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Comparative Performance of Different Linear 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 Wave Atom Transform (WAT), Discrete Cosine Transform (DCT), Discrete Sine Transform (DST) and Wavelet Transform (WT) 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). Wavelet transform performs well among the different transforms in terms of quality and compression of image. Future work needs to done by comparing different transforms by using different techniques for MRA image compression.

Key words: Wave Atom Transform, Discrete Cosine Transform, Discrete Sine Transform, Wavelet Transform

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INTRODUCTION

Magnetic Resonance Angiography (MRA) is a group of techniques based on Magnetic Resonance Imaging (MRI) to image blood vessels [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. Researchers [2-4] used Wave Atom Transform (WAT), Discrete Cosine Transform (DCT), Discrete Sine Transform (DST) and Wavelet Transform (WT) for ECG compression techniques. 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 WAT, DCT, DST and WT for MRA image compression.

PERFORMANCE EVALUATION

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 [5, 6]. For 16-bit data typical values for the PSNR were between 60 and 80 dB. In the absence of noise the PSNR was infinite.

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

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 [7].

METHODOLOGY

In this study, four transforms (Wave Atom transform (WAT), Discrete Cosine transform (DCT), Discrete Sine transform (DST) and Wavelet transform (WT)) were used for comparison. There was set of 75 samples images available on physionet.org [8]. Out of these, 20 sample images were selected randomly for this study. In the WT, MRA image is transformed using biorthogonal '6.8' and decomposition level 9. The MRA image was transformed using WAT with orthobasis. These images were transformed in to above said transforms independently. These

transformed coefficients were encoded by using SPHIT algorithm [7]. 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 [7] followed by inverse transforms. Then the reconstructed MRA images were compared with original MRA images and PSNR was calculated to check the MRA image quality. The data was analysed 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.

RESULTS AND DISCUSSION

The average PSNR varied from 30.8 to 34.8 in different MRA images in WAT (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 8.9, 15.2, 20.9, 25.4, 29.8, 34.1, 37.7, and 40.7 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 DCT, DST and WT (Table 2-4). However, average PSNR in different images of MRA varied from 25.7 to 28.8, 25.8 to 28.9 and 31.1 to 35.4, in DCT, DST and WT respectively. Likewise, in WAT, average PSNR in DCT, DST and WT increased with an increase in bpp but the magnitude was different. Similar findings were reported earlier [7]. They observed that with an increase in bpp, PSNR also 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 was significant difference among the transforms image wise and bpp wise (Table 6). The highest average PSNR was observed in WT (33.6) followed by WAT (33.3), DST (27.7) and lowest in DCT (27.6).

Table -1 Performance of MRA Compression with Wave Atom Transform on Different MRA Images

Wave Atom Transform											
S No.	MRA Image	bit per pixel									
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Mean
1	E1154S71000	26.18	28.45	30.02	31.58	32.82	33.87	35.07	36.09	36.92	32.33
2	E1154S71001	26.73	29.06	30.63	32.28	33.47	34.53	35.75	36.77	37.55	32.97
3	E1154S71002	26.96	29.28	30.88	32.46	33.64	34.69	35.93	36.91	37.68	33.16
4	E1154S71003	26.99	29.33	30.95	32.47	33.62	34.64	35.86	36.82	37.57	33.14
5	E1154S71004	26.8	29.11	30.63	32.21	33.34	34.37	35.53	36.5	37.24	32.86
6	E1154S71005	26.44	28.71	30.24	31.73	32.88	33.88	35	35.99	36.76	32.40
7	E1154S71010	24.96	27.12	28.63	29.95	31.3	32.33	33.21	34.17	35.12	30.75
8	E1154S71015	26.09	28.4	29.98	31.51	32.7	33.73	34.81	35.85	36.66	32.19
9	E1154S71020	26.6	29.02	30.63	32.27	33.48	34.53	35.74	36.73	37.48	32.94
10	E1154S71025	26.98	29.48	31.21	32.77	34.02	35.17	36.4	37.35	38.12	33.50
11	E1154S71030	27.05	29.52	31.24	32.82	34.08	35.27	36.54	37.49	38.29	33.59
12	E1154S71035	27.71	30.31	32.21	33.73	35.01	36.38	37.55	38.46	39.27	34.51
13	E1154S71040	27.32	30.01	31.94	33.48	34.74	36.13	37.34	38.25	39.07	34.25
14	E1154S71045	27.15	29.71	31.56	33.07	34.35	35.66	36.86	37.8	38.61	33.86
15	E1154S71050	27.23	29.82	31.68	33.21	34.45	35.77	36.95	37.88	38.73	33.97
16	E1154S71055	27.38	29.9	31.8	33.34	34.57	35.92	37.1	38.03	38.86	34.10
17	E1154S71060	27.45	29.81	31.65	33.15	34.38	35.68	36.85	37.76	38.56	33.92
18	E1154S71065	27.92	30.28	32.03	33.43	34.68	35.98	37.14	38.02	38.83	34.26
19	E1154S71070	28.63	30.77	32.62	33.95	35.17	36.5	37.57	38.47	39.3	34.78
20	E1154S71075	25.63	27.94	29.49	31.06	32.37	33.49	34.51	35.72	36.73	31.88
	Mean	26.91	29.30	31.00	32.52	33.75	34.93	36.09	37.05	37.87	33.27

Table -2 Performance of MRA Compression with Discrete Cosine Transform on Different MRA Images

Discrete Cosine Transform											
Sno.	MRA Image	bit per pixel									
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Mean
1	E1154S71000	22.83	24.48	25.73	26.77	27.65	28.58	29.48	30.24	30.97	27.41
2	E1154S71001	23.36	24.97	26.32	27.38	28.37	29.27	30.15	30.92	31.69	28.05
3	E1154S71002	23.49	25.18	26.51	27.57	28.57	29.51	30.36	31.13	31.92	28.25
4	E1154S71003	23.5	25.2	26.5	27.56	28.56	29.47	30.32	31.09	31.85	28.23
5	E1154S71004	23.34	24.97	26.26	27.36	28.29	29.17	30.05	30.79	31.52	27.97
6	E1154S71005	22.96	24.66	25.92	26.99	27.81	28.74	29.62	30.37	31.06	27.57
7	E1154S71010	21.27	22.9	24.23	25.33	26.33	27	27.82	28.61	29.36	25.87
8	E1154S71015	21.68	23.67	25.11	26.34	27.29	28.23	29.09	29.91	30.63	26.88
9	E1154S71020	22.14	24.19	25.78	26.96	27.83	28.84	29.77	30.53	31.28	27.48
10	E1154S71025	22.18	24.41	26.04	27.22	28.16	29.16	30.08	30.85	31.59	27.74
11	E1154S71030	21.39	23.78	25.46	26.8	27.81	28.83	29.83	30.62	31.38	27.32
12	E1154S71035	22.16	24.56	26.36	27.69	28.81	29.91	30.82	31.61	32.39	28.26
13	E1154S71040	21.84	24.21	25.98	27.29	28.35	29.44	30.43	31.25	32.04	27.87
14	E1154S71045	21.68	23.92	25.57	26.9	27.99	29.06	30.06	30.89	31.67	27.53
15	E1154S71050	21.68	23.96	25.58	26.89	27.87	28.91	29.93	30.76	31.56	27.46
16	E1154S71055	21.66	24.03	25.68	26.91	27.92	28.98	29.99	30.84	31.65	27.52
17	E1154S71060	22.35	24.46	26.03	27.18	28.13	29.16	30.1	30.93	31.68	27.78
18	E1154S71065	22.91	24.98	26.46	27.61	28.71	29.65	30.55	31.33	32.06	28.25
19	E1154S71070	23.62	25.72	27.13	28.22	29.25	30.2	31.04	31.84	32.49	28.83
20	E1154S71075	20.64	22.6	24.05	25.21	26.13	26.88	27.72	28.5	29.28	25.67
	Mean	22.33	24.34	25.84	27.01	27.99	28.95	29.86	30.65	31.40	27.60

Table -3 Performance of MRA Compression with Discrete Sine Transform on Different MRA Images

Discrete Sine Transform											
Sno.	MRA Image	bit per pixel									
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Mean
1	E1154S71000	22.86	24.49	25.78	26.84	27.7	28.63	29.52	30.26	31	27.45
2	E1154S71001	23.36	25.03	26.39	27.43	28.42	29.34	30.19	30.94	31.71	28.09
3	E1154S71002	23.5	25.23	26.56	27.63	28.62	29.56	30.4	31.17	31.93	28.29
4	E1154S71003	23.51	25.23	26.56	27.6	28.57	29.5	30.34	31.11	31.87	28.25
5	E1154S71004	23.35	25.04	26.32	27.41	28.36	29.24	30.09	30.85	31.59	28.03
6	E1154S71005	23.04	24.7	26	27.07	27.89	28.81	29.66	30.41	31.11	27.63
7	E1154S71010	21.35	22.97	24.29	25.36	26.25	27.03	27.85	28.64	29.39	25.90
8	E1154S71015	21.75	23.72	25.16	26.37	27.34	28.25	29.13	29.94	30.66	26.92
9	E1154S71020	22.17	24.3	25.85	27	27.87	28.86	29.79	30.55	31.28	27.52
10	E1154S71025	22.15	24.37	26	27.19	28.1	29.13	30.05	30.83	31.55	27.71
11	E1154S71030	21.55	23.83	25.52	26.85	27.87	28.88	29.87	30.66	31.41	27.38
12	E1154S71035	22.25	24.71	26.48	27.8	28.91	29.95	30.85	31.66	32.43	28.34
13	E1154S71040	21.94	24.27	26.09	27.35	28.4	29.5	30.46	31.25	32.01	27.92
14	E1154S71045	21.89	24.02	25.64	26.95	28.01	29.07	30.09	30.92	31.71	27.59
15	E1154S71050	21.71	23.98	25.59	26.93	27.91	28.94	29.95	30.78	31.57	27.48
16	E1154S71055	21.77	24.09	25.73	26.95	27.99	29.05	30.05	30.89	31.69	27.58
17	E1154S71060	22.45	24.52	26.1	27.27	28.22	29.24	30.17	30.98	31.71	27.85
18	E1154S71065	23.14	25.18	26.6	27.7	28.77	29.71	30.63	31.37	32.12	28.36
19	E1154S71070	23.8	25.83	27.2	28.28	29.3	30.27	31.1	31.89	32.53	28.91
20	E1154S71075	20.91	22.79	24.15	25.31	26.24	26.96	27.81	28.57	29.35	25.79
	Mean	22.42	24.42	25.90	27.06	28.04	29.00	29.90	30.68	31.43	27.65

Table -4 Performance of MRA Compression with Wavelet Transform on Different MRA Images

Wavelet Transform											
Sno.	MRA Image	bit per pixel									
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Mean
1	E1154S71000	27.11	29.11	30.66	31.96	33.02	34.02	34.95	35.79	36.46	32.56
2	E1154S71001	27.76	29.84	31.41	32.66	33.79	34.85	35.76	36.52	37.26	33.32
3	E1154S71002	28.04	30.11	31.68	32.89	34.04	35.05	35.97	36.68	37.44	33.54
4	E1154S71003	28.12	30.19	31.71	32.93	34.08	35.09	36	36.71	37.47	33.59
5	E1154S71004	27.95	29.99	31.49	32.7	33.79	34.82	35.7	36.44	37.17	33.34
6	E1154S71005	27.59	29.56	31.02	32.21	33.27	34.22	35.1	35.86	36.54	32.82
7	E1154S71010	25.89	27.87	29.27	30.51	31.56	32.5	33.36	34.19	34.97	31.12
8	E1154S71015	27.19	29.22	30.72	31.96	33.04	34.02	34.95	35.79	36.42	32.59
9	E1154S71020	27.71	29.85	31.35	32.58	33.73	34.77	35.65	36.38	37.11	33.24
10	E1154S71025	28.18	30.39	31.91	33.1	34.3	35.33	36.28	37	37.81	33.81
11	E1154S71030	28.21	30.42	31.99	33.22	34.42	35.49	36.44	37.19	38.05	33.94
12	E1154S71035	28.93	31.18	32.77	34.05	35.27	36.36	37.26	38.14	38.93	34.77
13	E1154S71040	28.58	30.93	32.56	33.81	34.99	36.11	37.04	37.9	38.74	34.52
14	E1154S71045	28.24	30.53	32.1	33.33	34.59	35.63	36.58	37.4	38.26	34.07
15	E1154S71050	28.39	30.68	32.29	33.52	34.73	35.79	36.74	37.58	38.4	34.24
16	E1154S71055	28.5	30.82	32.45	33.69	34.86	35.97	36.91	37.76	38.59	34.39
17	E1154S71060	28.46	30.67	32.31	33.51	34.7	35.77	36.68	37.47	38.32	34.21
18	E1154S71065	29.03	31.12	32.72	33.98	35.16	36.24	37.11	37.95	38.73	34.67
19	E1154S71070	29.74	31.82	33.45	34.77	35.96	36.98	37.86	38.77	39.59	35.44
20	E1154S71075	26.55	28.77	30.36	31.8	32.87	33.97	34.93	35.83	36.54	32.40
	Mean	28.01	30.15	31.71	32.96	34.11	35.15	36.06	36.87	37.64	33.63

Table -5 Comparison within Transform by using ANOVA

ANOVA Test with in transform ($p < 0.05$)				
	WA	DCT	DST	Wavelet
Image wise	0.84	0.93	0.92	0.62
rate bit per pixel	1.74×10^{-91}	4.15×10^{-95}	2.60×10^{-94}	2.81×10^{-83}

Table -6 Comparison of Difference Transforms by using ANOVA

ANOVA Test on transforms ($p < 0.05$)				
	WA	DCT	DST	Wavelet
Image wise	1.03×10^{-4}			
rate bit per pixel	2.93×10^{-41}			

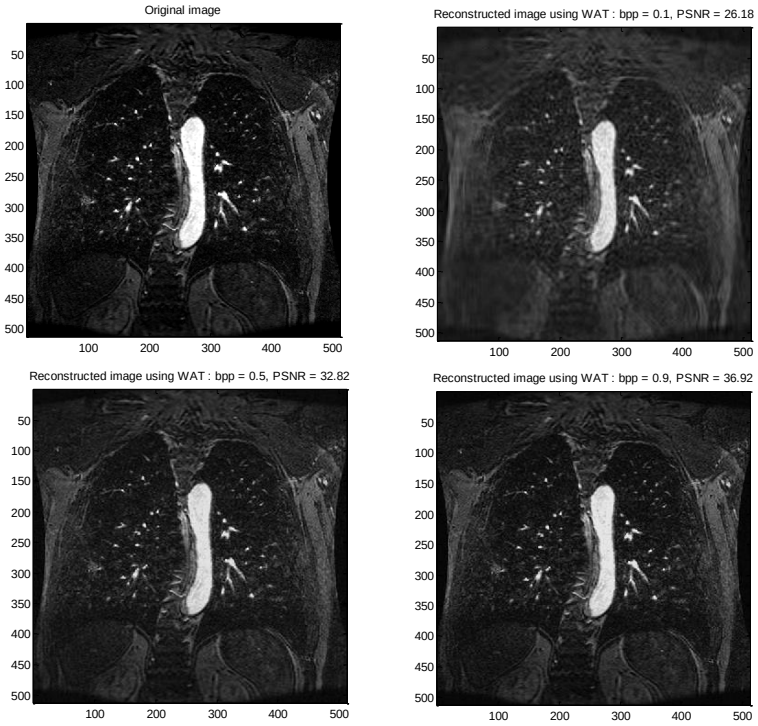

Fig.1 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Wave Atom Transform

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).

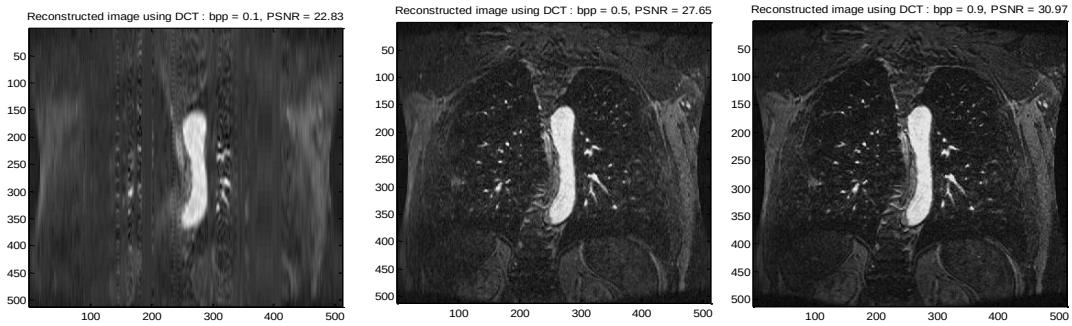

Fig.2 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Discrete Cosine Transform

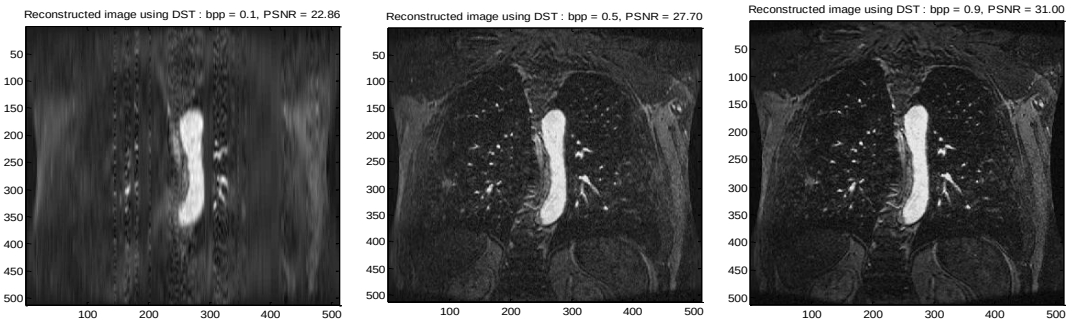

Fig.3 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Discrete Sine Transform

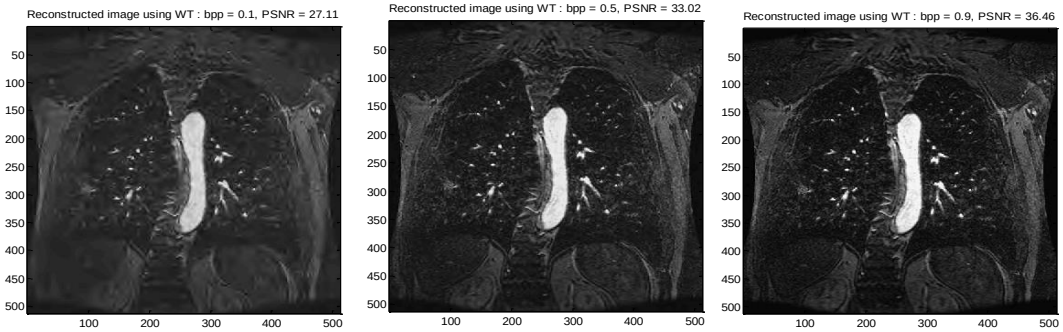

Fig.4 Comparison of original image with reconstructed image at 0.1, 0.5 and 0.9 bpp using Wavelet Transform.

CONCLUSION

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

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