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Comparative performance of two dimensional transforms for Magnetic Resonance Angiography image compression

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Abstract: ***Magnetic Resonance Angiography (MRA) is used to image blood vessels. The enhancement in image compression is largely related to fast and efficient methods for the storage and transmission of information between individuals. This effort examines the comparative performance of two dimensional Discrete Cosine transform (DCT), two dimensional Essentially Non-Oscillatory cell average (ENOCA) transform, two dimensional Maxlift transform, two dimensional Medlift transform methods using analysis of variance (ANOVA) for MRA image compression. There was no significant effect of different MRA image on peak signal to noise ratio (PSNR). In each transform, PSNR increases with an increase in bit per pixel (bpp). Two dimensional DCT performs well among the different transforms in terms of quality and compression of image.***

Keywords: SPHIT algorithm; peak signal to noise ratio; non-linear transform.

I. INTRODUCTION

Magnetic Resonance Angiography (MRA) is used to image blood vessels, a technique based on Magnetic Resonance Imaging (MRI) [1]. Imaging speed is important in many MRA applications. MRA images take large storage and time to transmission [1]. It is an urgent need to reduce the amount of acquired data without degrading the image quality. However, there is not much published data on MRA image compression with different transforms. Therefore, the research work was done by evaluating the performance of two dimensional Discrete Cosine transform (DCT), two dimensional Essentially Non-Oscillatory cell average (ENOCA) transform, two dimensional Maxlift transform, two dimensional Medlift transform methods for MRA image compression.

Section II describes the performance metrics. Section III presents the methodology. Finally, results and concluding remarks are given in section IV and V respectively.

II. PERFORMANCE METRICS

The performance of different transforms was measured by calculating the peak signal to noise ratio (PSNR) in dB. It was found that the performance evaluation criteria which best matches the individual visual quality of the image was the PSNR. For this cause, importance was placed on the PSNR. Typical values for the PSNR in Lossy image compression were between 30 and 50 dB, provided the bit depth is 8 bits, where higher was better [2, 3, 4]. For 16-bit data typical values for the PSNR were between 60 and 80 dB. In the absence of noise the PSNR was infinite.

$$\text{PSNR} = 10\log_{10}\left(\frac{255^2}{\text{MSE}}\right)\text{dB}$$

Where, MSE is mean squared-error between the original and reconstructed images. The bit rates are not entropy estimates, they were calculated from the actual size of the compressed files [5].

III. METHODOLOGY

In this study, four transforms (two dimensional Discrete Cosine transform (DCT), two dimensional Essentially Non-Oscillatory cell average (ENOCA) transform, two dimensional Maxlift transform and two dimensional Medlift transform) were used for comparison. There was set of 75 samples images available on physiobank database [6]. Out of these, 20 sample images were selected randomly for this study. In two dimensional ENOCA transform, MRA image was transformed with three stages and five-degree interpolation. Levels used for decomposition was 3 in case of two dimensional Maxlift and two dimensional Medlift transform. These images were transformed in to above said transforms independently. These transformed coefficients were encoded by using SPHIT algorithm [5]. The compression was done at different ranges varied from 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 bit per pixel. Compression ratio (CR) was calculated as follows:

CR= maximum bits / Total bits (262144)

Maximum bits were 26214, 52428, 78643, 104857, 131072, 157286, 183500, 209715 and 235929 at 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 bit per pixel, respectively.

The compressed MRA images decoded for reconstruction by using SPHIT algorithm [5] followed by inverse transforms. Then the reconstructed MRA images were compared with original MRA images and peak signal to noise ratio (PSNR) was calculated to check the MRA image quality. The data were analyzed by analysis of variance (ANOVA) to check the significant difference within and between transforms at various ranges of bit per pixel in various images. In ANOVA, there was significant difference only in case of $p< 0.05$.

Visual comparison of linear transforms for MRA image compression was done between original and reconstructed image by selecting E1154S7100 image only. The three different bpp values (0.1, 0.5 and 0.9) were taken to check the image quality.

IV. RESULTS AND DISCUSSION

The average PSNR varied from 29.76 to 33.31 in different MRA images in two dimensional DCT (Table 1). There were no significant effects of different MRA images on PSNR (Table 5). However, PSNR significantly ($p <0.05$) increases with an increase in bits per pixel (bpp) (Table 5). Average PSNR in different bpp was higher by 8.7, 15, 20.8, 25.8, 30, 34.1, 37.9, and 41.1 per cent in bpp of 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9, respectively compared to 0.1.

Similar were the findings in two dimensional ENOCA transform, two dimensional Maxlift transform and two dimensional Medlift transform (Table 2-4). However, average PSNR in different images of MRA varied from 17.49 to 20.95, 17.50 to 21.77 and 17.77 to 21.61 in two dimensional ENOCA transform, two dimensional Maxlift transform and two dimensional Medlift transform respectively. Likewise in two dimensional DCT, average PSNR in two dimensional ENOCA transform, two dimensional Maxlift transform and two dimensional Medlift transform increased with an increase in bpp but the magnitude was different. Similar findings were reported earlier [5]. They observed that with an increase in bpp, PSNR increases in WT using SPHIT algorithm. However, they did not report these results on medical images in comparison to present study.

Average PSNR of different transforms were compared to check the performance of transform. There were significant difference among the transforms image wise and bpp wise (Table 6). The highest average PSNR was observed in two dimensional DCT (32.04) followed by two dimensional Medlift transform (19.77), two dimensional Maxlift transform (19.75) and lowest in two dimensional ENOCA transform (19.21).

As there was no significant difference between different MRA images on PSNR, only one image (E1154S71000) was selected for visual comparison. With an increase in bpp value, the quality of reconstructed image improved (Fig. 1-4).

TABLE I Performance of MRA compression with two dimensional DCT on different MRA images.

Two Dimensional DCT											
Sno.	**MRA Image**	**bit per pixel**									**Mean**
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	
1	E1154S71000	25.52	27.61	29.15	30.55	31.81	32.93	33.76	34.83	35.74	31.32
2	E1154S71001	25.97	28.18	29.78	31.2	32.47	33.56	34.52	35.57	36.38	31.96
3	E1154S71002	26.13	28.38	29.92	31.37	32.61	33.7	34.74	35.71	36.52	32.12
4	E1154S71003	26.12	28.28	29.83	31.27	32.52	33.59	34.63	35.59	36.36	32.02
5	E1154S71004	25.89	28	29.55	30.96	32.18	33.26	34.13	35.15	35.92	31.67
6	E1154S71005	25.56	27.6	29.16	30.51	31.74	32.79	33.62	34.65	35.51	31.24
7	E1154S71010	24.12	26.13	27.67	29.02	30.28	31.38	32.29	33.01	33.95	29.76
8	E1154S71015	25.04	27.25	28.87	30.24	31.52	32.63	33.5	34.49	35.38	30.99
9	E1154S71020	25.69	27.96	29.66	31.15	32.48	33.61	34.57	35.66	36.48	31.92
10	E1154S71025	26.06	28.47	30.18	31.73	33.04	34.11	35.22	36.24	36.98	32.45
11	E1154S71030	26.06	28.48	30.18	31.78	33.13	34.22	35.37	36.43	37.21	32.54
12	E1154S71035	26.58	29.11	30.8	32.53	33.9	35.02	36.31	37.3	38.21	33.31
13	E1154S71040	26.14	28.68	30.45	32.15	33.5	34.58	35.86	36.85	37.69	32.88
14	E1154S71045	25.9	28.33	30.14	31.74	33.15	34.32	35.48	36.59	37.38	32.56
15	E1154S71050	26.12	28.48	30.23	31.85	33.24	34.37	35.56	36.65	37.42	32.66
16	E1154S71055	26.1	28.57	30.32	31.97	33.32	34.42	35.64	36.68	37.46	32.72
17	E1154S71060	26.24	28.58	30.23	31.78	33.07	34.16	35.27	36.31	37.08	32.52
18	E1154S71065	26.79	29.02	30.61	32.19	33.47	34.46	35.63	36.56	37.36	32.90
19	E1154S71070	27.24	29.56	31.17	32.62	33.82	34.86	35.96	36.84	37.59	33.30
20	E1154S71075	24.74	26.61	27.99	29.16	30.42	31.49	32.39	33.14	34.09	30.00
	Mean	25.90	28.16	29.79	31.29	32.58	33.67	34.72	35.71	36.54	32.04

TABLE II Performance of MRA compression with two dimensional ENOCA Transform on different MRA images.

Two Dimensional ENOCA Transform										
Sno.	MRA Image	bit per pixel								Mean
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
1	E1154S71000	18.31	17.8	19.15	18.95	18.82	18.71	18.64	19.76	19.94	18.90
2	E1154S71001	18.54	18.65	19.34	19.09	18.96	18.89	20.1	20.28	20.27	19.35
3	E1154S71002	18.49	19.39	19.45	19.25	19.12	19.06	20.52	20.38	20.36	19.56
4	E1154S71003	18.4	19.8	19.62	19.43	19.41	19.26	20.38	20.31	20.31	19.66
5	E1154S71004	18.4	19.5	19.69	19.56	19.41	19.33	20.42	20.33	20.32	19.66
6	E1154S71005	18.04	17.63	19.04	18.87	18.73	18.64	18.8	20.07	20.06	18.88
7	E1154S71010	17.18	17.09	17.41	17.9	17.71	17.64	17.54	17.5	17.46	17.49
8	E1154S71015	18.03	17.67	18.72	18.46	18.25	18.16	18.12	19.42	19.58	18.49
9	E1154S71020	17.92	18.72	18.78	18.64	18.49	18.4	19.94	20.05	20.05	19.00
10	E1154S71025	18.18	19.65	19.29	19.15	19.02	19.22	20.08	20.06	20.01	19.41
11	E1154S71030	18.26	19.18	18.8	18.61	18.49	19.57	20.12	19.98	19.91	19.21
12	E1154S71035	18.09	19.29	19.1	18.95	18.9	19.85	19.87	19.89	19.86	19.31
13	E1154S71040	17.48	18.73	18.62	18.46	18.36	19.61	19.71	19.71	19.67	18.93
14	E1154S71045	17.36	18.49	18.36	18.33	18.23	19.12	19.34	19.28	19.27	18.64
15	E1154S71050	17.94	19.02	18.91	18.76	18.65	19.86	19.92	19.86	19.83	19.19
16	E1154S71055	17.97	19.23	19.19	19.01	18.91	20.23	20.21	20.16	20.13	19.45

17	E1154S71060	18.41	19.21	19.18	19.03	18.91	20.12	20.29	20.23	20.2	19.51
18	E1154S71065	19	20.18	20.05	19.93	19.81	21.05	21.16	21.13	21.09	20.38
19	E1154S71070	19.54	20.76	20.47	20.27	21.56	21.53	21.53	21.46	21.45	20.95
20	E1154S71075	17.6	17.3	18.48	18.19	18.09	17.98	17.91	18.8	19.28	18.18
	Mean	18.16	18.86	19.08	18.94	18.89	19.31	19.73	19.93	19.95	19.21

TABLE III Performance of MRA compression with two dimensional Maxlift Transform on different MRA images.

Two Dimensional Maxlift Transform											
Sno.	**MRA Image**	**bit per pixel**									**Mean**
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	
1	E1154S71000	14.57	16.23	16.82	19.16	20.35	21.02	21.41	21.74	22.05	19.26
2	E1154S71001	14.81	16.16	17.59	19.2	19.86	20.2	20.53	21.72	23.2	19.25
3	E1154S71002	15.48	16.7	18.39	19.7	20.35	20.67	21.01	22.1	23.72	19.79
4	E1154S71003	15.59	16.83	18.55	19.84	20.49	20.8	21.11	22.4	23.97	19.95
5	E1154S71004	15.18	16.28	18.08	19.35	19.98	20.29	20.59	22.27	23.81	19.54
6	E1154S71005	15.01	16.1	17.8	19.23	19.99	20.45	20.82	21.13	21.6	19.13
7	E1154S71010	13.32	14.9	15.58	16.38	18.45	19.16	19.65	19.88	20.17	17.50
8	E1154S71015	14.25	15.6	16.34	18.49	19.64	20.25	20.61	20.97	21.23	18.60
9	E1154S71020	14.91	15.94	17.83	19.15	19.85	20.18	20.5	21.44	23.05	19.21
10	E1154S71025	15.67	16.72	18.69	19.93	20.47	20.8	21.06	22.33	23.95	19.96
11	E1154S71030	15.48	16.55	18.76	19.8	20.37	20.78	21.06	22.64	24.2	19.96
12	E1154S71035	15.84	16.96	19.32	20.11	20.56	20.93	22.71	24.23	25.08	20.64
13	E1154S71040	15.87	17.15	19.22	20.16	20.62	20.96	22.1	23.84	24.88	20.53
14	E1154S71045	15.7	16.94	18.81	19.99	20.66	21.04	21.37	22.61	24.28	20.16
15	E1154S71050	15.46	16.77	18.77	19.99	20.63	21.06	21.37	23.08	24.58	20.19
16	E1154S71055	15.31	16.66	18.7	19.81	20.36	20.75	21.36	23.26	24.63	20.09
17	E1154S71060	15.73	17.08	19.08	20.21	20.85	21.25	21.57	22.97	24.7	20.38
18	E1154S71065	16.13	17.23	19.25	20.07	20.44	20.77	22.69	24.33	25.11	20.67
19	E1154S71070	16.79	17.84	20.3	21.13	21.59	21.94	24.14	25.69	26.49	21.77
20	E1154S71075	13.64	15.8	16.44	18.29	19.49	20.1	20.42	20.77	21.16	18.46
	Mean	15.24	16.52	18.22	19.50	20.25	20.67	21.30	22.47	23.59	19.75

TABLE IV Performance of MRA compression with two dimensional Medlift Transform on different MRA images.

Two Dimensional Medlift Transform											
Sno.	**MRA Image**	**bit per pixel**									**Mean**
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	
1	E1154S71000	15.08	16.66	17.18	17.47	19.17	20.37	20.87	21.25	21.43	18.83
2	E1154S71001	15.85	17.34	17.79	18.76	20.44	21.04	21.48	21.68	21.87	19.58
3	E1154S71002	16.19	17.67	18	19.33	20.62	21.26	21.52	21.7	21.88	19.80
4	E1154S71003	16.46	17.83	18.09	19.42	20.44	21.25	21.56	21.77	21.92	19.86
5	E1154S71004	16.36	17.51	17.86	19.02	20.5	21.08	21.47	21.65	21.83	19.70
6	E1154S71005	16.12	17.2	17.47	17.76	19.92	20.59	21.1	21.34	21.48	19.22
7	E1154S71010	14.74	15.16	16.32	16.61	16.93	18.85	19.99	20.51	20.84	17.77
8	E1154S71015	15.6	16.59	17.19	17.44	19.01	20.29	20.79	21.27	21.45	18.85
9	E1154S71020	15.9	17.17	17.58	18.53	20.2	20.88	21.28	21.48	21.66	19.41
10	E1154S71025	15.97	17.52	17.82	19.32	20.69	21.24	21.57	21.75	21.99	19.76
11	E1154S71030	16.15	17.56	18.02	19.65	20.87	21.37	21.62	21.83	22.09	19.91
12	E1154S71035	16.75	18.09	18.35	20.58	21.36	21.68	21.9	22.75	24.77	20.69

13	E1154S71040	16.46	17.8	18.07	20.23	20.99	21.41	21.66	22.06	24.35	20.34
14	E1154S71045	16.19	17.64	17.95	19.56	20.89	21.39	21.7	21.88	22.2	19.93
15	E1154S71050	16.1	17.92	18.17	20.04	20.95	21.48	21.77	22.02	23.04	20.17
16	E1154S71055	16.15	18.02	18.29	20.27	21.19	21.66	21.91	22.11	23.75	20.37
17	E1154S71060	16.03	17.88	18.24	19.98	21.02	21.58	21.84	22.03	22.47	20.12
18	E1154S71065	17.07	18.16	18.53	20.71	21.36	21.83	22.03	22.71	24.68	20.79
19	E1154S71070	18.13	18.82	19.74	21.35	22.02	22.29	22.53	24.14	25.43	21.61
20	E1154S71075	14.46	16.2	17.15	17.43	18.94	20.28	20.9	21.27	21.45	18.68
	Mean	16.09	17.44	17.89	19.17	20.38	21.09	21.47	21.86	22.53	19.77

TABLE V Comparison within transform by using ANOVA

ANOVA Test with in transform (p<0.05)				
	Two Dimensional DCT	**Two Dimensional ENOCA Transform**	**Two Dimensional Maxlift Transform**	**Two Dimensional Medlift Transform**
Image wise	0.84	$1.87x10^{-19}$	0.22	0.42
rate bit per pixel	$7.48x10^{-91}$	$6.29x10^{-12}$	$1.48x10^{-64}$	$2.34x10^{-70}$

TABLE VII Comparison of different transform by using ANOVA

ANOVA Test on transforms (p<0.05)				
	Two Dimensional DCT	**Two Dimensional ENOCA Transform**	**Two Dimensional Maxlift Transform**	**Two Dimensional Medlift Transform**
Image wise	$4.54x10^{-61}$			
rate bit per pixel	$9.94x10^{-13}$			

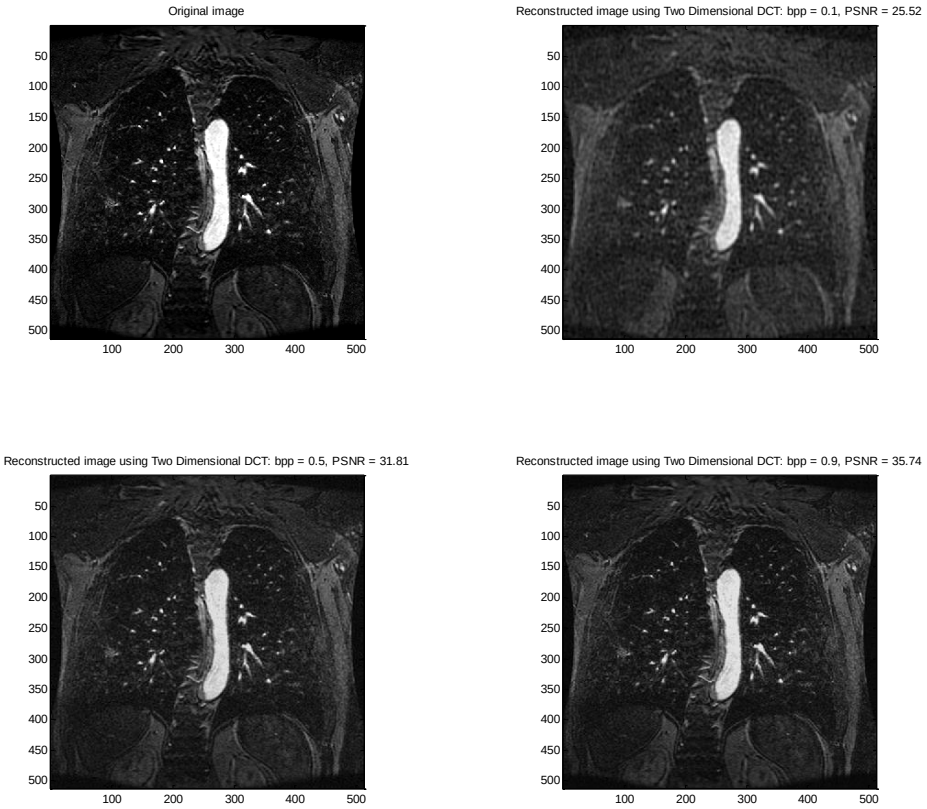

Fig. 1 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Two Dimensional DCT

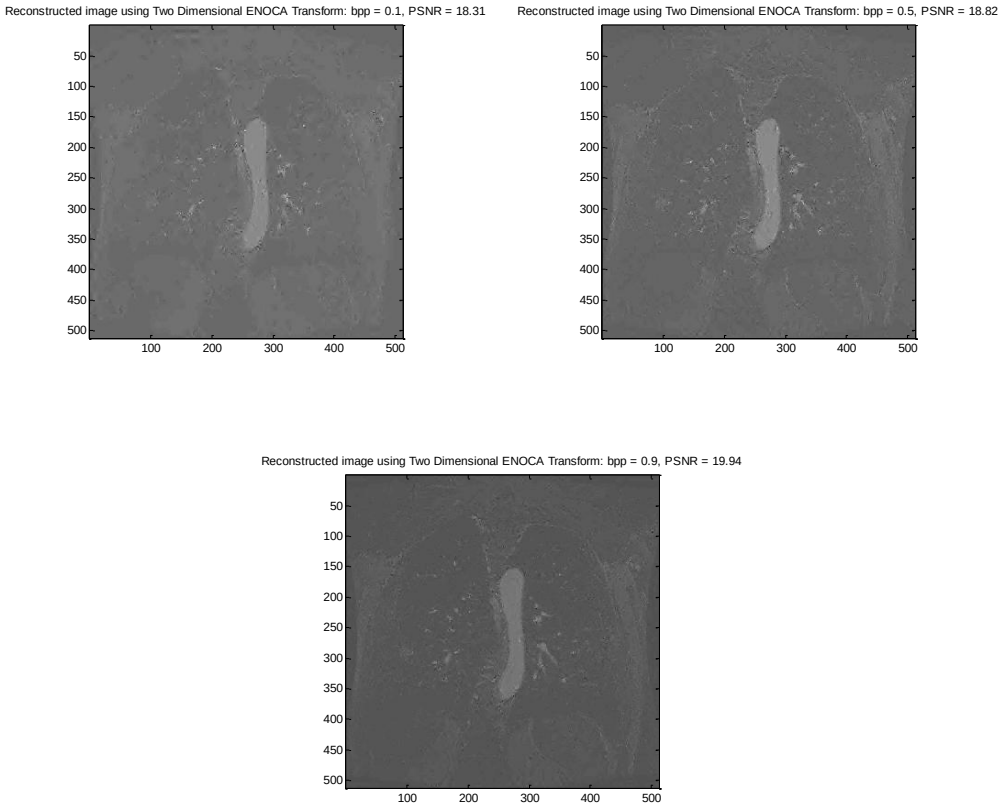

Fig. 2 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Two Dimensional ENOCA Transform .

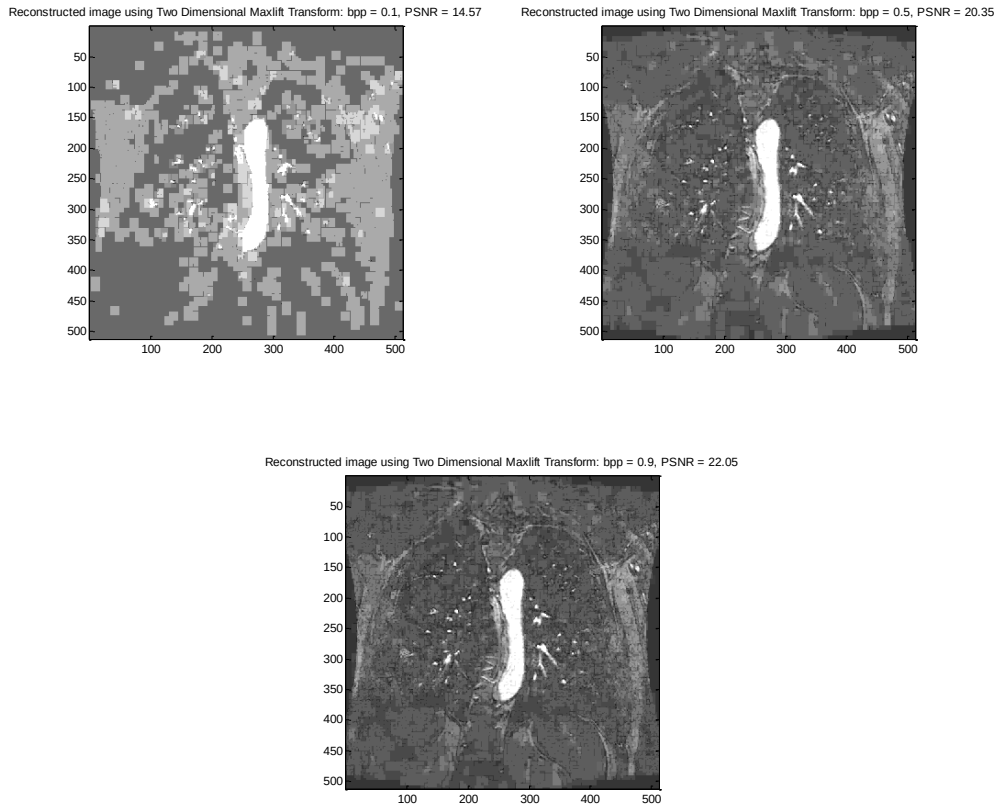

Fig. 3 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Two Dimensional Maxlift Transform .

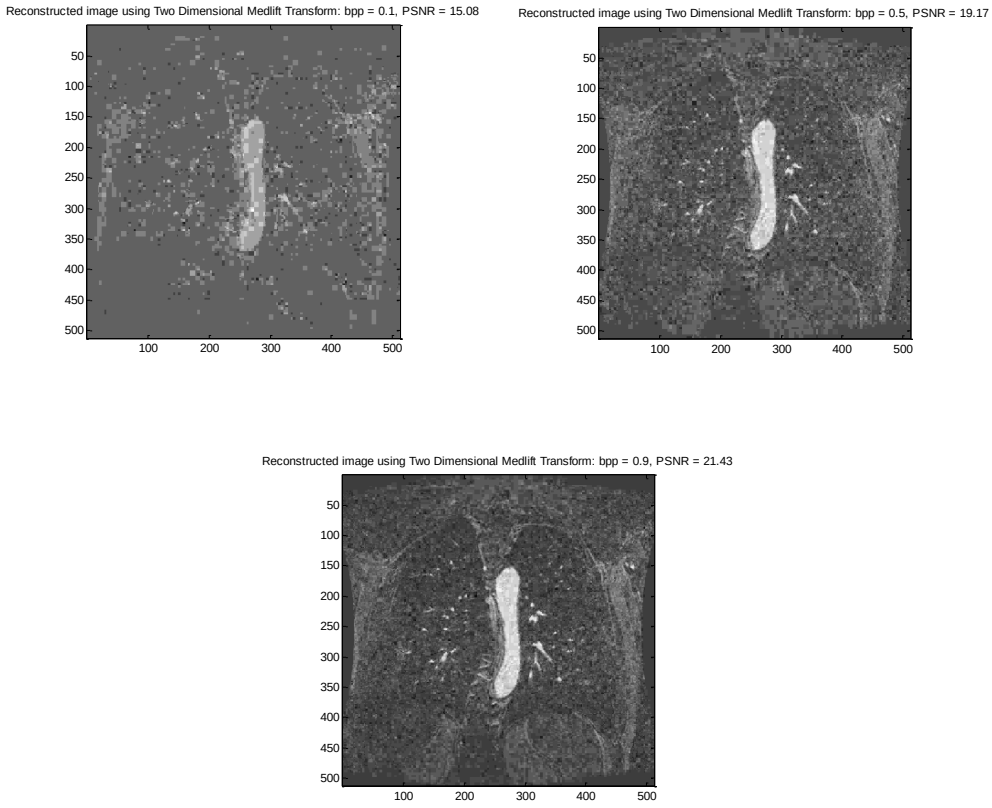

Fig. 4 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Two Dimensional Medlift Transform .

V. CONCLUSION

There was no significant effect of different images on PSNR. With an increase in bpp value, quality of image improved. Two dimensional DCT performed better among all the transforms in terms of quality and compression of image. Future research need to done by comparing different transforms by using different techniques for MRA image compression.

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