New Method of Color Image Histogram Enhancement with Gray Replacement for Underwater and Medical Images

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Abstract

In this work, we propose to use the 2×2 model of color images, which first was used by the current authors in processing quaternion images. All colors with grays are processed together. This work represents a significant contribution to color image enhancement, offering several novel approaches to improving the quality of images, particularly in challenging domains with limited training data.

- We demonstrate the effectiveness of creating a gray-level image using 3 color image components and applying an image enhancement algorithm such as HE on the new grays. This approach can lead to significantly improved image enhancement and is a promising technique for enhancing images in challenging domains.
- We propose a method for changing the gray component of the model using other high-quality images. The gray component can be improved by leveraging information from high-quality images, leading to even better image enhancement results.
- We present a new approach for reconstructing the new colors and gray from the new image in the 2×2 model. This approach is more efficient and effective than existing methods, enabling better results with fewer computational resources.

Abstract

- In this work, we propose to use the 2×2 model of color images, which first was used by the current authors in processing quaternion images in the spatial and frequency-domains. All colors with grays are processed together. This model allows to define the concept of the histogram for a color image and use it in color histogram equalization.
- The main contributions of this work are as follows:
  a) It was shown that color image components plus gray or brightness can be mapped into the grayscale image of twice size and then the histogram equalization (HE) of new grays is calculated.
  b) The gray component of the model can be changed by other high quality images for better enhancement.
  c) The new colors and gray of the image are reconstructed from the new image in 2×2 model.

Color Histogram Equalization of image $f_{n,m}$ of $N \times M$-pixels

At each pixel, the components of colors plus the gray are united in the 2×2 cell. The new image is the grayscale image $\tilde{f}_{n_1,m_1} = [a_{n,m}, r_{n,m}; b_{n,m}, g_{n,m}]$ of $(2N) \times (2M)$-pixels.
The gray $a_{n,m}$ is the average of the primary colors,

$$(r_{n,m} + b_{n,m} + g_{n,m})/3, \text{ or the intensity by } 0.3r_{n,m} + 0.5b_{n,m} + 0.11g_{n,m}.$$

The case, when $a_{n,m} = 0$ for all pixels, is also considered. In this case, the histogram of the grayscale image $\tilde{f}_{n_1,m_1}$ is called the histogram of the color image $f_{n,m}$.

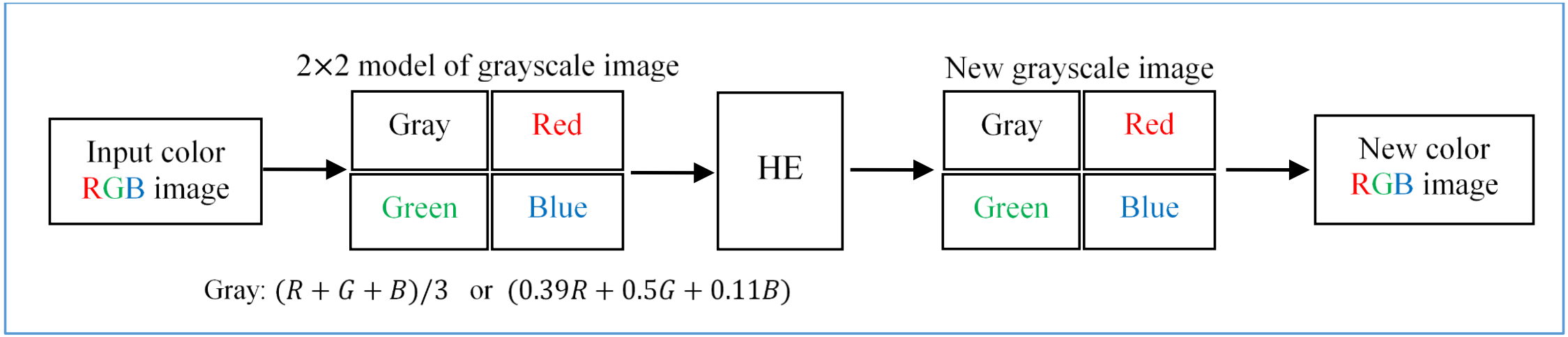


Figure 1. Block-diagram of the color histogram equalization (CHE).

Example 1: The 877×1024-pixel color retina image $f_{n,m}$ is shown in Fig. 2 in part (a).

The range of this image is [0,255]. The histogram $h(r), r = 0{:}\,255$, of the twice larger grayscale image in the 2×2 model is shown in part (b). Its distribution function $F(r)$ is shown in part (c).
The HE of the grayscale image in the 2×2 model was performed. The color image restored from this HE is shown in part (d). This image is called the color histogram equalization (CHE) of the image $f_{n,m}$.

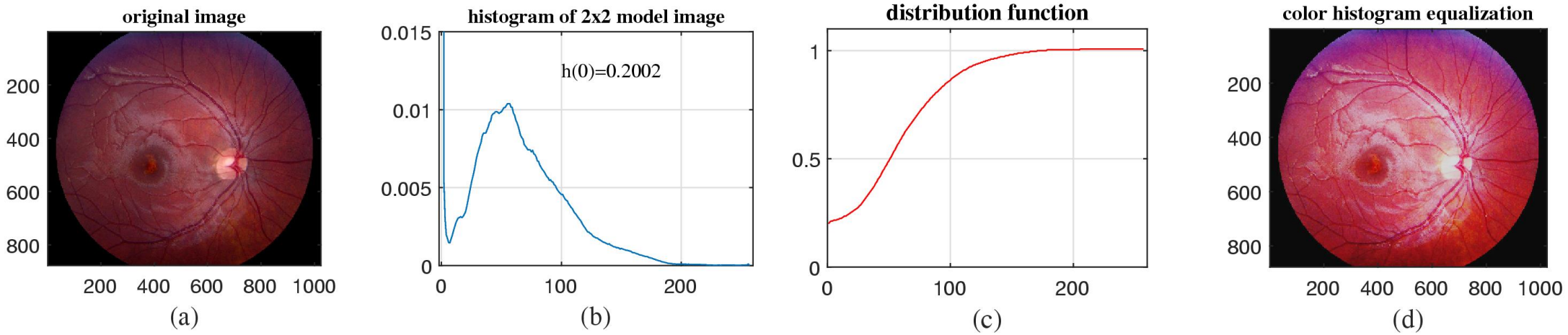


Figure 2. (a) The original color image, (b) the histogram of the 2×2 model grayscale image and (c) the distribution function, and (d) the color histogram equalization (CHE).

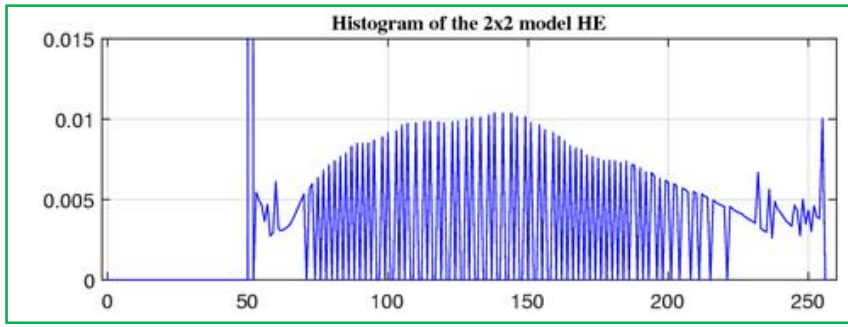


Figure 3. The histogram of the 2×2 model grayscale image after HE.

For comparison, Figure 4 shows the result of the above color histogram equalization in part (b) and the color image which is called the 3-color HE in part (c).

In 3-color HE, each primary color of this RGB image was processed separately by the method of the HE. One can see the combination of colors that is not inherent in the original image.

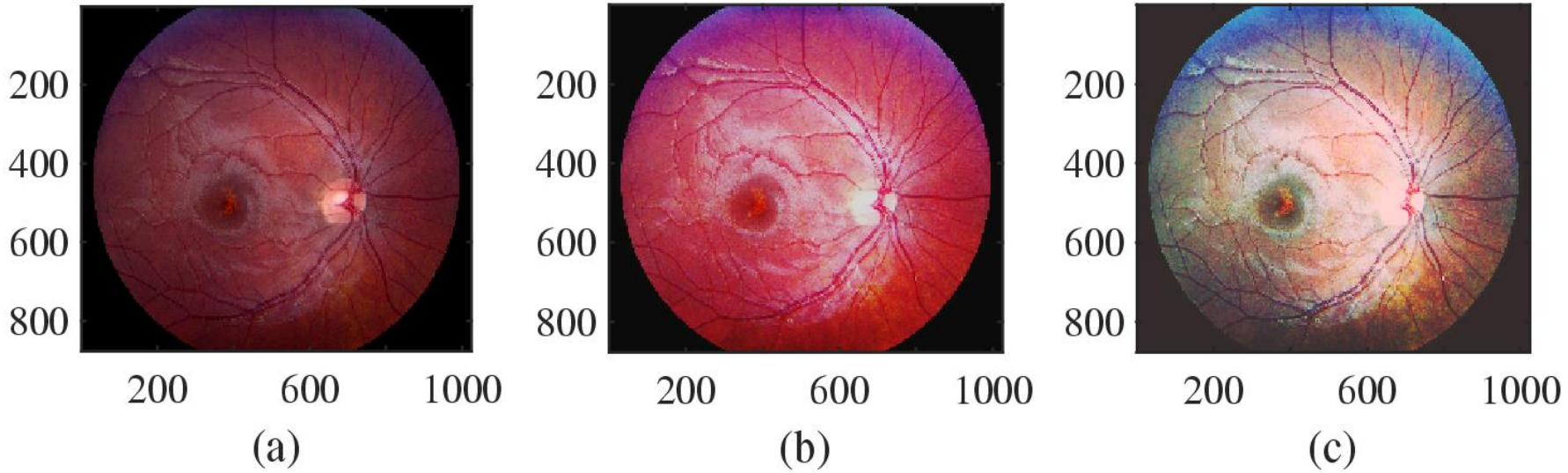


Figure 4. (a) The original color image, (b) the color histogram equalization, and (c) the 3-color histogram equalization.

Example 5: Consider the color ‘corals’ image of 405×763 pixels, which is shown in Fig. 14 in part (a). The histogram and distribution function of the corresponding 2×2 model of this color image with the grays are shown in part (b) and (c), respectively. The image of the color HE is shown in part (d).

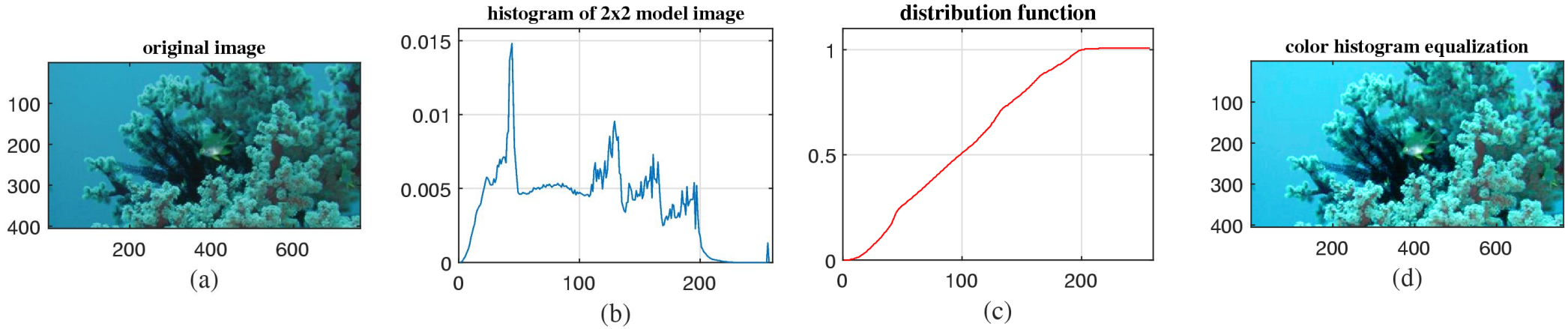
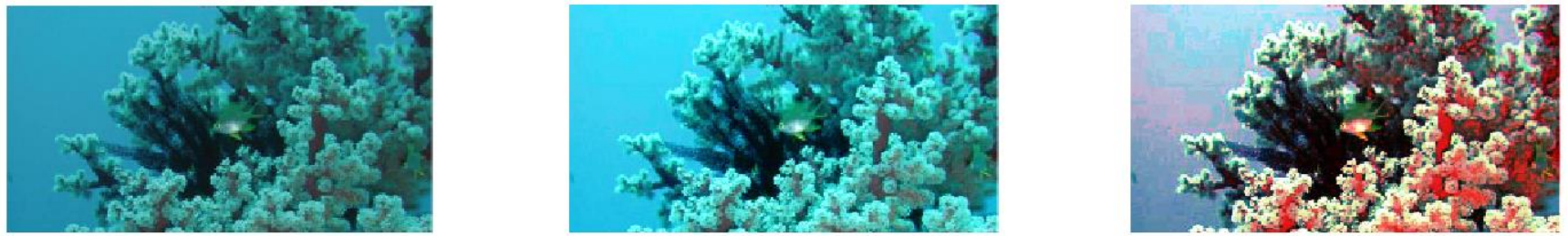


Figure 14. (a) The original color ‘corals’ image, (b) the histogram of the 2×2 model grayscale image and (c) the distribution function, and (d) the color histogram equalization.



(a) (b) (c)

Figure 15. (a) The original ‘corals’ image, (b) the color histogram equalization, and (c) the 3-color histogram equalization.

Example 2 (with a small size image and small range of intensities). Figure 5 shows the color image of 236×360 pixels in part (a). Its 2×2 model grayscale image is shown in part (b); it is the 472×720-pixel image. The HE of this model is shown in part (c). In part (d), the histogram of the model is shown and in part (e) its distribution function. The color histogram equalization is shown in part (f).

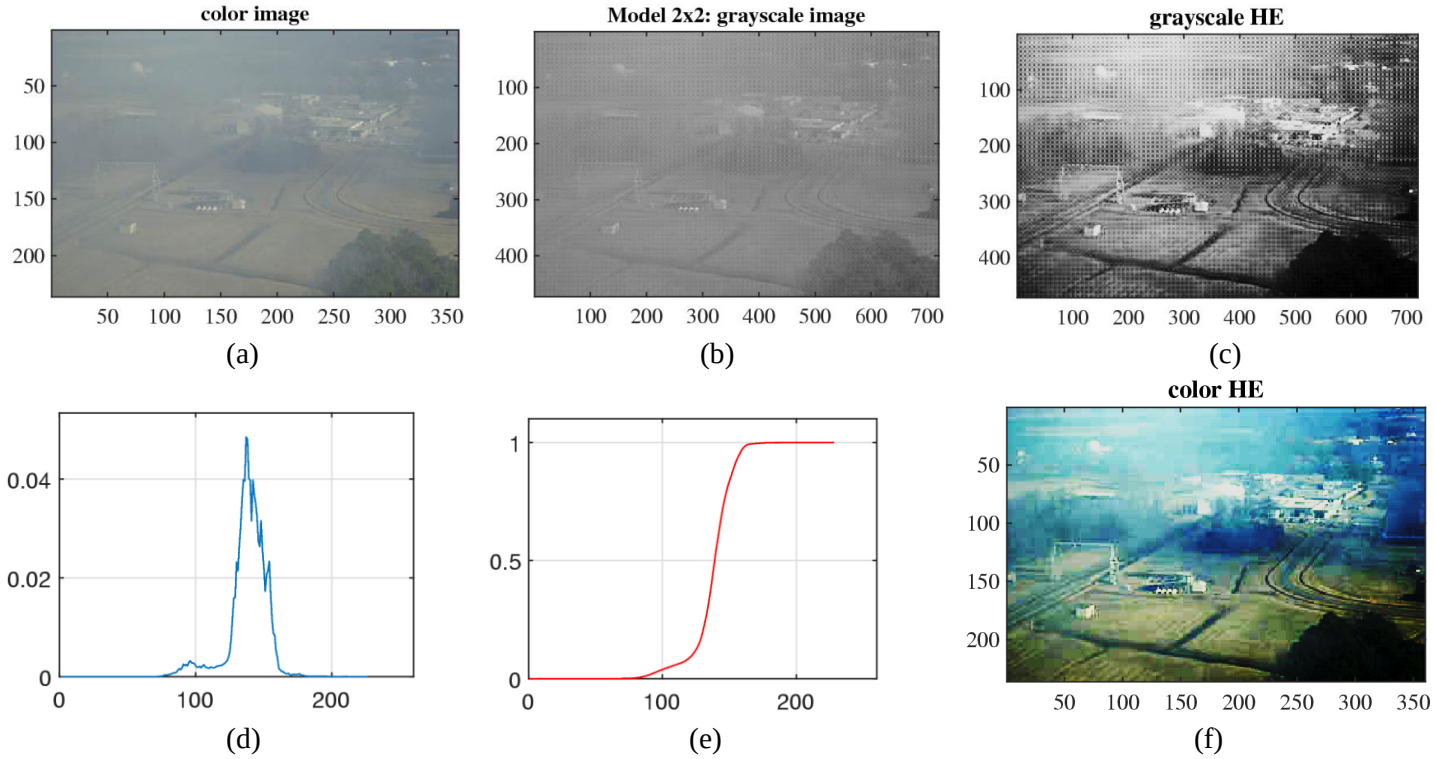


Figure 5. (a) The original color image, (b) the 2×2-model of the image, (c) the HE of the 2×2 model, (d) the histogram of the 2×2 model grayscale image and (e) the distribution function, and (f) the CHE.

Example 2: (The color image of 236×360 pixels)

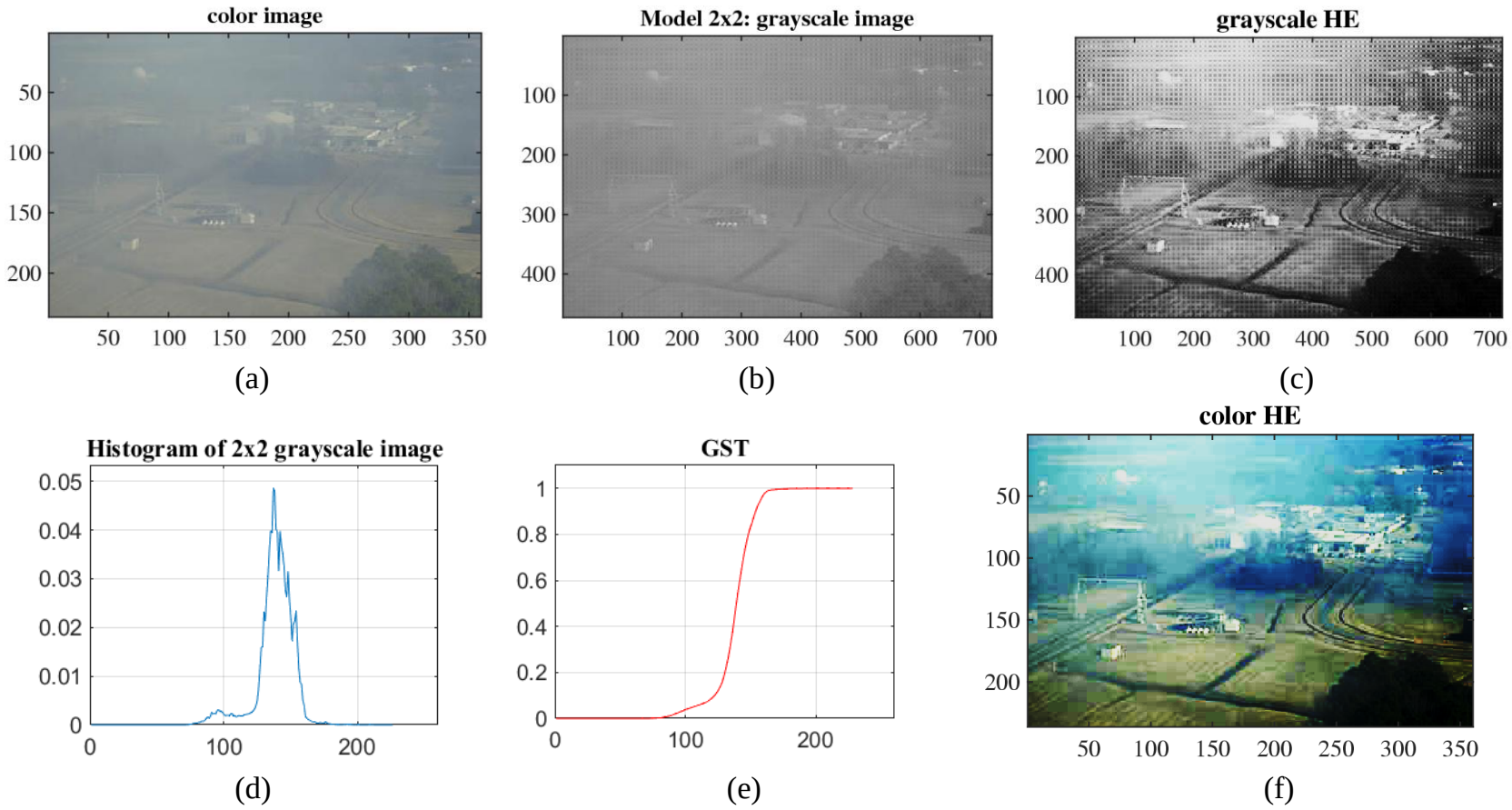


Figure 5. (a) The original color image, (b) the 2×2-model of the image, (c) the HE of the 2×2 model, (d) the histogram of the 2×2 model grayscale image and (e) the distribution function, and (f) the color histogram equalization.

Parameterized Color Histogram Equalization

We consider the color image enhancement, which is accomplished by the parameterized method described by the block-diagram given in Fig. 7. The new image of $(2N) \times (2M)$-pixels in the 2×2 model is the grayscale image $\tilde{f}_{n_1,m_1} = [ka_{n,m}, r_{n,m}; b_{n,m}, g_{n,m}]$, where the parameter k is from the interval [0,1].

- The $k = 0$ case is with the color components only, i.e., $\tilde{f}_{n_1,m_1} = [0, r_{n,m}; b_{n,m}, g_{n,m}]$.
- The $k = 1$ case corresponds to the grayscale image $\tilde{f}_{n_1,m_1} = [a_{n,m}, r_{n,m}; b_{n,m}, g_{n,m}]$ described above. The cases when $k \in (0,1)$ are also interesting.

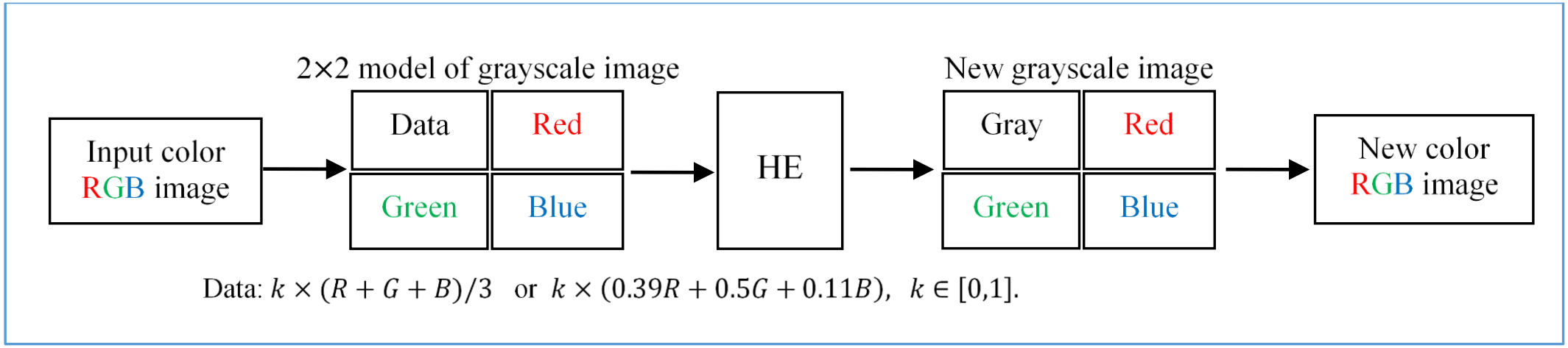
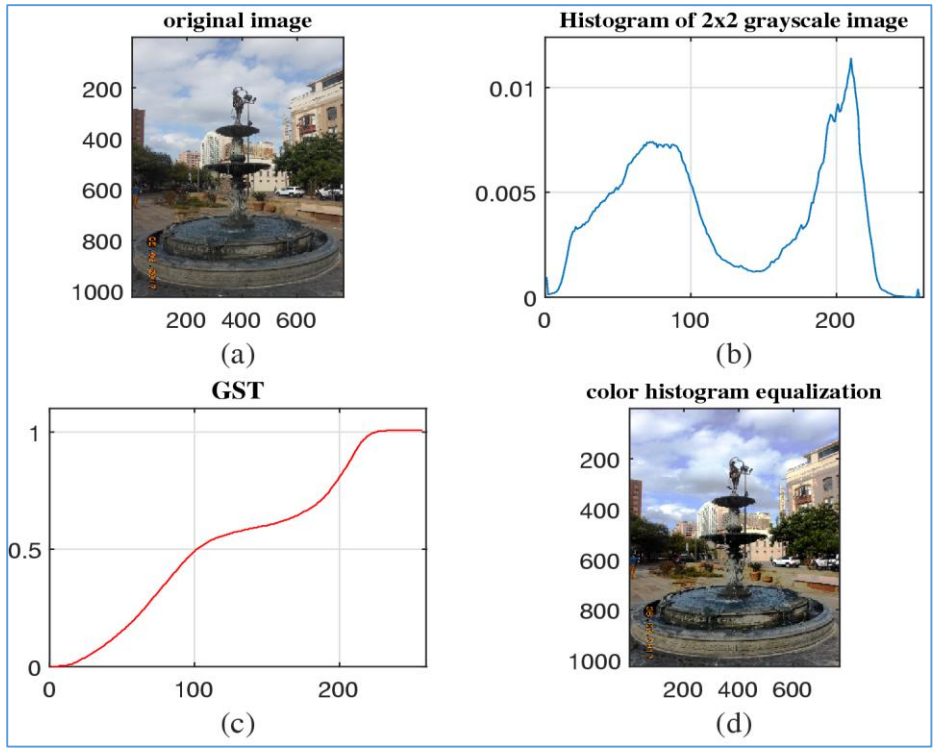


Figure 7. Block-diagram of the parameterized color histogram equalization.

Illustration of the method of parameterized CHE

Fig. 7. The CHE of the image.



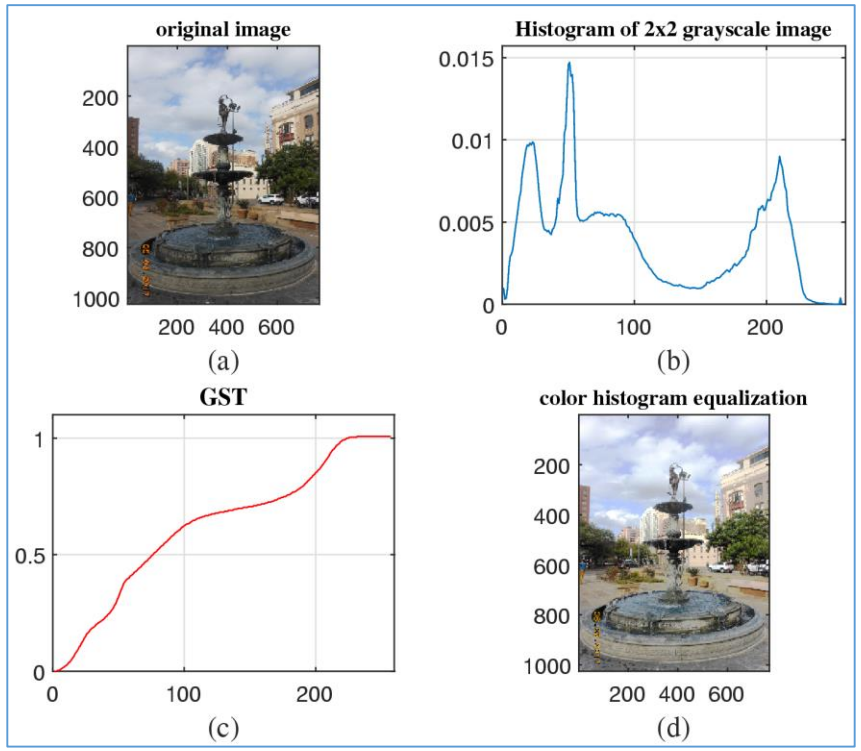


Fig. 8. The CHE of the image with the ¼ of grays.

Fig. 9. (a) The image and processed images by the CHE with no gray, ¼ of gray, ½ of gray, ¾ of gray.

Example 4: The color ‘fish’ image of 340×561 pixels is shown in Fig. 10 in part (a). The histogram and distribution function of the corresponding 2×2 model of this color image are shown in part (b) and (c), respectively. The result of the color HE is shown in part (d). The histogram of the processed 2×2 model is shown in Fig. 11.

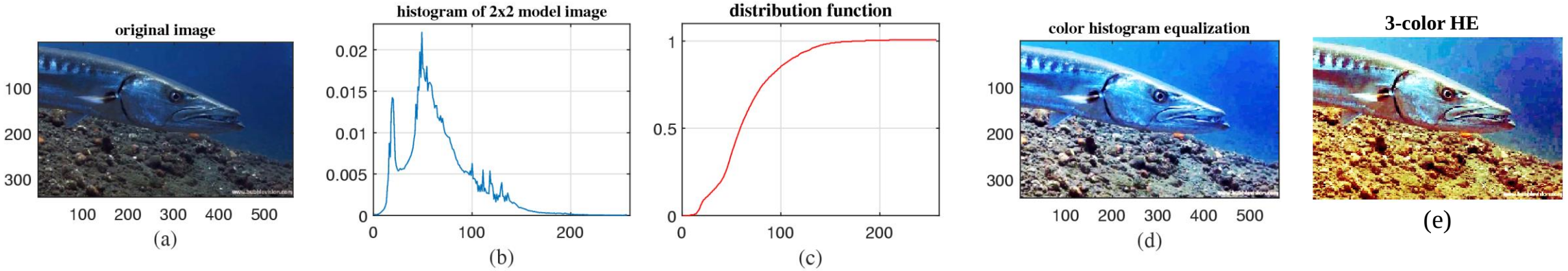


Figure 12. (a) The ‘fish’ image, (b) histogram, (c) distribution function, (d) the CHE, and (e) the 3-color HE.

Figure 13. (a) The original image and processed images with (b) ¼ of gray, (c) ½ of gray, (d) ¾ gray, and (e) gray.

Color Histogram Equalization with Gray Substitution

In this method, it is assumed that the gray component in the 2×2-model can be changed by another grayscale image. Such an image can be selected or prepared, in order to enhance better a given color image. For that, we can consider images with high quality.

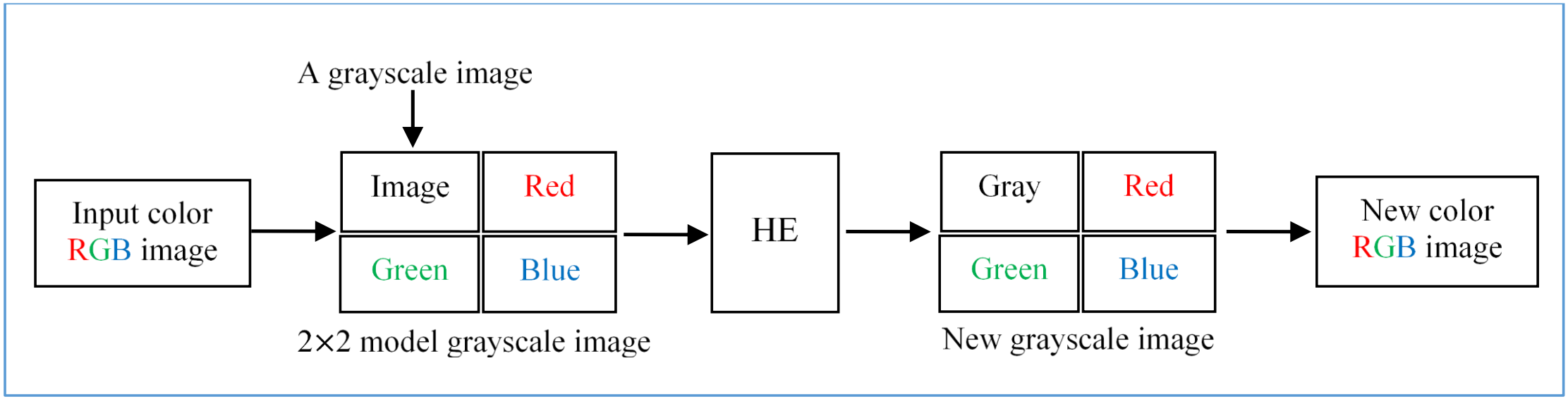


Figure 16. Block-diagram of the modified color HE with substitution of grays.

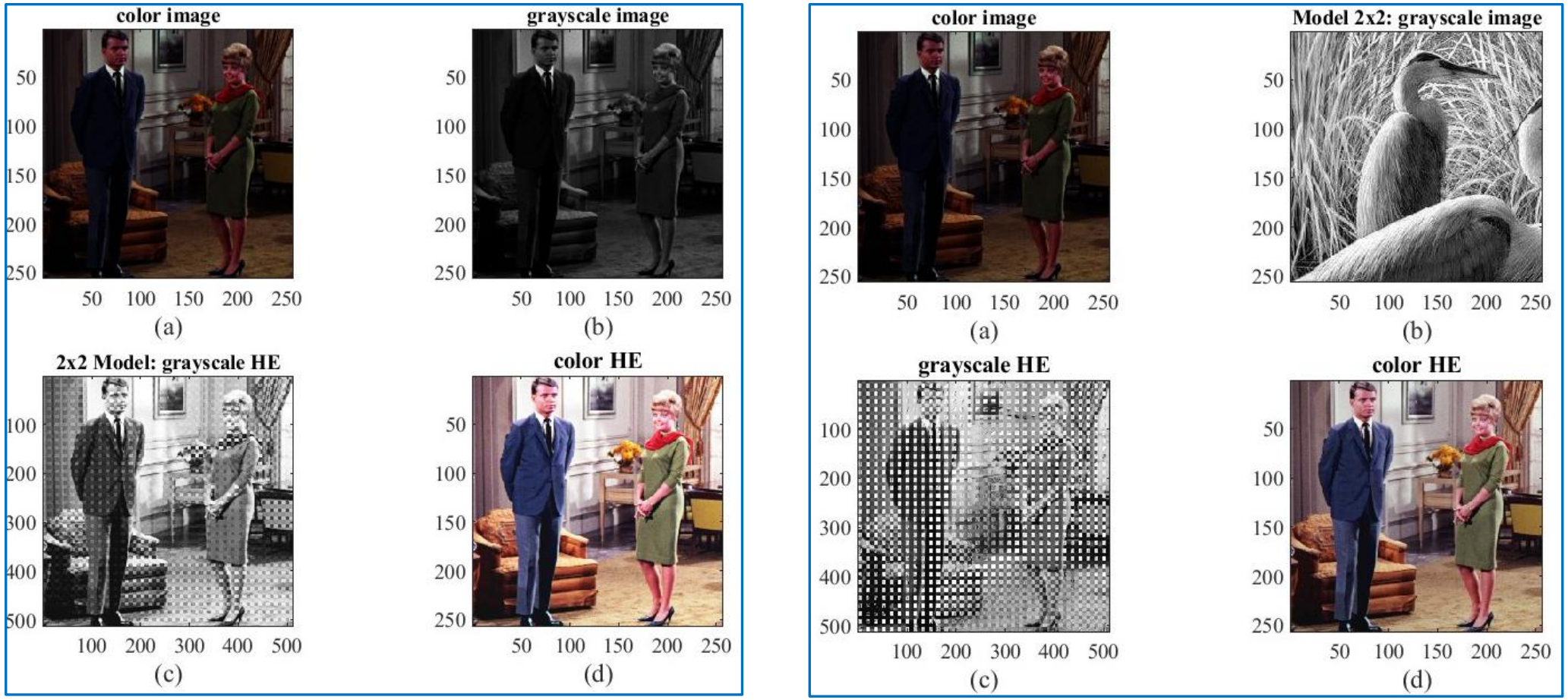


Figure 17. Part I: Color histogram equalization without substitution. (a) The original color ‘living room’ image, (b) the grayscale image, (c) the 2×2 model after HE, and (d) CHE of the image. Part II: Color histogram equalization with substitution. (a) The color image, (b) the new grayscale ‘herons’ image, (c) the 2×2 model after HE, and (d) the CHE of the image.

The new grayscale image in the 2×2 model allows to change the result of the CHE and make it better. Figure 18 shows the original image in part (a), the color histogram equalization in part (b), and CHE with substitution in part (c). For comparison, the 3-color HE of the image is shown in part (d).

(a) (b) (c) (d)

Figure 18. (a) The original color ‘living room’ image, (b) the CHE, (c) the CHE with substation, and (d) the 3-color HE.

Example 7: We consider the image of retina in Figure 19 in part (a) and the grayscale ‘herons’ image of size of 623×519 pixels. The size of this image is smaller than size 877×1024-pixels of the ‘retina’ image. The ‘herons’ image was places in the middle of the grayscale image in the 2×2-model, as shown in part (b). The gray component of the 2×2-model after HE is shown in part (c). The color component of this model is shown in part (d).

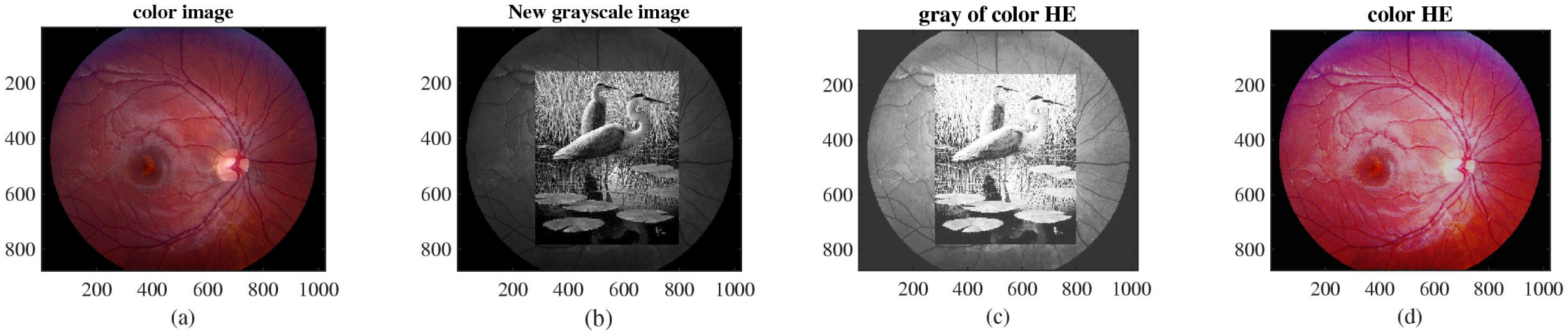


Figure 19. (a) The original color image, the new grayscale image (b) before and (c) after HE of the 2×2-model, and (c) the enhanced color image.

Example 8: The color image of size 1024× 902-pixel of the prostate cancer image on the glass is shown in Fig. 20 in part (a). The grayscale component of the 2×2-model model with the ‘herons’ image in the middle is shown in part (b). The gray component of the histogram equalization of the grayscale 2×2-model is shown in part (c). The result of the color histogram equalization with such substitution of grays is shown in part (d).

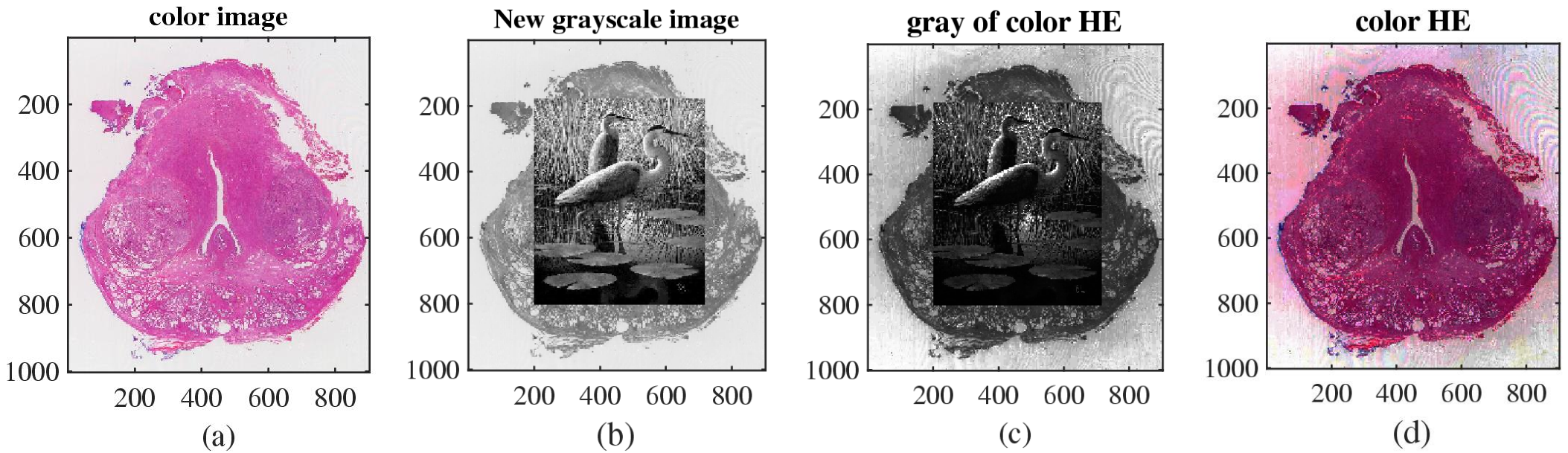


Figure 20. (a) The original color image, the new grayscale image (b) before and (c) after HE of the 2×2-model, and (c) the enhanced color image

For comparison with the 3-color HE, we consider Fig. 21 with the original image in part (a). The color histogram equalization with substitution and 3-color histogram equalization are shown in part (b) and (c), respectively.

The colors in 3-color HE (especially the green) differ much from the real colors in the original image. The processing each color channel separately results in such an effect of wrong colors.

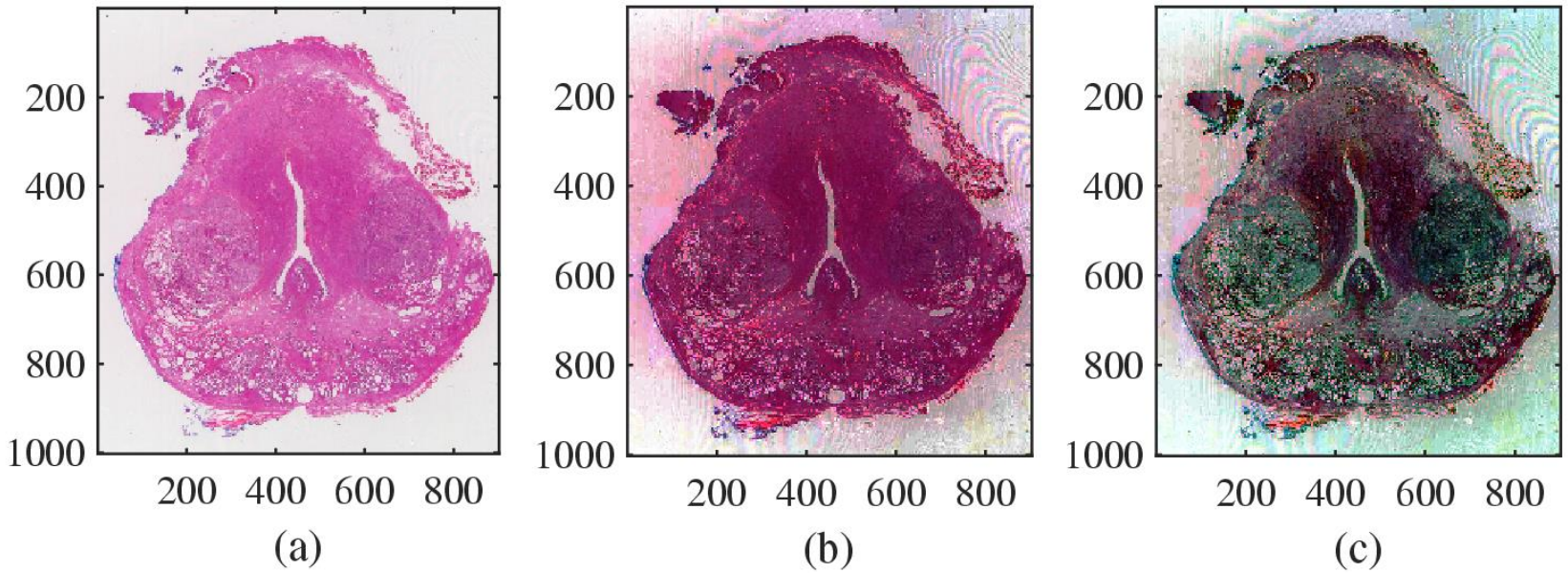


Figure 21. (a) The original color image, (b) the color HE with the ‘herons’ image in grays, and (c) the 3-color HE.

Example 9: The color image of size 350×525-pixel of small fish is shown in Fig. 22 in part (a). The grayscale component of the 2×2-model model with the part of ‘flowers’ image is shown in part (b). The color histogram equalization with such substitution of grays is shown in part (c). In part (d), the 3-color histogram equalization is shown.

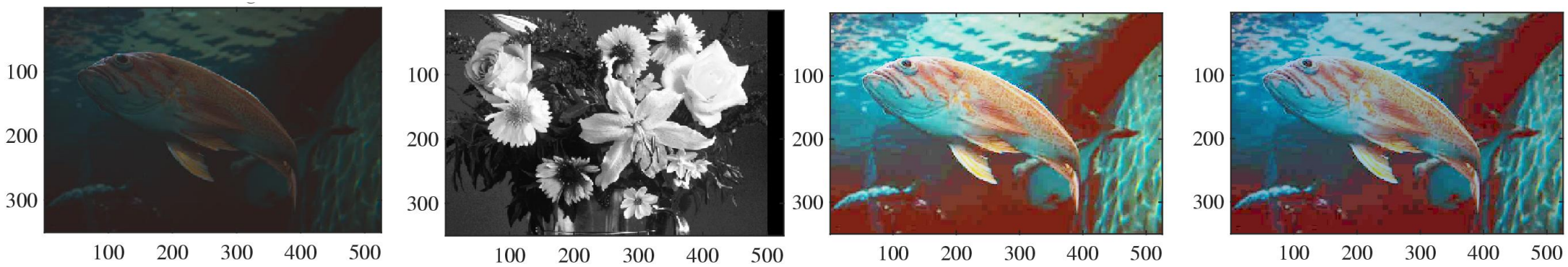


Figure 22. (a) The original color ‘small fish’ image, (b) the grays component in the 2×2 model, (c) the color HE with the ‘flowers’ image in grays, and (d) the 3-color HE.

SUMMARY

Two new parameterized histogram equalizations of color images were described, which are based on the idea of mapping the color image into the 2×2-model of grayscale image and process this image by the known histogram equalization method [1]-[5]. Then, the new color image was extracted from the enhanced model.

- In first method, the gray component of the 2×2-model is considered the k-times intensity of the color image, where $k \in [0,1]$.
- The second method is called the CHE with substitution of gray component with another high-quality grayscale image. The proposed methods are simple and use only single equalization of the histogram, unlike the traditional method of histogram equalization by color channels separately. The above methods were described with illustrative examples for the color images in the RGB model. Different color models can also be considered, including the XYZ, and CMYK. The preliminary experimental examples show effectiveness of the proposed method for color underwater and medical image enhancement.

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