Quaternion Alpha-Rooting Image Enhancement of Grayscale Images

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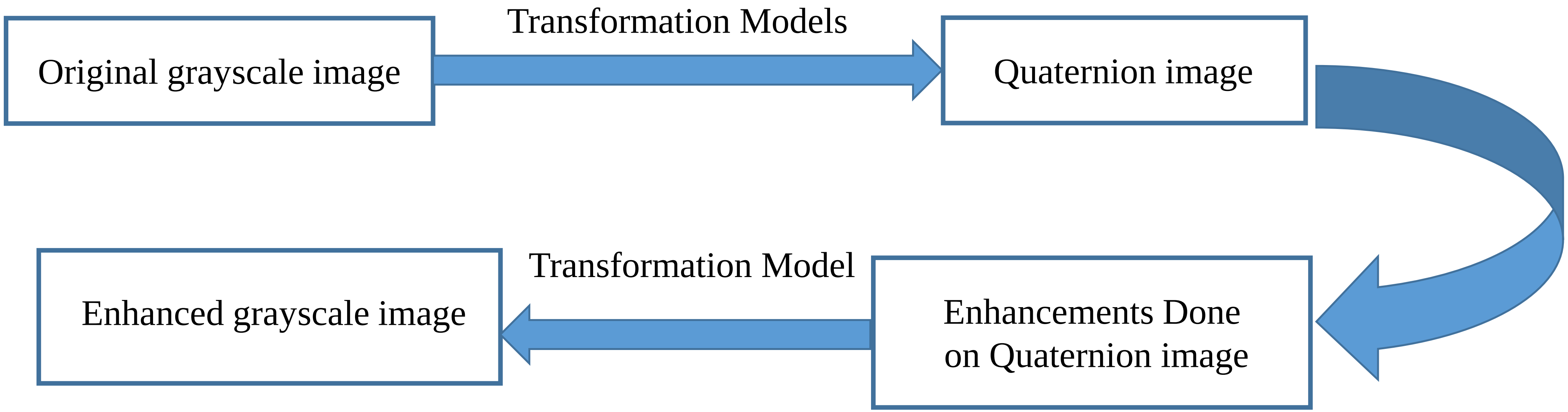
Abstract

- The proposed method is a novel image enhancement for grayscale images.
- In this method, the grayscale image is transformed first to quaternion image and then the enhancement algorithm, quaternion alpha-rooting, is applied to the quaternion image.
- This paper also makes a comparative study of image processing on grayscale images by quaternion alpha-rooting method and direct alpha-rooting method.
- The enhancement is quantitatively measured by the metric called the enhancement measure estimation (EME).
- SNR and MSE values of the resulting images are also determined.

Enhancement Method



Transformation Models

2×2 model

	Gray (n,0)	Gray (n,1)	Gray (n,2)	Gray (n,3)	
Gray (0,m)	**Q1(0,0)**	**Q2(0,0)**	**Q1(0,1)**	**Q2(0,1)**	**…**
Gray (1,m)	**Q3(0,0)**	**Q4(0,0)**	**Q3(0,1)**	**Q4(0,1)**	**…**
Gray (2,m)	**Q1(1,0)**	**Q2(1,0)**	**Q1(1,1)**	**Q2(1,1)**	**…**
Gray (3,m)	**Q3(1,0)**	**Q4(1,0)**	**Q3(1,1)**	**Q4(1,1)**	**…**
	…	**…**	**…**	**…**	**…**

Quaternion Alpha-Rooting Method

- In the Quaternion Alpha-rooting method of image enhancement, for each frequency point (p,s), the magnitude of the Quaternion Discrete Fourier transform are transformed as

$$|\boldsymbol{F}_{\boldsymbol{p},\boldsymbol{s}}| \rightarrow |\boldsymbol{F}_{\boldsymbol{p},\boldsymbol{s}}|^{\boldsymbol{\alpha}}, \qquad \boldsymbol{\alpha} \in (\boldsymbol{0}, \boldsymbol{1}).$$

- By alpha-rooting method, the magnitude of the transform co-efficient are reduced exponentially by alpha.
- The modified high frequency and low frequency transform co-efficient provides image enhancement in both the edges and smooth surfaces.
- The optimum choice of alpha for is the alpha which gives the best visual perception. The alpha that has the maximum EME is optimum alpha.

Enhancement Measure Estimation (EME)

- $f \to \hat{f}$

- $EME_{\alpha}(\hat{f}) = \frac{1}{k_1 k_2} \sum_{k=1}^{k_1} \sum_{l=1}^{k_2} 20\, log_{10} \left[\frac{max_{k,l}\,(\hat{f})}{min_{k,l}\,(\hat{f})} \right]$

Experimental Results -1

(a) (b) (c)

Figure 1: (a) Original image “Snow on Leaves.jpg”; (b) Quaternion Alpha-rooting (alpha = 0.92); (c) Direct Grayscale Alpha-rooting (alpha = 0.93).

Image “Snow on Leaves.jpg”	Enhancement Method	Alpha	EME	SNR	MSE	Time Elapsed (Seconds)
	Quaternion Alpha-Rooting	0.92	25.1154	8.8886	991.47	4.9158
	Direct Grayscale Alpha-Rooting	0.93	25.0611	2.8643	2047.65	9.0271

Experimental Results -1 (contd) – Choosing best Alpha

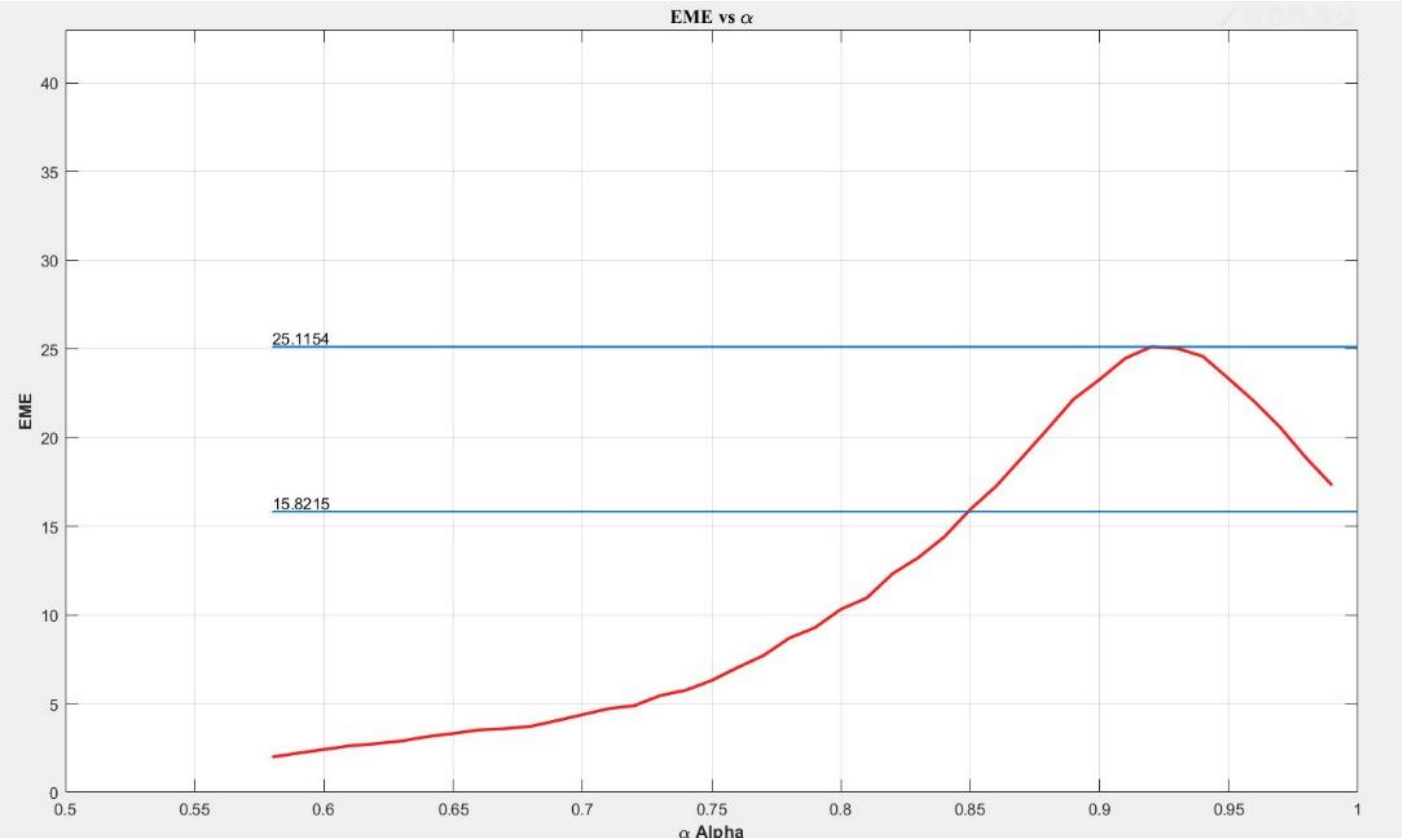


Figure 2: EME vs alpha of Quaternion Alpha-rooting (Snow on Leaves.jpg)

Experimental Results - 2

(a) (b) (c)

Figure 3: (a) Original image “Platform RP.jpg”; (b) Quaternion Alpha-rooting (alpha = 0.97); (c) Direct Grayscale Alpha-rooting (alpha = 0.97).

Image “Platform RP.jpg”	Enhancement Method	Alpha	EME	SNR	MSE	Time Elapsed (Seconds)
	Quaternion Alpha-Rooting	0.97	17.3439	63.37	210.41	6.1608
	Direct Grayscale Alpha-Rooting	0.97	17.0455	2.22	2654.17	14.7279

Experimental Results - 3

(a) (b) (c)

Figure 4: (a) Original image “White Flower.jpg”; (b) Quaternion Alpha-rooting (alpha = 0.92); (c) Direct Grayscale Alpha-rooting (alpha = 0.92).

Image “White Flower.jpg”	Enhancement Method	Alpha	EME	SNR	MSE	Time Elapsed (Seconds)
	Quaternion Alpha- Rooting	0.92	14.9033	7.58	1219.01	16.9903
	Direct Grayscale Alpha-Rooting	0.92	14.9816	5.07	1585.01	52.1153

Experimental Results - 4

(a) (b) (c)

Figure 5: (a) Original image “Platform Fence.jpg”; (b) Quaternion Alpha-rooting (alpha = 0.96); (c) Direct Grayscale Alpha-rooting (alpha = 0.97).

Image “Platform Fence.jpg”	Enhancement Method	Alpha	EME	SNR	MSE	Time Elapsed (Seconds)
	Quaternion Alpha-Rooting	0.96	20.4245	32.17	518.49	6.1505
	Direct Grayscale Alpha-Rooting	0.97	20.1653	2.11	3725.33	15.4689

Experimental Results - 5

(a) (b) (c)

Figure 6: (a) Original image “Journey to Emmaus.jpg”; (b) Quaternion Alpha-rooting (alpha = 0.93); (c) Direct Grayscale Alpha-rooting (alpha = 0.93).

Image “Journey to Emmaus.jpg”	Enhancement Method	Alpha	EME	SNR	MSE	Time Elapsed (Seconds)
	Quaternion Alpha- Rooting	0.93	13.5407	8.49	1431.30	8.6243
	Direct Grayscale Alpha-Rooting	0.93	13.2209	2.10	3539.45	18.0678

Summary

- The transformation of the grayscale image into quaternion image helps in using quaternion based enhancement algorithms.
- The proposed image processing method enables us to transform a grayscale image to 3-4 channel image.
- EME values are used to select the optimum alpha.
- The proposed method shows good enhancement image results. The SNR and MSE values of the proposed images are better than the images enhanced by direct application of the alpha-rooting method.

References

1. A.M. Grigoryan, S.S. Agaian, *Practical Quaternion and Octonion Imaging With MATLAB*, SPIE PRESS, 2018.

2. A. M. Grigoryan, A. John, S. S. Agaian, “A Novel Color Image Enhancement Method by the Transformation of Color Images to 2-D Grayscale Images”, p16, International Journal of Signal Processing and Analysis (2017)..

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