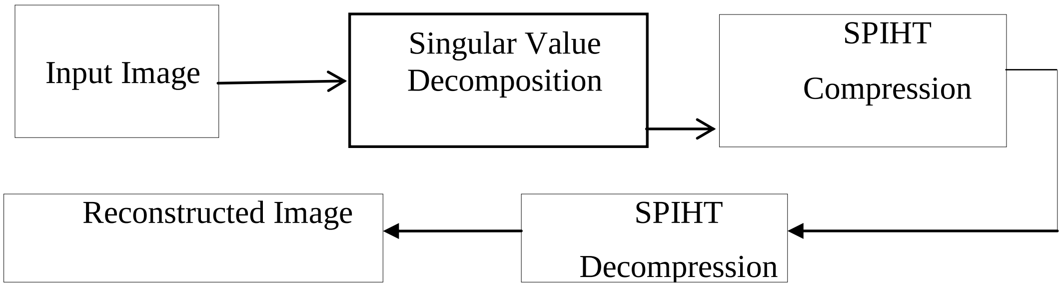


Figure 3. Block diagram of the Proposed Technique for compression and decompression of images.

3.4 Quality Metrics

The objective quality assessment methods are based on computational models,which can predict perceptual quality of images.These quality assessment methods are explained below

1. Mean Squared Error (MSE**)** offers the amount of degradation in the quality of reconstructed image compared to the input image. It's outlined in Eq.9.

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[I(i,j) - I^{'}(i,j)\right] \qquad (9)$$

Where, the size of an image is M × N. $I(i,j)$ Inputimage, Reconstructedimageis $I^{'}(i,j)$.

2. Peak Signal to Noise Ratio (PSNR) gives magnitude relation of maximum signal to noise ratio.

$$PSNR = 10\log_{10}\left(\frac{(2^{n}-1)^{2}}{MSE}\right) \qquad (10)$$

Where n is number of bits per pixel.

3. Compression Ratio (CR) is ratio of compressed image bits to original image bits and it is taken as percentage.
4. Structural Similarity Index Measurement (SSIM) is quality assessment metric predicted on the computation of luminance, contrast and structural terms.

$$SSIM = \frac{\left(2\mu_i\mu_j + c_1\right)\left(2\sigma_{ij} + c_2\right)}{\left(\mu_i^2 + \mu_j^2 + c_1\right)\left(\sigma_i^2 + \sigma_j^2 + c_2\right)} \qquad (11)$$

μ_i, μ_j and σ_i, σ_j are mean intensity and standard deviation of two images respectively. The covariance of the two images is σ_{ij} . c_1, c_2, c_3 are the regularization constants for the luminance, contrast, and structural terms and are used to avoid variability for image regions where the standard deviation or mean is nearer to zero. Hence, small non-zero values are used for as constant.

4. Results and Discussion

The input images of three brain MRI, hand X-ray, and chest X-ray are taken from Brats data set. These are experimented with individual SVD, SPIHT, and the hybrid technique. The evaluated performance metrics i.e. PSNR, MSE, CR are compared among these three techniques. Table 1 gives these experimented results with their corresponding input images. From the results, it is observed that the proposed hybrid methodology turns out additional PSNR and less MSE compared to other methods. Table 2 gives the comparison of proposed techniques with the state of art techniques [8, 11, and 12]. Fig.4 gives the input image of MRI of brain and decompressed images of SVD Technique with 50, 100 singular values, SPIHT technique with 13 encoding loops and Proposed Technique respectively. From the results, it is observed that the proposed method for medical images produce more PSNR and less MSE compared to SPIHT and SVD methods alone.

Table 1 Quality measures of compression techniques

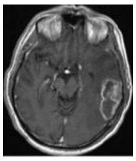
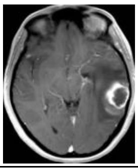
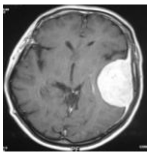
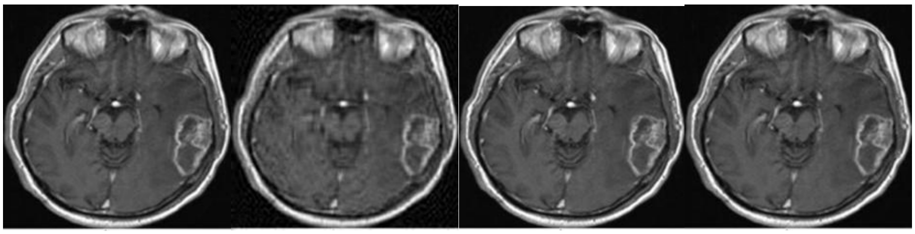
Input Image	Size of Input Image	Compression Techniques	MSE	PSNR (dB)	CR (%)	Size of Output Image (KB)	SSIM
(a) 	76KB	SVD	88.727	28.6502	50.8	37.39	0.5819
		SPIHT	6.0659	40.3019	44.92	41.86	0.7993
		Proposed	2.1914	44.7236	43.48	42.95	0.9689
(b) 	128KB	SVD	95.024	27.8271	51.32	70.5	0.5642
		SPIHT	6.9779	39.6935	46.78	68.12	0.7668
		Proposed	2.3937	44.3453	46.06	69.04	0.9566
(c) 	20KB	SVD	145.15	26.5124	53.2	9.36	0.5261
		SPIHT	7.7884	39.2163	49.23	10.15	0.7957
		Proposed	2.4041	44.3212	48.68	10.26	0.9642
(d) 	27KB	SVD	55.829	30.6624	34.36	17.72	0.4015
		SPIHT	2.9681	43.4060	28.56	19.28	0.6580
		Proposed	1.6546	45.9439	28.44	19.32	0.8676
(e) 	51KB	SVD	34.661	32.7323	40.21	30.49	0.7565
		SPIHT	2.1145	44.8787	36.31	32.48	0.9291
		Proposed	0.9309	48.4420	34.54	33.38	0.9579

Table 2 Comparison of PSNR and MSE Values of the proposed method with state of art techniques for MRI image

Authors	PSNR (dB)	MSE
Wavelet transform and Vector quantization[14]	37.9788	10.356
PCA-SPIHT[13]	38.8807	8.558
Block BWT–MTF and hybrid fractal compression techniques[10]	39.539	7.230
Proposed method	44.7236	2.1914

Fig. 5 and Fig.6 gives bar chart representation for the variation of PSNR and MSE of proposed Hybrid technique for the images of a, b, c, d ,e respectively with the Wavelet transform and Vector quantization[14], PCA-SPIHT[10], Block BWT–MTF and hybrid fractal compression techniques[13].



(a)Input Image (b) Decompressed image (c)Decompressed image of (d) Decompressed image of

for 50 singular values SPIHT Technique Proposed hybrid method

Figure 4.Input image (brain MRI) and decompressed images of SVD, SPIHT and Proposed Techniques

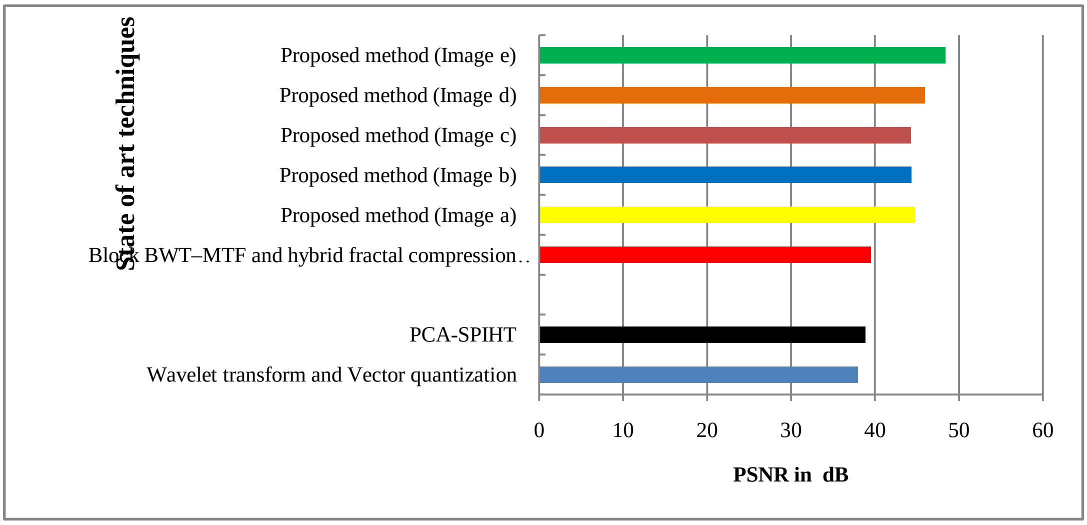


Figure 5. Bar chart for the comparison of PSNR values of proposed technique with some state of art techniques.

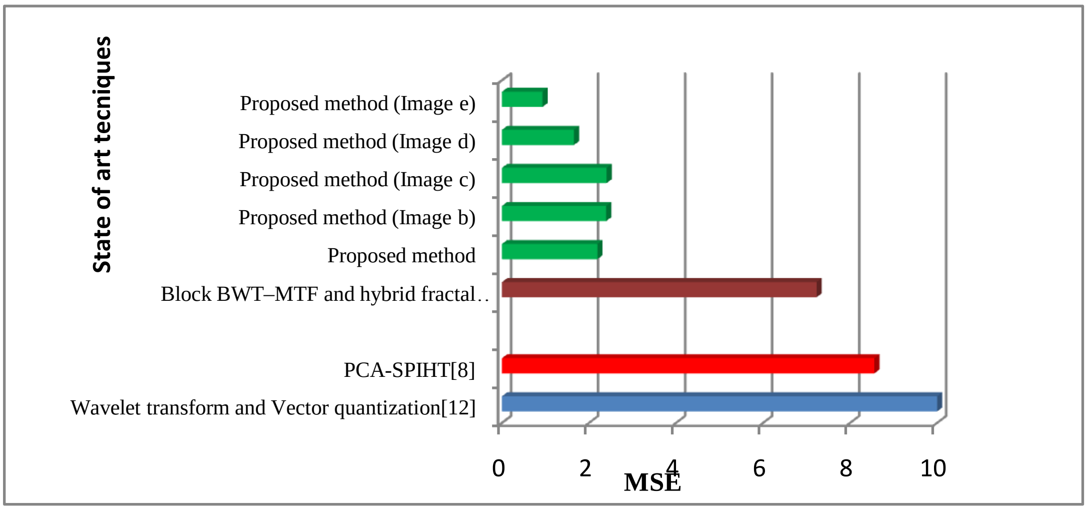


Figure 6. Bar chart for the comparison of MSE values of proposed technique with some state of art techniques.

8. Conclusion

This paper presents a proposed hybrid method which combines SVD and SPIHT techniques. In this hybrid technique, the image is compressed using SVD using less singular values and the reconstructed image is given to SPIHT technique to get better quality output with high compression rate. This hybrid technique produces more PSNR, decreased values of MSE compared to SPIHT and SVD alone. From the results, it is concluded that the proposed method of SVD-SPIHT enhances the performance of SVD and SPIHT used alone. From the results, it is also shows that proposed SVD-SPIHT algorithm produce more PSNR and less MSE compared to several state of art techniques. This hybrid approach is proficient with the advantages of each SVD, SPIHT and also reduces the memory for medical management systems.

References

MeenakshiChaudhary, AnupmaDhamija (2013), Compression of Medical Images using Hybrid Wavelet Decomposition Technique, International Journal of Science and Research (IJSR), 2(6), 269-275.

Mohammed H.Rasheed, Omar M.Salih, Mohammed M.Siddeq, Marcos A.Rodrigues(2020), Image compression based on 2D Discrete Fourier Transform and matrix minimization algorithm, Array, 6, 1-13.

J. Anitha a , P. Eben Sophia b , Le Hoang Son c,d, , Victor Hugo C. de Albuquerque e(2019) , Performance enhanced ripplet transform based compression method for medical images, Measurement, 144, 203-21.

Hong Pan, W. C. Siu and N. F. Law (2008) Efficient and low-complexity image coding with the lifting scheme and modified SPIHT, IEEE International Joint Conference on Neural Networks (IEEE World Congress on Computational Intelligence), Hong Kong, pp. 1959-1963.

Miss SamruddhiKahu, Ms.ReenaRahate(2013), Image Compression using Singular Value Decomposition, International Journal of Advancements in Research & Technology, 2(8),244-248.

Pandey, Jay Prakash and Singh Umrao, Lokendra(2019), Digital Image Processing using Singular Value Decomposition, Proceedings of 2nd International Conference on Advanced Computing and Software Engineering (ICACSE) 2019.

B. SreeVidya, Mukul Kishore, H. M. Guruprasad(2016), Wavelet Transform Analysis on Image Compression using SPIHT, International Journal of Computer Applications, 146(8), 1-7.

Ms. Sana Shafik Desai, Prof. Dr. M. S. Chavan(2017), Comparative Analysis of Singular Value Decomposition (SVD) and Wavelet Difference Reduction (WDR) based Image Compression, International Journal of Engineering Research and Technology. 10(1) 491-496.

Rufai AM, Golamreza A, demirel H.(2014),Lossy image compression using singular value decomposition and Wavelet difference reduction, Elsevier, Digital signal processing, 24, 117–23.

Rajasekhar Reddy M, Ravichandran KS, Venkatraman B, Suganya SD (2018) A new approach for the image compression to the medical images using PCA- SPIHT, Biomedical Research 2018; Special Issue, S481-S486.

S. J. Nivedita (2012) Performance Analysis of SVD and SPIHT Algorithm for Image Compression Application, International Journal of Advanced Research in Computer Science and Software Engineering, 2(2).

RanjeetKumar, A.Kumar, G.K.Singh (2016), Hybrid method based on singular value decomposition and embedded zero tree wavelet technique for ECG signal compression, Computer Methods and Programs in Biomedicine, 129, 135-148

Devadoss, C.P., Sankaragomathi, B. (2019), Near lossless medical image Compression using block BWT–MTF and hybrid fractal compression techniques , Cluster Computing, 22, 12929–12937.

Paul NiiTackieAmmah, Ebenezer Owusu(2019).Robust medical image compression based on wavelet transform and vector quantization, Informatics in Medicine Unlocked, 15, 1-11.

Nivedita,Pardeep Singh, Sonika J (2012), A Comparative Study of DCT and DWT-SPIHT, International Journal of Computational Engineering & Management, 15(2), 26-32.