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# An Image Enhancement Method Using Nonlinear Function

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**ABSTRACT-** Image enhancement plays an important role in image processing. This paper proposed an image enhancement method using a nonlinear(exponential) function. Firstly, we use the exponential function to construct the gray transformation equation. Then, depending on the position of each pixel, the gray scale obtained by gray transformation is further adjusted based on the compression factor. In *section 3*, the comparative experiment shows that the proposed method could achieve good performance.

**Keywords:** Image enhancement, exponential function, threshold.

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## 1. INTRODUCTION

Image enhancement is mainly aimed to enhance the contrast of the image. Grayscale transformation enhancement in the spatial domain algorithm is presented in the first and the most direct method, including histogram equalization, Gamma correction, based on the logarithmic function transformation and based on the linear function transform, image enhancement methods, such as its main changing the grayscale distribution to stretch the global contrast of image, achieve the purpose of enhancing the image enhancement in the spatial domain. Histogram equalization (HE) is a well-known and effective image enhancement method. HE redistributes the gray values of pixels to make the gray intensity distribution more uniform overall [1-11]. Gray scale transformation method is the earliest and easiest image enhancement method. The commonly used gray transformation method are composed by direct stretching, quadratic function, sine function, complex function, and other nonlinear functions [12-20]. Fuzzy set has been applied effectively in image enhancement [21-27]. Image enhancement is more and more widely used in various fields.

Based on the characteristics of an exponential function, this paper proposed a new nonlinear transformation function. Then, depending on the position information of each pixel, the grayscale obtained by the nonlinear transformation function is further adjusted. In the section 3, the proposed enhancement method is compared with the method in [16]. The result shows that the method in this paper could achieve better performance than traditional methods.

## 2. METHODOLOGY

### 2.1 Gray Transformation Based on Quadratic Function

In 2020, using quadratic function, Zhang and Feng proposed an new image enhancement method [16]. The function defined as follows:

$$f(x)=\begin{cases}\dfrac{(x-a)^2}{q-a}+a, & a\le x\le q\\ -\dfrac{(x-b)^2}{b-q}+b, & q<x\le b\end{cases} \tag{1}$$

In *eq. (1)*, $a$ is the minimum value of pixels gray in original image, $b$ is the maximum value of pixels gray, $q$ is image threshold.

### 2.2 Proposed Exponential Function

According to the characteristics of exponential function, the gray transformation function is established as follow:

$$f(x)=\begin{cases}e^{\lambda_1(x-a)}+a-1, & a\le x\le q\\ -e^{\lambda_2(x-b)}+b+1, & q<x\le b\end{cases} \tag{2}$$

In *eq. (2)*, $\lambda_1=\ln(q-a+1)/(q-a)$, $\lambda_2=\ln(b-q+1)/(q-b)$

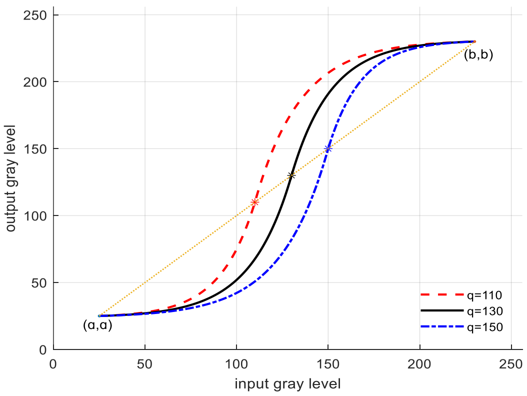


**Figure 1:** A example of gray transformation exponential function

In order to improve the use of *eq. (2)*, compresses the curve image {*eq.* (2)} vertically towards the line $y = x$. The equation of the compressed curve is as follows:

$$F(x,y)=\begin{cases} e^{\lambda_1(x-\delta(x,y)-a)}+\delta(x,y) \\ \quad -y+a-1=0 \end{cases},a\le x\le q \quad \begin{cases} -e^{\lambda_2(x+\delta(x,y)-b)}+\delta(x,y) \\ \quad -y+b+1=0 \end{cases},q<x\le b \tag{3}$$

Where $\delta(x,y)=(1-t)(x-y)/2t$ , $t$ ( $0\le t\le 1$ ) is the compression factor.

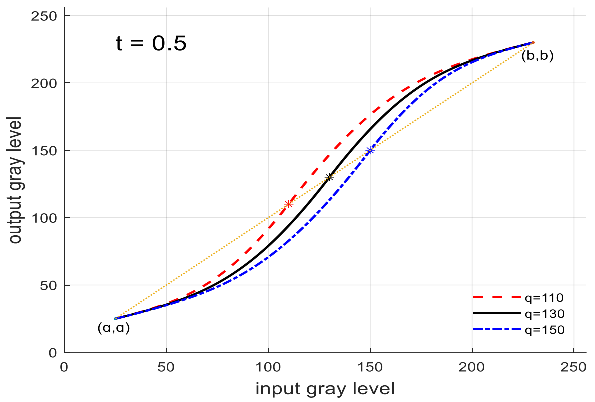


**Figure 2:** Compressed exponential curve with the compression factor t=0.5

### 2.3 Image Pixel's Local Gradient

Image $I=\{x_{ij}\,|\,i=1,2,3,\ldots,m,\ j=1,2,3,\ldots,n\}$, where $x_{ij}$ is the image pixel's gray scale in row $i$ and column $j$ of the image. $I_G=\{g_{ij}\}$ is the local gradient matrix of image $I$

$$g_{ij}=\sqrt{(x_{i+1j}-x_{ij})^2+(x_{ij+1}-x_{ij})^2} \tag{4}$$

When $i=m$ or $j=n$, $g_{ij}=0$. $I_G$ Shows the changing trend of all pixels of image $I$ .

## 3. RESULTS AND DISCUSSION

To analyze the performance, the proposed method is compared with the enhancement method in [16] and histogram equalization (HE) in terms of its visual perception. In this section, we set the compression factor $t$ as follow:

$$t=t_{ij}=\frac{0.8\times g_{ij}}{g_{\max}-g_{\min}}+0.2 \tag{5}$$

Where $g_{\max}$ ( $g_{\min}$ ) is the maximum (minimum) value of $I_G$

For further image enhancement effect evaluation, commonly used algorithms include mean squared error (MSE), structural similarity (SSIM) and peak signal-noise ratio (PSNR). The lower MSE or the higher SSIM(PSNR) indicates a better enhancement effect [22]. In this paper, we use the MSE, PSNR, and SSIM values to evaluate the effect of the enhancement methods.

$$\mathrm{MSE}=\frac{1}{M\times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{ij}-y_{ij})^2 \tag{6}$$

$$\mathrm{PSNR}=10\times\log_{10}\frac{(2^n-1)^2}{MSE}dB \tag{7}$$

$$\mathrm{SSIM}(\mathrm{I}_1,\mathrm{I}_2)=\frac{(2\mu_1\mu_2+c_1)(2\sigma_{12}+c_2)}{(\mu_1^2+\mu_2^2+c_1)(\sigma_1^2+\sigma_y^2+c_2)} \tag{8}$$

In *eq. (7)*, $n=8$. In *eq. (8)*, $\mu_1$ is the pixels' mean of image $\mathrm{I}_1$, $\mu_2$ is the pixels' mean of image $\mathrm{I}_2$, $\sigma_1^2$ is the variance of $\mathrm{I}_1$, $\sigma_2^2$ is the variance of $\mathrm{I}_2$, $\sigma_{12}$ is the covariance of image $\mathrm{I}_1$ ,and $\mathrm{I}_2$. $c_1$ and $c_2$ are constants [28].

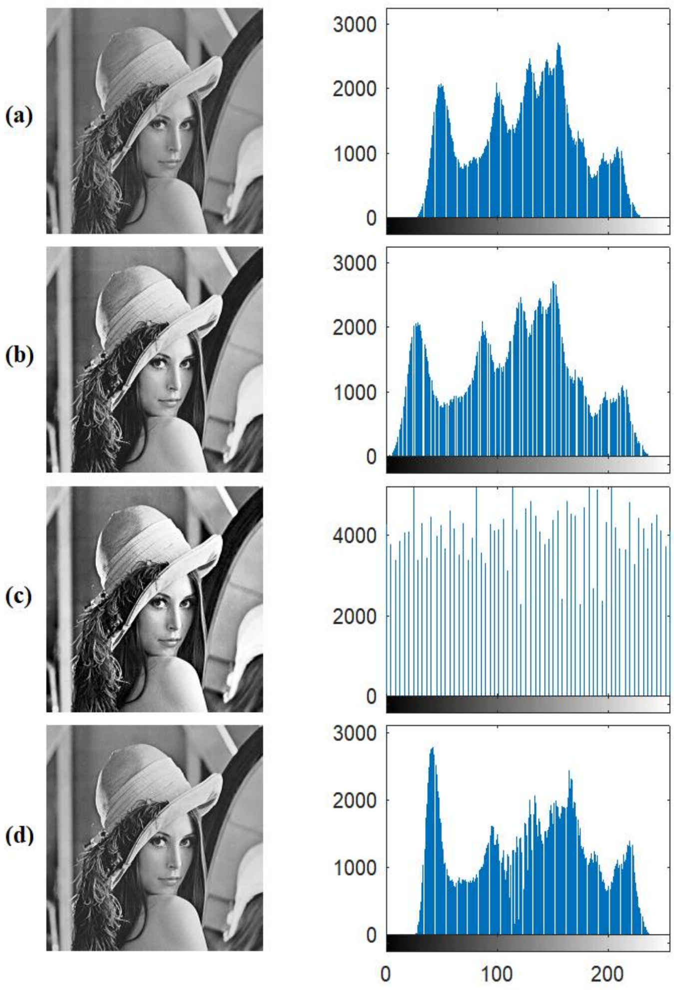


**Figure 3:** Enhancement results of the lena image. (a).original image; (b). processed by HE; (c). processed by method in [16];(d). processed by proposed method

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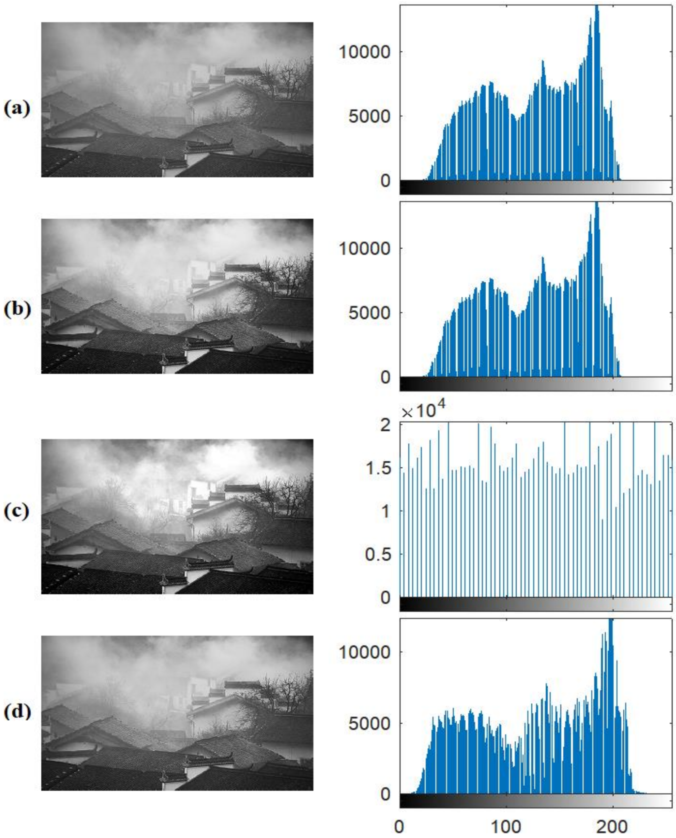


**Figure 4:** Enhancement results of the house image. (a).original image; (b). processed by HE; (c). processed by method in [16]; (d). processed by proposed method

In *figure 3, figure 3(b)* has the widest grayscale range, but, it's a little bit overexposed visually. *Figure 3(c)* also shows the phenomenon of overexposure. *Figure 3(d)* has a more suitable enhancement effect, which is most similar to the original image. The frequency histogram in *figure 3(d)* also shows that the proposed method can transfer the gray value of image pixels to both ends, which results in enhanced image contrast. *In figure 4, figure 4(c)* overexposure. Compared with *figure 4(b), figure 4(d)* has a larger gray range than *figure 4(b).*

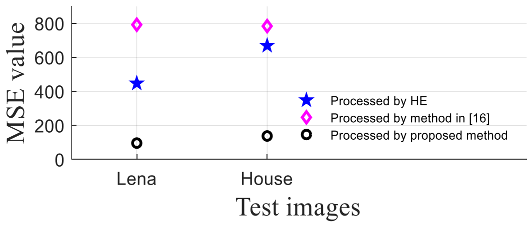


**Figure 5:** MSE test results


**Figure 6:** PSNR test results


**Figure 7:** SSIM test results

*Figure 5, 6, and 7* show that the proposed method achieve lower MSE value, higher PSNR and higher SSIM value. This means that for test images *lena* and *house*, the proposed has a better enhancement effect.

For further experimentation, we considered more 22 test images from Miscellaneous (MISC) dataset as the test image (https://sipi.usc.edu/database/database.php?volume=misc).

**Table 1: MSE test results**

| Method / Image | HE | In [16] | Proposed |
|---|---|---|---|
| APC | 3319.11 | 553.23 | **101.80** |
| Aerial | 1157.93 | 612.48 | **160.74** |
| Aerial2 | 4724.80 | 502.06 | **121.74** |
| Airplane (U-2) | 12512.85 | 192.75 | **41.67** |
| Airplane | 6636.69 | 217.35 | **59.92** |
| Airplane2 | 6171.68 | 747.31 | **117.45** |
| Airport | 3929.97 | 435.15 | **122.34** |
| Car and APCs | 2222.48 | 567.22 | **107.32** |
| Car and APCs2 | 2604.80 | 309.50 | **78.86** |
| Chemical plant | 1758.64 | 451.87 | **167.40** |
| Clock | 4692.85 | 336.53 | **88.52** |
| Couple | 1553.43 | 493.30 | **83.30** |
| Fishing Boat | 1305.72 | 834.87 | **167.51** |
| Male | 1818.22 | 671.62 | **123.67** |
| Moon surface | 2552.64 | 314.75 | **80.67** |
| Stream and bridge | 741.44 | 585.35 | **190.06** |
| Tank | 2724.20 | 396.68 | **88.03** |
| Tank2 | 3148.40 | 286.85 | **61.84** |
| Tank3 | 1638.34 | 500.41 | **114.94** |
| Truck and APCs | 2098.07 | 407.91 | **84.01** |
| Truck and APCs2 | 3165.58 | 402.96 | **108.12** |
| Truck | 2915.86 | 418.47 | **79.83** |

**Table 2: PSNR test results**

| Method / Image | HE | In [16] | Proposed |
|---|---|---|---|
| APC | 12.9206 | 20.7017 | **28.0533** |
| Aerial | 17.4940 | 20.2599 | **26.0696** |
| Aerial2 | 11.3870 | 21.1232 | **27.2763** |
| Airplane (U-2) | 7.1572 | 25.2808 | **31.9326** |
| Airplane | 9.9113 | 24.7591 | **30.3550** |
| Airplane2 | 10.2268 | 19.3958 | **27.4323** |
| Airport | 12.1869 | 21.7444 | **27.2552** |
| Car and APCs | 14.6624 | 20.5933 | **27.8241** |
| Car and APCs2 | 13.9731 | 23.2242 | **29.1624** |
| Chemical plant | 15.6790 | 21.5807 | **25.8932** |
| Clock | 11.4164 | 22.8606 | **28.6605** |

| | | | |
|---|---|---|---|
| Couple | 16.2179 | 21.1997 | **28.9241** |
| Fishing Boat | 16.9723 | 18.9146 | **25.8903** |
| Male | 15.5343 | 19.8596 | **27.2080** |
| Moon surface | 14.0609 | 23.1512 | **29.0635** |
| Stream and bridge | 19.4300 | 20.4566 | **25.3419** |
| Tank | 13.7784 | 22.1464 | **28.6844** |
| Tank2 | 13.1499 | 23.5542 | **30.2179** |
| Tank3 | 15.9868 | 21.1376 | **27.5261** |
| Truck and APCs | 14.9126 | 22.0252 | **28.8873** |
| Truck and APCs2 | 13.1263 | 22.0781 | **27.7917** |
| Truck | 13.4831 | 21.9141 | **29.1091** |

**Table 3: SSIM test results**

| Method / Image | HE | In [23] | Proposed |
|---|---|---|---|
| APC | 0.3585 | 0.9382 | **0.9836** |
| Aerial | 0.8055 | 0.8945 | **0.9623** |
| Aerial2 | 0.6148 | 0.9403 | **0.9804** |
| Airplane (U-2) | 0.1946 | 0.7868 | **0.9689** |
| Airplane | 0.5667 | 0.9678 | **0.9870** |
| Airplane2 | 0.3827 | 0.9713 | **0.9930** |
| Airport | 0.6645 | 0.8856 | **0.9668** |
| Car and APCs | 0.5977 | 0.9015 | **0.9758** |
| Car and APCs2 | 0.5234 | 0.9061 | **0.9679** |
| Chemical plant | 0.7740 | 0.8900 | **0.9497** |
| Clock | 0.5808 | 0.9594 | **0.9818** |
| Couple | 0.7042 | 0.9023 | **0.9791** |
| Fishing Boat | 0.7017 | 0.9016 | **0.9767** |
| Male | 0.8412 | 0.8537 | **0.9763** |
| Moon surface | 0.5188 | 0.8878 | **0.9531** |
| Stream and bridge | 0.8851 | 0.8765 | **0.9596** |
| Tank | 0.4418 | 0.9187 | **0.9746** |
| Tank2 | 0.5034 | 0.8773 | **0.9647** |
| Tank3 | 0.6819 | 0.9099 | **0.9732** |
| Truck and APCs | 0.6861 | 0.8797 | **0.9695** |
| Truck and APCs2 | 0.6718 | 0.8642 | **0.9586** |
| Truck | 0.5795 | 0.8914 | **0.9716** |

*Table 1, 2, and 3* show that the proposed method achieves lower MSE values and higher PSNR and SSIM values. This result indicates method has a better enhancement effect.

## 4. CONCLUSION

The paper presents a gray scale transformation function which is a piecewise function consisting of exponential functions. The segmentation points $p$ of the piecewise function corresponds to the threshold of the test image. The function has a compression factor $t$ which is calculated based on pixel's neighborhood information {eq. (4), eq. (5)}. The enhancement method (transformation function) can not only adjust according to the changes of test images, but also make use of the test image's neighborhood information. The comparative experiment also shows that the proposed enhancement method has a good effect.

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## REFERENCES

[1] Cheng, H.D. and Shi, X.J., 2004. A simple and effective histogram equalization approach to image enhancement. Digital signal processing, 14(2), pp.158-170.

[2] Sim, K.S., Tso, C.P. and Tan, Y.Y., 2007. Recursive sub-image histogram equalization applied to gray scale images. Pattern Recognition Letters, 28(10), pp.1209-1221.

[3] Kaur, H. and Sohi, N., 2017. A study for applications of histogram in image enhancement. Int. J. Eng. Sci, 6(6), pp.59-63.

[4] Onyedinma, E., Onyenwe, I. and Inyiama, H., 2019. Performance Evaluation of Histogram Equalization and Fuzzy image Enhancement Techniques on Low Contrast Images. arXiv preprint arXiv:1909.03957.

[5] Salem, N., Malik, H. and Shams, A., 2019. Medical image enhancement based on histogram algorithms. Procedia Computer Science, 163, pp.300-311.

[6] Magudeeswaran, V., Ravichandran, C.G. and Thirumurugan, P., 2017. Brightness preserving bi-level fuzzy histogram equalization for MRI brain image contrast enhancement. International Journal of Imaging Systems and Technology, 27(2), pp.153-161.

[7] Wang, X. and Chen, L., 2017. An effective histogram modification scheme for image contrast enhancement. Signal Processing: Image Communication, 58, pp.187-198.

[8] Wong, C.Y., Jiang, G., Rahman, M.A., Liu, S., Lin, S.C.F., Kwok, N., Shi, H., Yu, Y.H. and Wu, T., 2016. Histogram equalization and optimal profile compression based approach for colour image enhancement. Journal of Visual Communication and Image Representation, 38, pp.802-813.

[9] Mirbolouk, S., Valizadeh, M., Amirani, M.C. and Choukali, M.A., 2021. A fuzzy histogram weighting method for efficient image contrast enhancement. Multimedia Tools and Applications, 80(2), pp.2221-2241.

[10] Cheng, F.C. and Huang, S.C., 2013. Efficient histogram modification using bilateral Bezier curve for the contrast enhancement. Journal of Display Technology, 9(1), pp.44-50.

[11] Veluchamy, M. and Subramani, B., 2020. Fuzzy dissimilarity color histogram equalization for contrast enhancement and color correction. Applied Soft Computing, 89, p.106077.

[12] Aghagolzadeh, S. and Ersoy, O.K., 1992. Transform image enhancement. Optical Engineering, 31(3), pp.614-626.

[13] Gao, H., Zeng, W. and Chen, J., 2019. An improved gray-scale transformation method for pseudo-color image enhancement. Компьютерная оптика, 43(1), pp.78-82.

[14] Yelmanov, S. and Romanyshyn, Y., 2019, July. A new image enhancement technique based on adaptive non-linear contrast stretching. In 2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON) (pp. 864-870). IEEE.

[15] Gong, C., Luo, C. and Yang, D. 2012. Improved image enhancement algorithm based on sine gray level transformation. Video Engineering, 36(13):60–63.

[16] Zhang, Y. R. K. Y. and Feng, C. 2020. Image enhancement algorithm based on quadratic function and its implementation with fpga, Modern Electronics Technique 43(8): 72–76,81.

[17] Zhang, B., Xiao, D., Wang, L., Bai, S. and Yang, L., 2021. Efficient Compressed Sensing Based Image Coding by Using Gray Transformation. arXiv preprint arXiv:2102.01272.

[18] Yang, L., Zenian, S., Zakaria, R., 2021. An image enhancement method based on a S-sharp function and pixel neighborhood information. Borneo Science Journal. 42(1):18-24.

[19] Agaian, S.S., Panetta, K. and Grigoryan, A.M., 2001. Transform-based image enhancement algorithms with performance measure. IEEE Transactions on image processing, 10(3), pp.367-382.

[20] Zhang, B., Xiao, D., Wang, L., Bai, S. and Yang, L., 2021. Efficient Compressed Sensing Based Image Coding by Using Gray Transformation. arXiv preprint arXiv:2102.01272.

[21] Pal, S.K. and King, R.A., 1980. Image enhancement using fuzzy set. ELECTRONICS LETTERS, 16(10):376-278.

[22] Chandrasekharan, R. and Sasikumar, M., 2018. Fuzzy transform for contrast enhancement of nonuniform illumination images. Ieee signal processing letters, 25(6), pp.813-817.

[23] Reshmalakshmi, C., Sasikumar, M. and Shiny, G., 2018. Fuzzy transform for low-contrast image enhancement [J]. Intrenational Journal of Applied Engineering Research, 11(1), pp.9103-9108.

[24] Liu, X. 2012. An improved image enhancement algorithm based on fuzzy set. Physics Procedia, 33, 790-797

[25] Zenian, S., Ahmad, T. and Idris, A., 2019. Intuitionistic fuzzy set: fEEG image representation, AIP Conference Proceedings, 2019, https://doi.org/10.1063/1.5136486

[26] Yang, L., Zenian, S., Zakaria, R., 2021. Fuzzy Image Enhancement Based on Algebraic Function and Cycloid Arc Length, IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET), 2021, pp. 1-4, doi: 10.1109/IICAIET51634. 2021.9573686.

[27] Yang, L., Zenian, S., Zakaria, R., 2022. Fuzzy Image Enhancement Method based on a New Intensifier Operator, International Journal of Advanced Computer Science and Applications, 13(9), pp.30-34.

[28] Wang, Z., Bovik, A.C., Sheikh, H.R. and Simoncelli, E.P., 2004. Image quality assessment: from error visibility to structural similarity. IEEE transactions on image processing, 13(4), pp.600-612.