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CT Scan and X-Ray Medical Images Compression using WDR and PCA techniques: A Performance Analysis

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Abstract**: *Image compression which is a subset of data compression plays a crucial task in medical field. The medical images like CT, MRI, PET scan and X-Ray imagery which is a huge data, should be compressed to facilitate storage capacity without losing its details to diagnose the patient correctly. Now a days artificial neural network is being extensively researched in the domain of image processing. This paper examines the performance of two techniques namely Principle Component Analysis (PCA) and Wavelet difference reduction (WDR). Wavelet difference reduction method is a wavelet coding technique. The potential of the techniques to compress the medical image and achieving good quality, is measured by MSE and PSNR quality metrics. The investigation is carried on CT scan of lower abdomen and X-ray scan of Rib Cage medical images.***

Index Terms**: *Image Compression, PCA, Wavelet, WDR.***

I. INTRODUCTION

Because of the vast development in communication and multimedia technology, image storage is a key task in today's scenario. Now a days, remote diagnosis of patient and treatment has been increased. With the current momentous growth in telemedicine, e-health, teleradiology and teleconsultation , the research interest has been growing in the field of medical image compression[1]. In medical field, there are various imaging technology namely Computed Tomography (CT) scan, X-Rays, Magnetic Resonance Imaging (MRI) scan, ultrasound scan , Positron- Emission Tomography (PET) scan, that is useful to diagnose the patient. These scans result a raw data that occupies large space. In medical field storing a huge data in terms of Scan and X-Ray imaging is a challenge. Therefore, compression is an important task in medical field. The image compression allows to reduce the redundant bits with adequate quality of image. This allows faster transmission of images. Medical images should be compressed in such a way that the subjective quality of the medical image is good so that the patient is diagnosed correctly i.e. the image is compressed while preserving its details.

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In this paper, Section II explains the WDR and PCA techniques, Section III discusses the performance evaluators, Section IV examines the results and after all Section V concludes the work.

II. METHODOLOGY

A. Wavelet Difference Reduction

Localization in time as well as in frequency is achieved in DWT.DWT is one of the popular method and a number of compression techniques have been developed depending on DWT [2]. Some of them are Embedded Zero tree Wavelet, Set Partitioning in Hierarchical Trees, Wavelet Difference Reduction.EZW is the basic technique introduced in wavelet domain.

In EZW, the image is first transformed, and then these transformed coefficients will be encoded. It is faster but achieves less compression ratio. SPIHT is the advanced form of EZW. In SPIHT, at threshold value, quad trees will partition the wavelet coefficients. The whole insignificant region is prearranged with only one symbol. EZW and SPIHT are based on zero tree structure while WDR technique does not rely on embedded zero [3].

In WDR, the transformed coefficients are obtained by first applying wavelet transform to the original image. There are number of wavelets such as Haar, Daubechies, biorthogonal, Symlet and so on. Image is decomposed into sub bands namely LL, LH, HL and HH using wavelet transform. The process of image decomposition and the block diagram of image compression is shown in Fig. 1.

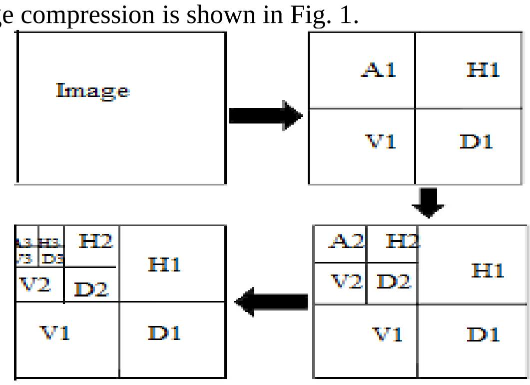


Fig. 1. Image decomposition Process

The next step is, apply bit plane encoding to the decomposed image. WDR encoding method consists of four steps namely initialization, threshold updating, significant pass, refinement pass [4]. The wavelet difference reduction encoding is illustrated with the help of a block diagram as shown in Fig. 3.The steps are explained below:

(i) Initial 'T_0' is selected in a way that T_0 > transformed coefficients and at least one $|transformed\ value| = {}^{t_0}/_{2}$. [5]
(ii) Update the value of threshold to (T_i – 1)/2 [6].
(iii) The difference of the indices of the transformed values that are greater than or equal to the value of threshold are encoded.
(iv) Refine the previous quantized value that is greater than or equal to 2T.Every refined assessment is enhanced approximation of true value.
(v) Repeat the steps from (ii) to (iv)

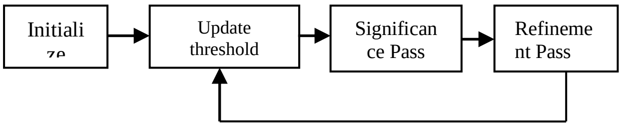


Fig. 2. Illustration of WDR encoding

B. Principle Components Analysis

Principle component analysis is a statistical technique that maps a huge data set to a reduced data set. PCA is also known as Karhunen Loeve transform or Hotelling transform [7],[8]. PCA consists of orthogonal vectors which are uncorrelated. This technique transforms the likely correlated variables into lesser number of variables which are called as principle components[9],[10]. It constructs new set of data called principle components which are orthogonal and uncorrelated with each other. These orthogonal linear combinations of original variables have largest variance. These principle components give the maximum variance direction. The maximum variance is for first principle component , second principle component has second leading variance and so on[11]. The dimension reduction technique, PCA, can be summarized into four key steps. They are, image normalization, covariance matrix calculation, finding Eigen vectors and Eigen values and finally projecting onto a new space. The brief explanation of the steps involved in PCA is given below:

- *Image Normalization*

Take the original input image 'O' of size a x b and obtain a mean centered matrix 'D' by subtracting the mean M calculated using (1) from every column of O as in (2) [12].

$$M = \frac{1}{j}\sum_{b=1}^{j} O_b \tag{1}$$

$$D_k = O_k - \mathrm{M} \tag{2}$$

- *Covariance Matrix*

In the dataset, trace the maximum variance. That is, construct the covariance matrix C using (3)

$$C = \frac{1}{j}\sum_{b=1}^{j} D_b D_b^T \tag{3}$$

- *Eigen Vectors and Eigen Values*

Eigen vector gives the direction of the maximum variance in the image. Eigen vectors are called principle components. Hence Eigen values and eigen vectors of the covariance matrix is found from the characteristic equation[13]. This step provides significant information and characteristic of the data. Sort the eigen values and the associated eigen vectors in descending order. The dominant principle components are considered while ignoring the rest.

- *Projection onto New dataset*

This step projects the original image onto new dataset which is of reduced dimension using (4)

$$O_{transformed} = E^T O_{normaliz} \tag{4}$$

Where E^T is the Eigen vector matrix transpose and $O_{normaliz}$ is the normalized original dataset.

III. PERFORMANCE EVALUATORS

The image quality is calculated using the metrics like Mean Square Error, MSE; Peak Signal to Noise ratio, PSNR and Structural Similarity Index Measure, SSIM. These define the reconstructed image quality at the output layer of ANN. The MSE should be possibly small i.e. the mean square error must be zero for ideal decompression.

$$MSE = \frac{1}{kl}\sum_{m=0}^{k-1}\sum_{n=0}^{l-1}[O(m,n) - R(m,n)]^2 \tag{5}$$

$$PSNR = 20\ log\left(\frac{Max_i}{\sqrt{MSE}}\right)\ \text{dB} \tag{6}$$

Where, O and R indicate the original and reconstructed images and Max_i represents the maximum of pixel value. Compression Ratio is given by the following formula,

$$CR = \frac{uncompressed\ image\ size}{compressed\ image\ size} \tag{7}$$

IV. RESULTS & DISCUSSION

The performance of two image compression techniques Principle component analysis and wavelet difference reduction has been tested on medical images. Experiment is carried on lower abdomen CT scan and X-ray scan of rib cage. Table I provides information on the objective quality measures like PSNR, MSE so on. The average deviation of reconstructed image from the original image is MSE and quality of the image is given by PSNR. Table I shows variation of these quality measures with respect to the principle components. The number of PC's has been varied from 5 to 100 in steps of 5. It can be clearly seen that, as the number of principle components are increased the PSNR is increasing and MSE is decreasing for both CT scan and X-ray scan medical images. For x-ray scan image the compression achieved is less while achieving more PSNR than the compression and PSNR of CT scan medical image with the same principle components. The maximum PSNR and minimum MSE for CT scanned lower abdomen is 53.077 and 0.212, and for X-ray scanned rib cage is 47.1604 and 0.6225.

Table II illustrates the variation of PSNR and MSE with increasing the number of encoding loops. As the encoding loops are increasing the relative error between original image and reconstructed image is decreasing. The medical images is decomposed using biorthogonal wavelet with level of decomposition as'4'. The maximum PSNR and minimum MSE for CT scanned lower abdomen is 46.73 and 1.38, and for X-ray scanned rib cage is 51.86 and 0.4233. Fig.3 and Fig. 4 shows the original and reconstructed images of CT scanned lower abdomen and X-ray scanned rib cage medical images for different values of principle components. It is clearly seen that as principle components increasing the clarity of the image increases for both the medical images. Following figures measures the subjective fidelity i.e. perception of human eye while tabular forms gives the objective fidelity.

Fig.5 and Fig. 6 shows the original and reconstructed images for WDR technique. As the number of encoding loops increases, the subjective fidelity improves.

Table 1 – Quality metrics for various principle components for CT Scan lower abdomen and X-ray scan of Rib cage

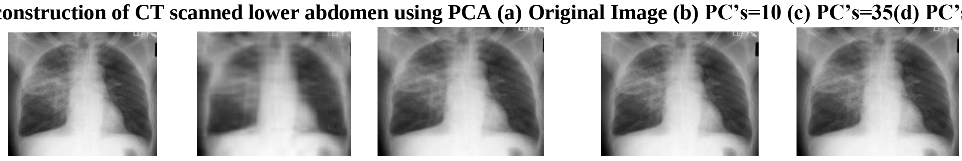
PC's	Lower Abdomen CT Scan				Rib cage X-Ray scan			
	MSE	PSNR	%CR	BPP	MSE	PSNR	%CR	BPP
5	604.213	20.5277	77.9400	6.2352	112.2450	27.7721	36.5600	2.9248
10	298.412	23.0796	74.6400	5.9712	48.575	32.3126	30.9600	2.4768
15	190.02	25.0562	71.6600	5.7328	20.2501	34.5942	27.3000	2.1840
20	138.141	26.8630	69.8800	5.5904	16.2150	36.3151	24.1300	1.9304
25	93.7481	28.5535	68.5900	5.4872	15.7990	37.5576	21.4300	1.7144
30	65.412	30.1049	67.8900	5.4312	8.5565	38.6139	19.3900	1.5512
35	53.12	31.6325	67.0700	5.3656	7.6901	39.4953	16.9500	1.3560
45	21.1436	34.5515	65.8900	5.2712	5.2100	41.0478	13.3800	1.0704
50	17.6201	35.9461	65.5800	5.2464	4.5592	41.7045	11.6500	0.9320
55	15.001	37.3421	65.2200	5.2176	3.7540	42.3154	9.6000	0.7680
60	9.015	38.7056	65.0400	5.2032	3.4240	42.8806	8.4300	0.6744
65	7.169	40.1162	65.0000	5.2000	3.7774	43.4442	7.0700	0.5656
70	4.952	41.7032	64.9600	5.1968	2.8650	44.0032	6.1500	0.4920
80	1.972	45.1653	64.7400	5.1792	2.1012	45.0649	4.1900	0.3352
90	0.5284	48.7033	64.5400	5.1632	1.6200	46.1214	2.8800	0.2304
95	0.4071	50.7642	64.4500	5.1560	0.8950	46.6424	2.4400	0.1952
100	0.212	53.0077	64.3400	5.1472	0.6225	47.1604	2.2800	0.1824

Table II – Performance analysis of WDR technique on CT scan and X-ray scan medical image for various encoding loops.

No. of Encoding loops	CT Scan				X-Ray			
	MSE	PSNR	% CR	BPP	MSE	PSNR	% CR	BPP
2	1361.00	16.79	0.38	0.030029	776.4	19.23	0.36	0.029053
3	842.20	18.88	0.51	0.040894	193.6	25.26	0.49	0.039429
4	526.80	20.91	0.83	0.066528	95.97	28.31	0.58	0.0466
5	280.10	23.66	1.69	0.13501	50.3	31.11	0.74	0.059113
6	127.60	27.07	3.62	0.28979	24.91	34.17	1.05	0.083893
7	45.48	31.55	7.39	0.59143	13.65	36.78	1.66	0.133
8	17.12	35.8	13.02	1.0415	7.082	39.63	3.05	0.24405
9	6.37	40.09	21.78	1.7421	3.383	42.84	6.22	0.49768
10	2.68	43.85	34.35	2.7482	1.564	46.19	12.51	1.0011
12	1.38	46.73	60.64	4.8513	0.4233	51.86	37.99	3.0395
14	1.38	46.73	60.64	4.8513	0.4233	51.86	37.99	3.0395

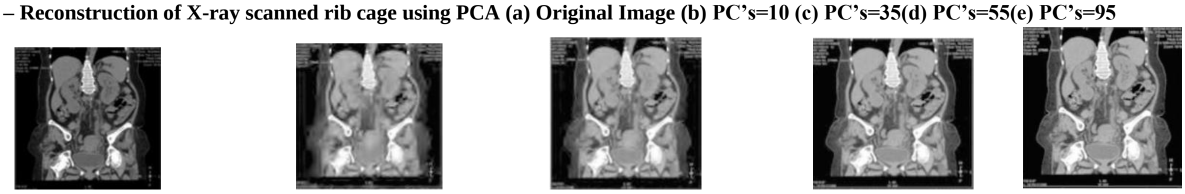
(a) (b) (c) (d) (e)

Fig. 3 – Reconstruction of CT scanned lower abdomen using PCA (a) Original Image (b) PC's=10 (c) PC's=35(d) PC's=55(e) PC's=95



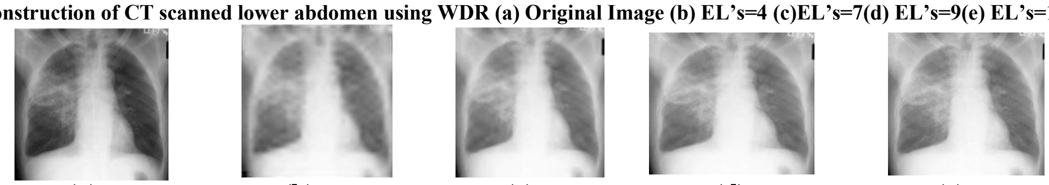
(a) (b) (c) (d) (e)

Fig. 4 – Reconstruction of X-ray scanned rib cage using PCA (a) Original Image (b) PC's=10 (c) PC's=35(d) PC's=55(e) PC's=95



(a) (b) (c) (d) (e)

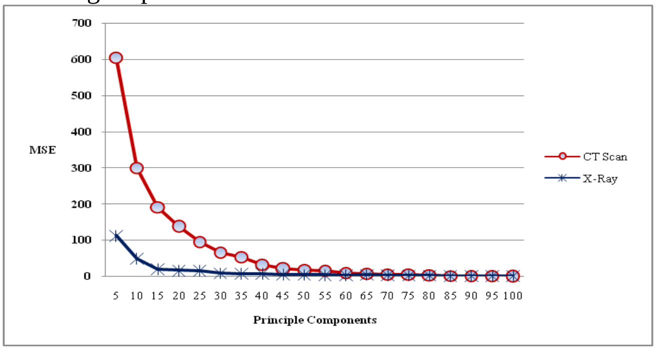
Fig. 5 – Reconstruction of CT scanned lower abdomen using WDR (a) Original Image (b) EL's=4 (c)EL's=7(d) EL's=9(e) EL's=11



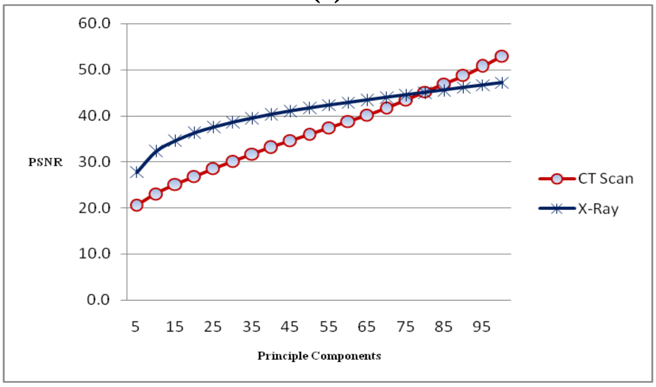
(a) (b) (c) (d) (e)

Fig. 6 – Reconstruction of X-ray scanned rib cage using WDR (a) Original Image (b) EL's=4 (c)EL's=7(d) EL's=9(e) EL's=11

Fig. 7 and Fig. 8 shows the variation of MSE and PSNR with respect to principle components and with respect to encoding loops.

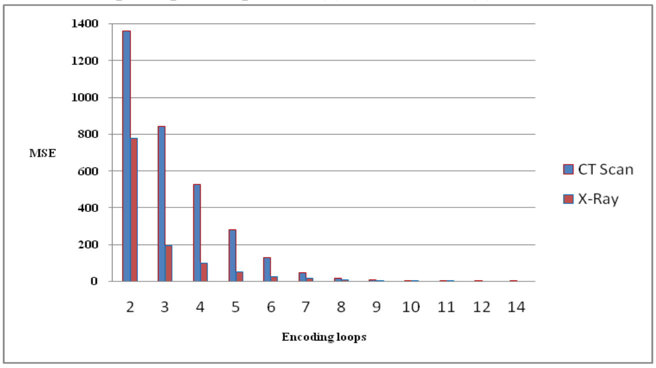


(a)

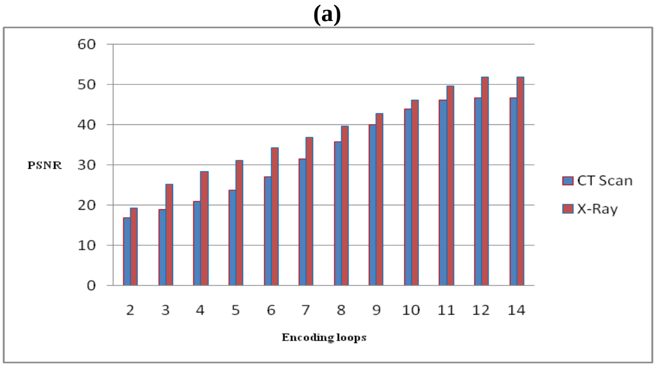


(b)

Fig. 7 – Graphs illustrating variation of quality metrics with different principal components (a)MSE vs PC's (b)PSNR vs PC's



(a)



(b)

Fig. 8 – Graphs illustrating variation of quality metrics with different Encoding loops (a)MSE Vs EL's (b) PSNR Vs EL's

V. CONCLUSION

In this work Principle component analysis and wavelet difference reduction techniques are performed for image compression. PCA uses dimensionality reduction property while WDR is based on wavelet transform. PCA projects the original image onto lower dimensionality space .In PCA, the accurateness of the outcome obtained depends on the number of principle components chosen. Reducing the image dimensions may reduce the transmission time but it has to be done with an acceptable quality which is important for medical images. In WDR, the accurateness of the outcome obtained depends on the number of encoding loops. When compared to WDR, image compression with PCA yields better quality for both CT scanned lower abdomen and X-ray of rib cage medical image. For CT scan, PCA performs better compared to X-ray scan while WDR reconstructs the X-ray image better than PCA.

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