A Novel Image Enhancement Method of 3-D Medical Images by Transforming the 3-D Images to 2-D Grayscale Images

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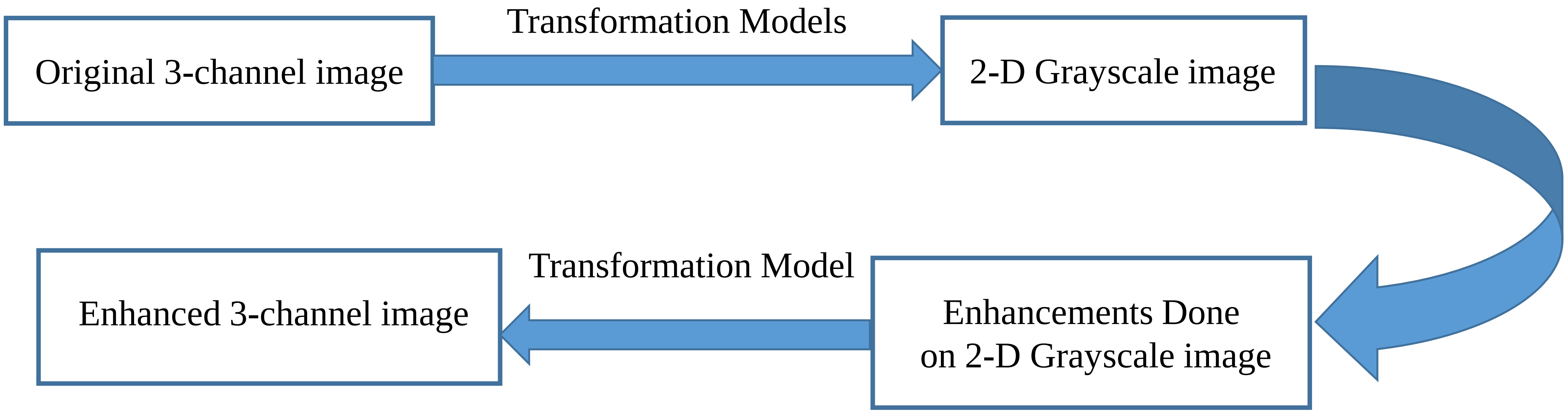
Abstract

- The proposed method is a novel image enhancement for color medical images.
- In this method, the 3-D medical image is transformed first to the 2-D grayscale image and then the enhancement algorithms, either in frequency domain or spatial domain, are applied to the grayscale image.
- This paper describes the enhancement effects on the medical images by the proposed transformation model and then the enhancement by the alpha-rooting method, for the frequency domain algorithm, and the histogram equalization, for the spatial domain enhancement algorithm.
- The enhancement is quantitatively measured with respect to the metric which is called the color enhancement measure estimation (CEME).

Enhancement Method



Transformation Models

2×2 model

I(0,0)	R(0,0)	I(0,1)	R(0,1)	…
G(0,0)	B(0,0)	G(0,1)	B(0,1)	…
I(1,0)	R(1,0)	I(1,1)	R(1,1)	…
G(1,0)	B(1,0)	G(1,1)	B(1,1)	…
…	…	…	…	…

row model

I(0,0)	I(0,1)	…
R(0,0)	R(0,1)	…
G(0,0)	G(0,1)	…
B(0,0)	B(0,1)	…
I(1,0)	I(1,1)	…
R(1,0)	R(1,1)	…
G(1,0)	G(1,1)	…
B(1,0)	B(1,1)	…
…	…	…

2×3 model

R(0,0)	G(0,0)	B(0,1)	R(0,2)	G(0,2)	B(0,3)	…
B(0,0)	R(0,1)	G(0,1)	B(0,2)	R(0,3)	G(0,3)	…
R(1,0)	G(1,0)	B(1,1)	R(1,2)	G(1,2)	B(1,3)	…
B(1,0)	R(1,1)	G(1,1)	B(1,2)	R(1,3)	G(1,3)	…
…	…	…	…	…	…	…

column model

I(0,0)	R(0,0)	G(0,0)	B(0,0)	I(0,1)	R(0,1)	G(0,1)	B(0,1)	…
I(1,0)	R(1,0)	G(1,0)	B(1,0)	I(1,1)	R(1,1)	G(1,1)	B(1,1)	…
…	…	…	…	…	…	…	…	…

Alpha-Rooting Method

- In the alpha-rooting method of image enhancement, for each frequency point (p,s), the magnitude of the discrete Fourier transform are transformed as
- $|\boldsymbol{F}_{\boldsymbol{p},\boldsymbol{s}}| \to |\boldsymbol{F}_{\boldsymbol{p},\boldsymbol{s}}|^{\boldsymbol{\alpha}}, \quad \boldsymbol{\alpha} \in (\mathbf{0}, \mathbf{1})$.
- 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 which gives the maximum CEME is optimum value of alpha.

Histogram Equalization

- For the image fn,m of size M × N, the histogram is a non-negative function

$$h(r) = card\{(m,n);\ f_{m,n} = r, m = 0,1,\dots,(M-1), \qquad n = 0,1,\dots,(N-1)\}$$

- The histogram is normalized,

h(r)=h(r)/(MN) so that 0 < h(r) < 1.

- In the case when [w_min,w_max]=[0,255], the histogram equalization is calculated by the transformation

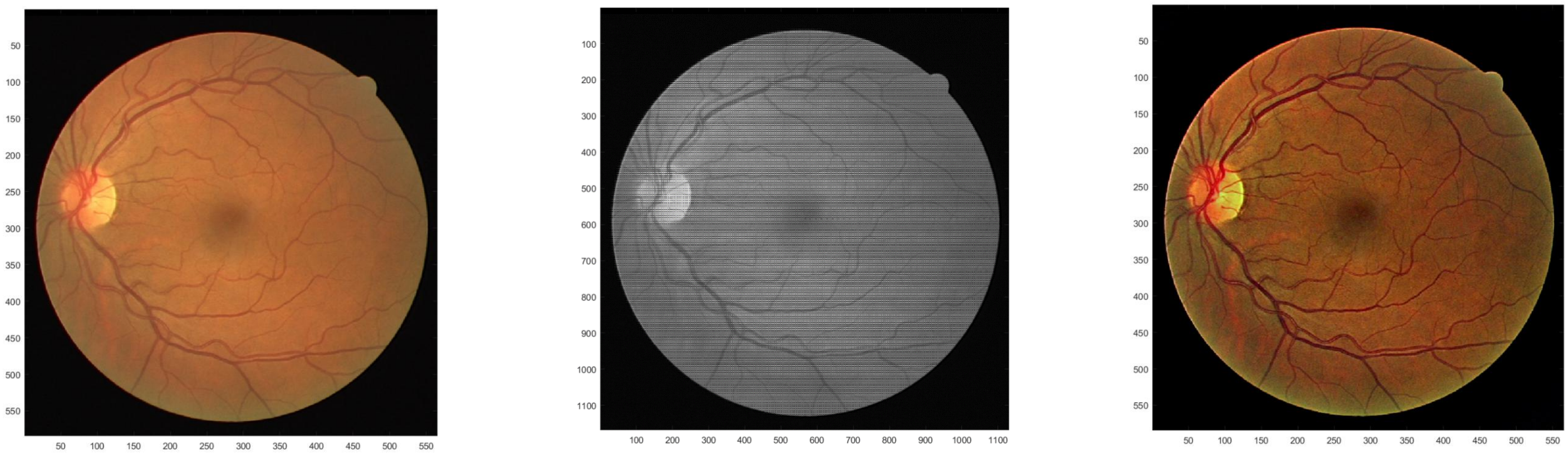
$$r \to s = \begin{cases} \left[255 \sum_{k=0}^{r} h(k)\right], & if\ r = 0{:}255, \\ 0, & if\ r = 0. \end{cases}$$

Color Enhancement Measure Estimation (CEME)

- $f = (f_R, f_G, f_B) \rightarrow \hat{f} = (\widehat{f_R}, \widehat{f_G}, \widehat{f_B}),$

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

Experimental Results – Alpha-rooting Method

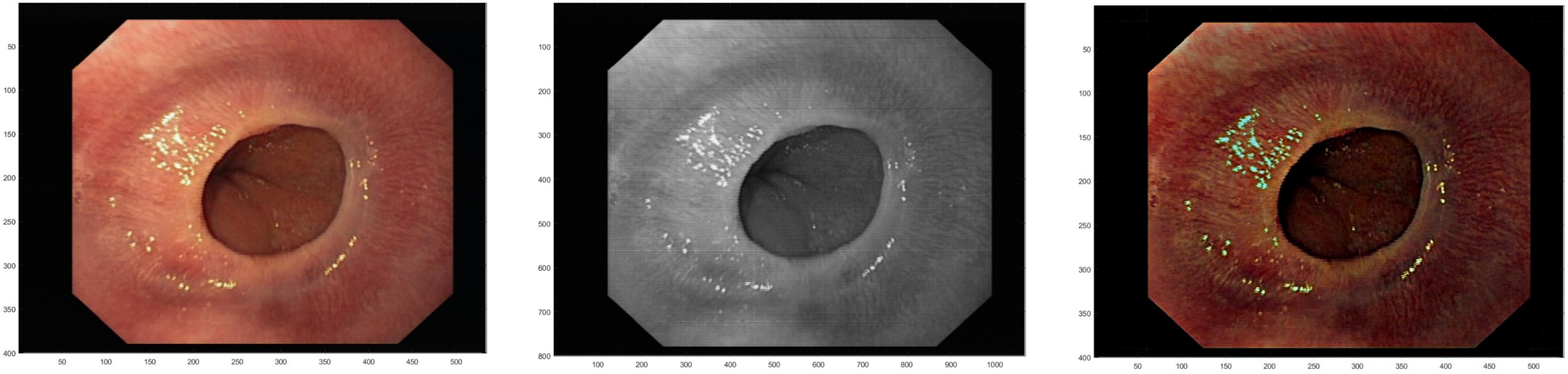


(a) (b) (c)

Figure 1: (a) Original 3-D Image “eye.tif”; (b) 2-D grayscale image after transformation by 2×2 model; (c) 3-D image after alpha-rooting of image (b) with alpha = 0.84.

Image	**CEME**
Original Image “eye.jpg”	16.2284
After transforming by 2×2 model and Alpha-rooting at alpha = 0.84	30.3832

Experimental Results – Alpha-rooting Method

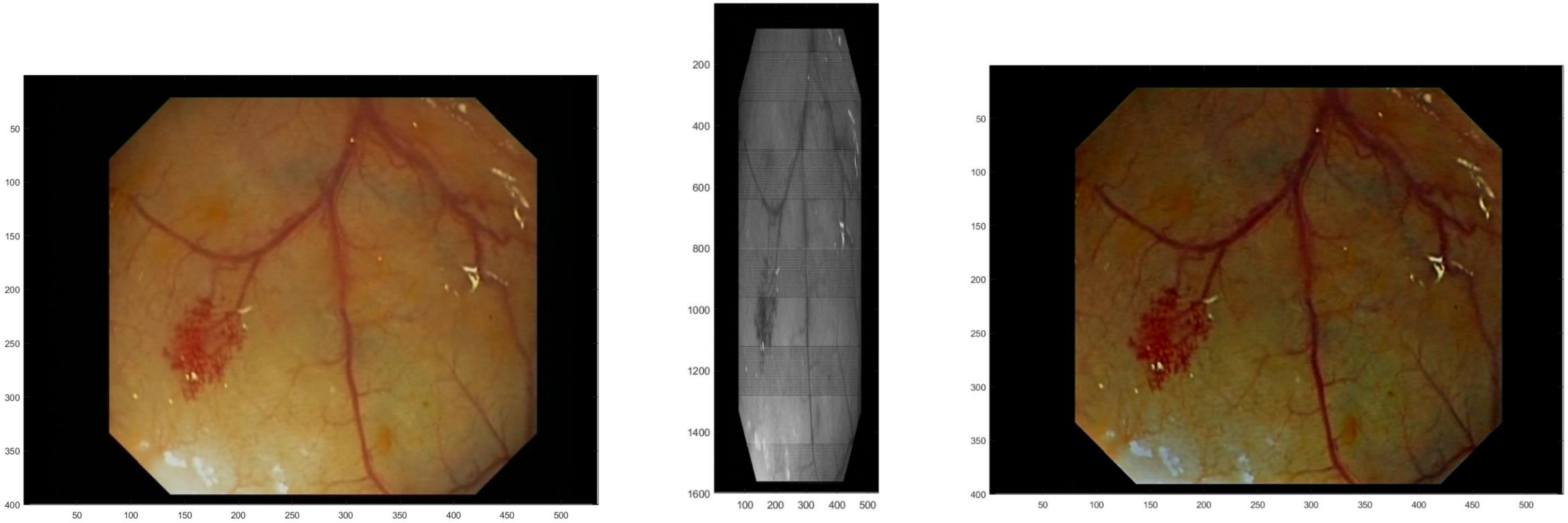


(a) (b) (c)

Figure 2: (a) Original 3-D Image “weo_eso_ringcardia_costam.jpg”; (b) 2-D grayscale image after transformation by 2×2 model; (c) 3-D image after alpha-rooting of image (b) with alpha = 0.82.

Image	**CEME**
Original Image “weo_eso_ringcardia_costam.jpg”	19.0793
After transforming by 2×2 model and Alpha-rooting by 0.82	22.4460

Experimental Results – Alpha-rooting Method

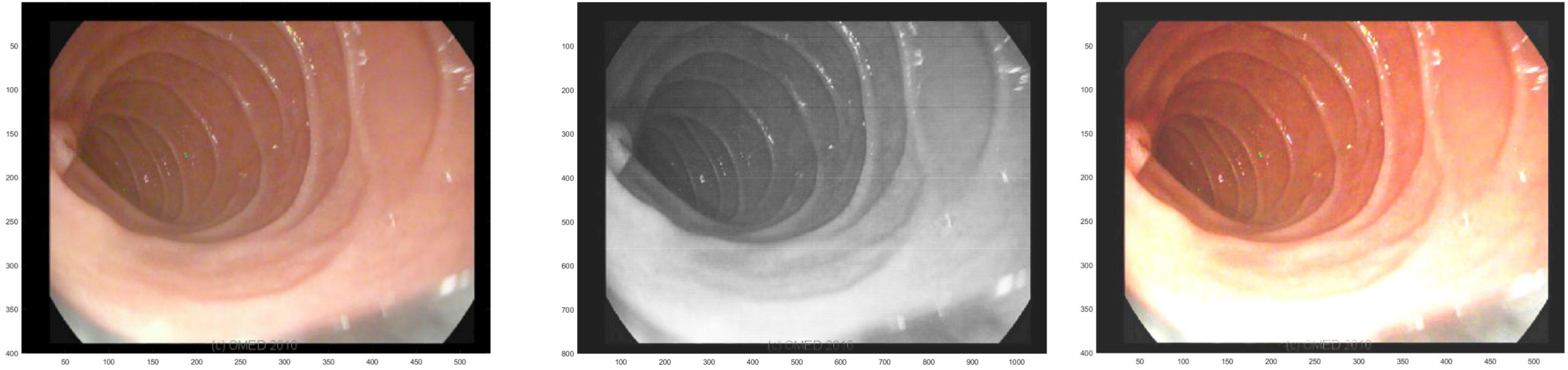


(a) (b) (c)

Figure 3: (a) Original 3-D Image "weo_col_angiodysplasia1_costam.jpg"; (b) 2-D grayscale image after transformation by row model; (c) 3-D image after alpha-rooting of image (b) with alpha = 0.88.

Image	**CEME**
Original Image "weo_col_angiodysplasia1_costam.jpg"	17.9263
After transforming by row model and Alpha-rooting by 0.88	23.2641

Experimental Results – Histogram Equalization

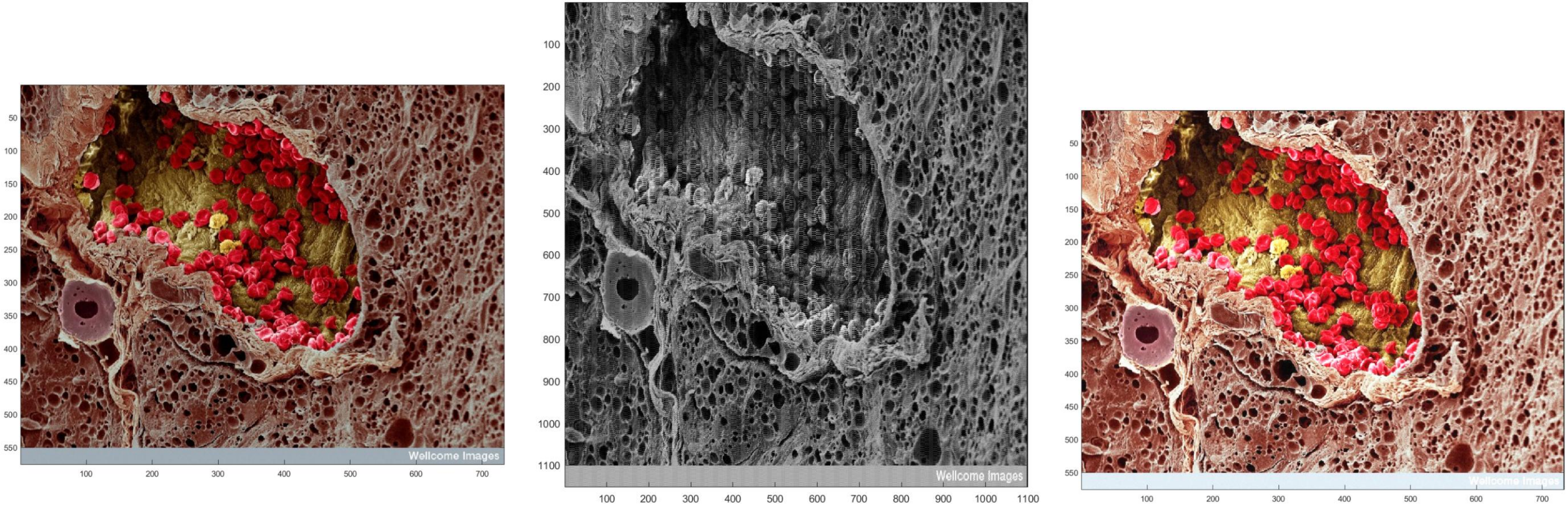


(a) (b) (c)

Figure 4: (a) Original 3-D Image "weo_duodenum_ampulla_normal_brugge.jpg"; (b) 2-D grayscale image after transformation by 2×2 model; (c) 3-D image after histogram equalization of image (b).

Image	**CEME**
Original Image "weo_duodenum_ampulla_normal_brugge.jpg"	12.4033
After transforming by 2×2 model and Histogram Equalization	14.5537

Experimental Results – Histogram Equalization

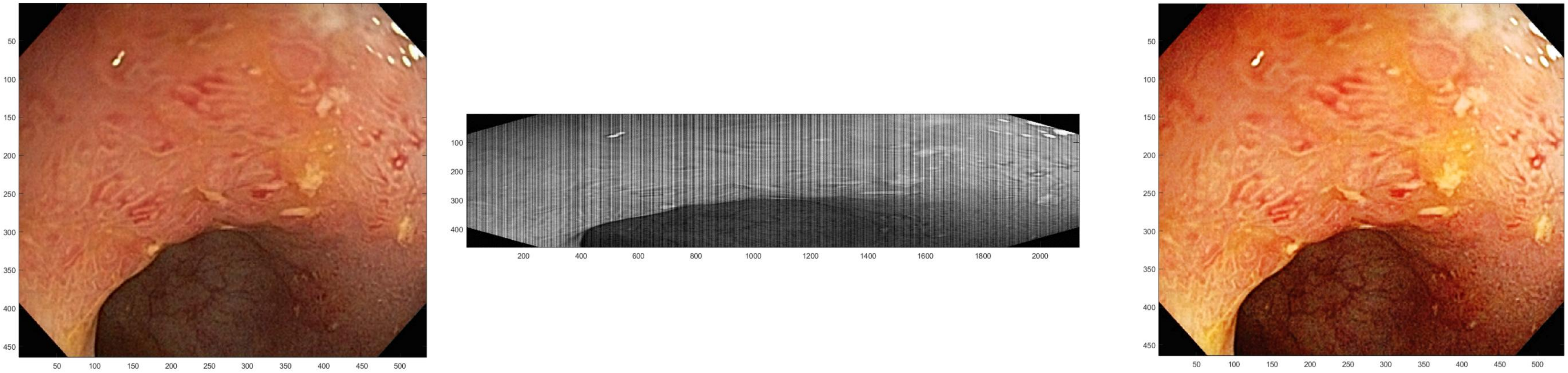


(a) (b) (c)

Figure 5: (a) Original 3-D Image “blood vessel.jpg”; (b) 2-D grayscale image after transformation by 2×3 model; (c) 3-D image after histogram equalization of image (b).

Image	**CEME**
Original Image “blood vessels.jpg”	19.8688
After transforming by 2×3 model and Histogram Equalization	50.8066

Experimental Results – Histogram Equalization



(a) (b) (c)

Figure 6: (a) Original 3-D Image “weo_col_crohns_ti_waye.jpg”; (b) 2-D grayscale image after transformation by column model; (c) 3-D image after histogram equalization of image (b).

Image	**CEME**
Original Image “weo_col_crohns_ti_waye.jpg”	26.9653
After transforming by column model and Histogram Equalization	34.1393

Summary

- The transformation of the 3-D medical image into 2-D grayscale image helps us to use many well-known enhancement algorithms, which are effective on 2-D grayscale images.
- The image processing is simplified, by applying the enhancement algorithm on to one channel transformed image, than to the 3-D medical image.
- The proposed method shows good enhancement image results on both frequency domain enhancement such as the alpha-rooting method, and on spatial domain enhancement algorithms, such as the histogram equalization.
- CEME is higher in the enhanced images, when compared with the original CEME values.

References

1. A.M. Grigoryan and S.S. Agaian, Quaternion and Octonion Color Image Processing with MATLAB, p. 404, SPIE, vol. PM279, April 5, 2018. [ISBN: 9781510611351]

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)..

3. …