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Hazy Image Enhancement Using DCP and AHE Algorithms with YIQ Colour Space

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Abstract: The use of hazy images is amongst the fastest ways to identify natural resources. Aerial photography has overcome the obstacles faced in land areas, such as rugged areas, swamps and sand dunes. It has important applications in tracking and monitoring studies during wars and peace. However, aerial images often suffer from the lack of contrast due to dust and pollutants. Therefore, this study attempts to improve aerial images by modified dark channel prior (DCP) and adaptive histogram equalisation (AHE) algorithms with YIQ. The images are first improved through DCP and then converted into YIQ colour space that saves the chromatic compounds (IQ). The lighting component comes out after improving the original aerial image via the stretch technique and AHE. Afterwards, all the compounds are merged, and reverse transformation is performed. The proposed method for improving aerial photographs was compared with several other methods. By analyzing the results, the proposed method obtained the best measures of quality, including an entropy value of (7.771), an average gradient value of (14.207) and a naturalness image quality evaluator value of (3.700).

Keywords: Adaptive histogram equalisation, Dark channel prior, Hazy image, Image stretch, YIQ colour space.

1. Introduction

Enhancement of images is an important area in digital image [1–3]. This manipulation includes low lightness and contrast, as is often the case in hazy images, in which the lack of contrast plays an important role in many applications. Aerial imaging is any photographic process in the air using any modern imaging technology, whether by a drone or any other technology. Aerial images play a major role in clarifying phenomena and solving the relevant problems, given that some phenomena cannot be understood clearly except through aerial photography. Land surveys are also performed to collect map information and data for commercial and real estates, including photographing buildings from above and photographing geographical phenomena in valleys. Aerial photography shows the effect of valleys on buildings and clarifies the directions of the waters of the valleys. Through photography, geographers may be able to identify problems and solve them, as well as to know the terrain gradients of mountains and clarify the highs and lows.

Dharejo et al. introduced an algorithm for enhancing hazy images. This algorithm is based on the direct processing of RGB components without the the use of colour transformations. The method of piecewise linear transformation was adopted to improve the lighting, and mathematical optimisation was conducted to find the mathematical compounds. Their results demonstrated a good enhancement in the hazy images [4].

Hana et al Suggest a method to improve aerial photos based on dark channel prior and Rtinex (DCPR) using HSV transformation where the chromatic components are optimized by DCP As for the lighting component, it was improved by Retinex algorithm, this algorithm is a good method for enhancing hazy Image at low distortion levels, but it is not effective at high distortion levels. [5].

Jobson et al. introduced an algorithm for the enhancement of contrast and lightness of low-lightness images. Through this method, they

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discovered that the special retinex model in human vision and the colour stability in image processing experiments use mathematical foundations based on the following steps: mapping log function, surround function and surround space function and treatment of retinex. The rendered images looked somewhat similar to the original scene [6].

Kareem et al. proposed a new algorithm for improving a group of aerial photographs that suffer from haze. Four aerial images of type JPG were selected by relying on the YCbCr colour space with the use of a composed sigmoid function [7], this method succeeded in improving the aerial images after using entropy and average gradient, but, this method is not successful in retrieving the color information.

He et al. suggested that an aerial image is simple but contains haze. The fog was removed through the dark channel prior (DCP) by transmission estimation, estimation of atmospheric light, soft matting and recovering the scene radiance and patch size. Van Herk's algorithm was successful in obtaining improved images [8], it is conventional methods do not work well at high deformation levels.

Ngo et al. presented an algorithm for recovering a clear image from images degraded by fog, snow or yellow dust. It relies on machine learning approach (MLA) technology and an accelerator with a capacity of 4K. The algorithm improved the colour attenuation prior and enhanced the equi-distribution for a more reliable training data set, solution constraints for the transmission map, solution for background noises, colour distortion and adaptive tone. An accelerator method was used for devices, in which the overall architecture, an optimised merging–sorting network-based architecture for a modified dual median filter, atmospheric light estimation, compensation and hardware verification were considered. The algorithm succeeded in terms of image improvement and image recovery with high efficiency [9].

Tan et al. suggested a new algorithm based on the introduction of multiple images of a scene, which may include polarisation to different degrees or under different weather conditions. The algorithm utilises images with improved visibility, that is, images that do not contain fog, rain or dust and have great contrast. Fog, rain or dust and the air exert great effects on the contrast of the scene. This algorithm is aimed at vision improvement. The data cost algorithm succeeded in obtaining images with improved natural scenes that are free of fog, rain or dust [10].

Wang et al introduced an image dehazing method, which depends on physical models and the DCP principle. They also provided an algorithm for fast transmission estimation to reduce the processing time. Image quality was evaluated using MSE, PSNR and mean regression. The method included estimation of the scene transmission, optimisation of the scene, estimation of the atmospheric light value based on a variogram and recovery of the scene radiance. It obtained improved images without atmospheric dispersion, enhanced the operational efficiency and achieved good and accurate results in dehazing [11].

Fayaz A. et al. suggested a method using scene estimation approach (SEA) to improve expressive images based on basic RGB color space with color correction by color compensation which includes Fourier transform [12]. By analyzing their results, they reached a good improvement in colors for dusty images, but the contrast in those images was low.

In this study a new algorithm is proposed for enhanced high-distortion aerial images bydeveloping DCP and AHE algorithms depending on YIQ color space, this algorithm increases contrast and brightness without distorting colors.

2. Suggested method

The proposed method is modified DCP and adaptive histogram equalisation (MDCAHE) based on the development of DHP and adaptive histogram equalisation (AHE) techniques, with the addition of YIQ colour transform and histogram stretch. The chromatic compounds are processed in accordance with the DCP algorithm and the lighting component results from the original image that is enhanced twice via histogram stretch and AHE.

2.1 DCP algorithm

The general attenuation model that describes a physically hazy scene in aerial images can be represented by the following relationship [8]:

$$f\,(v) = I(v)\,tr(v) + Ac\,(1 - T_r(v)) \qquad (1)$$

where f is the hazy image intensity, and I is the radiance in the scene. Ac is the atmospheric light, and T_r is the transmission channel. The DCP technique solves the attenuation model, which is used to improve aerial or dusty images. At a very low intensity in one of the RGB components, Ii is given by [8]

$$I_{dark}(v) = min_{i \in \{r,g,b\}}\,(min_{y \in \mathrm{R}(v)}\,(Ii\,(y))) \qquad (2)$$

where Ii refers to the three channels (red, green and blue) of i, and R (v) is the local patch with v centre coordinate. The DCP technique makes the intensity of the dark channel of Ii low and become zero. Ji is an outdoor haze-free image (image without haze, except the bright area) and is expressed by:

$$I_{dark}(v) \cong 0 \tag{3}$$

Accordingly, the transmission component value can be given by [8]

$$T_r\,(v) = 1 - d_{\,miny\epsilon\,\mathrm{R(v)}}\,(\,min_{i\,\epsilon\,\{r,g,b\}}\,\frac{\mathrm{J}(y)}{Ac}) \tag{4}$$

Soft mapping can be used to refine a transmission. If the dust or haze is removed, the image becomes unnatural. Thus, the value is $(0 < d < 1)$, where d is set to 0.95, and the atmospheric light (optimal value) is $Ac = 0.1$, with patch size (15×15) [1]. Then, the enhanced image is given by [8]

$$I(v) = \frac{J(v) - Ac}{\max\,(T_r(v), 0.1\,)} + Ac \tag{5}$$

2.2 Enhancement-based image stretch and AHE using YIQ

The image stretch for a colour image $\mathrm{I}(\mathrm{x}, \mathrm{y}, v), v = 1, 2, 3$ (red, green and blue) components, is implemented to restore the image colour. This stretch relies on the standard deviation and mean value of the RGB channels calculated by [13]:

$$D_{\,max,v} = D_{\,mean,i} + \gamma D_{\,std,v} \tag{6}$$

$$D_{min,v} = D_{\,mean,v} - \gamma D_{\,std,v} \tag{7}$$

where $v\,\epsilon\{\mathrm{R}, \mathrm{G}, \mathrm{B}\}$; $\mathrm{D}_{\,\mathrm{mean},v}$ and $\mathrm{D}_{\,\mathrm{std},v}$ are the mean value and the standard deviation of the lightness component, respectively; γ is a parameter for controlling dynamic histograms; and $\mathrm{D}_{\,\mathrm{max},v}$, $\mathrm{D}_{\,\mathrm{min},v}$ are the maximum and minimum of $(\,v\,)$ component, respectively. The colour-restored image is obtained by image stretch as follows [13]:

$$D_{\,r,v} = \frac{I_{\,v} - D_{\,min,v}}{D_{\,max,v} - D_{\,min,v}} \times 255. \tag{8}$$

The next step is the CLAHE technique, in which the image is divided into many areas that do not overlap and have almost the same size. Then, it computes the graph for each region. The segment term is obtained for cutoff graphs. Each histogram is redistributed in a professional manner, so that its height does not exceed the segment limit. By β, the section term is obtained, which is described as [14]

$$\beta = \frac{M\,N}{L}\Big(1 + \frac{\alpha}{100}\,(S_{max} - 1)\,\Big) \tag{9}$$

Y, I and Q are the colour coordinates in the development of the NTSC TV system. This system is mainly used for transmission to send a colour signal with high efficiency. In this study, we use the YIQ colour transform after image enhancement, HE and AHE for full chromaticity within the additive procedure I and Q, which is represented as a chromaticity signal in television technology as well [15]. Component (I) contains the hue orange-cyan info and hue green-magenta information e in (Q) [16]:

$$M_{RGB\;to\;YIQ} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.270 & -0.322 \\ 0.211 & -0.253 & 0.312 \end{bmatrix} \tag{10}$$

2.3 Component enhancement and inverse transform

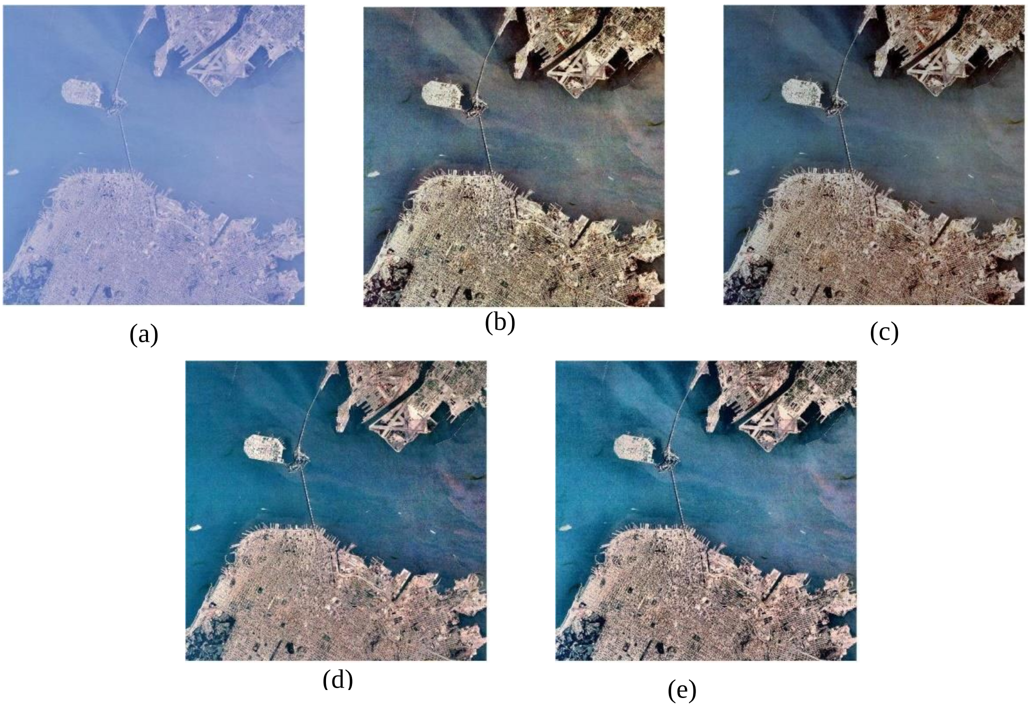
The inverse conversion is realised by [16]:

$$M_{YIQ\;to\;RGB} = \begin{bmatrix} 1 & 0.956 & 0.621 \\ 1 & -0.272 & -0.647 \\ 1 & -1.060 & 1.703 \end{bmatrix} \tag{11}$$

This model connects two colour YIQ models: The first model is the least sensitive of the systems to differences in chromaticity compared with the differences in luminance. The second model is a colour gamut that is very small and is determined by one colour dimension instead of two colour dimensions. This is very suitable for transmitting television signals [17].

3. Results and discussion

In this study, aerial images were improved using the proposed algorithm, the MDCAHE algorithm, with YIQ colour space. The USC-SIPI Image Database [19] that include (36) aerial images with size 512×512, JPG format used in this study, as shown in Fig. 3. All algorithms for enhancement were implemented using MATLAB R2020a. A comparison was made to determine the efficiency of improving aerial images. Specifically, MDCAHE was compared with several algorithms (AHE, DCP, DCPR, MLA, YCbCr and SEA) depending on many nonreferenced quality measures, such as EN [18], AG [20] and mean of standard deviation (MSD) [21].



(a) (b) (c)

(d) (e)

Figure. 1 Steps of the suggested algorithm: (a) original image, (b) image stretch, (c) AHE for the image stretch, (d) DCP for the original image, and (e) final enhancement

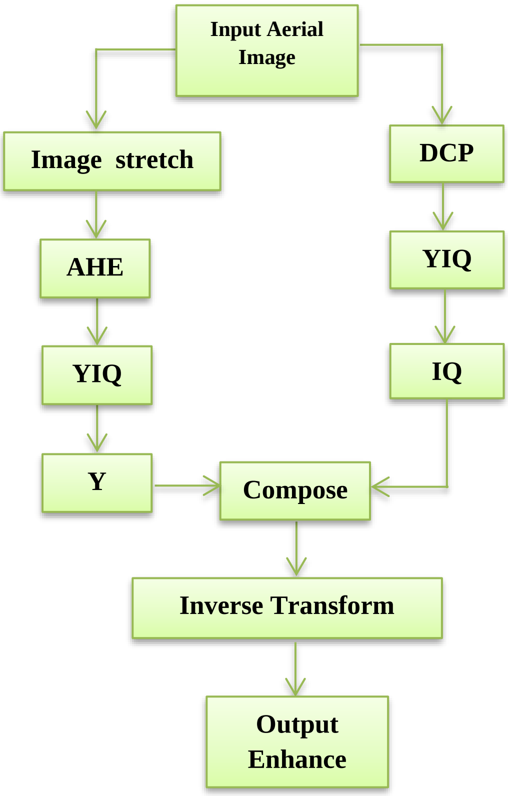


Figure. 2 Scheme of the MDCAHE algorithm

Table 1 shows the average quality of the 14 images for these measures, where we note that the proposed method obtained the best values. For quality measurement, four images, as shown in Fig. 4, were selected as a general model to evaluate the improvement quality. The results are presented in Table 2, which indicated that the proposed method obtained the best quality measures. Fig. 5 shows that image b was improved by the various methods. We specifically note the success of the MDCAHE algorithm in retrieving chromaticity details and increasing contrast. This behaviour was reflected in the histogram distributions. In Fig. 6, the MDCAHE method had the best and widest distribution ranges for the channels (red, green and blue) that transformed by the YCbCr and AHE algorithms. To focus on the aerial details, a specific area was selected within the image and enlarged, as demonstrated in Fig. 7. The MDCAHE method increased the details and contrast compared with the rest of the methods.

4. Conclusions

In this study, the MDCAHE algorithm is suggested to enhance aerial images that suffer from low contrast. This algorithm is compared with the methods AHE, DHP, DCPR, MLA, YCbCr and SEA by using nonreferenced scales, namely, EN, AG and MSD. It has succeeded in enhancing aerial images better than other methods and achieved high values in EN (7.751), AG (18.198) and MSD (44.156). In the future, the suggested algorithm can be used to enhance under water images.

Table 1. Quality average for no referenced scales

Method	EN	AG	MSD
MDCAHE	7.751	18.198	44.156
AHE[14]	7.663	12.682	30.298
DCP[8]	7.338	13.645	32.355
DCPR [5]	6.596	5.002	11.708
MLA[9]	6.507	5.239	12.254
Ycbcr[7]	7.506	13.659	33.722
SEA[12]	7.353	13.584	34.104

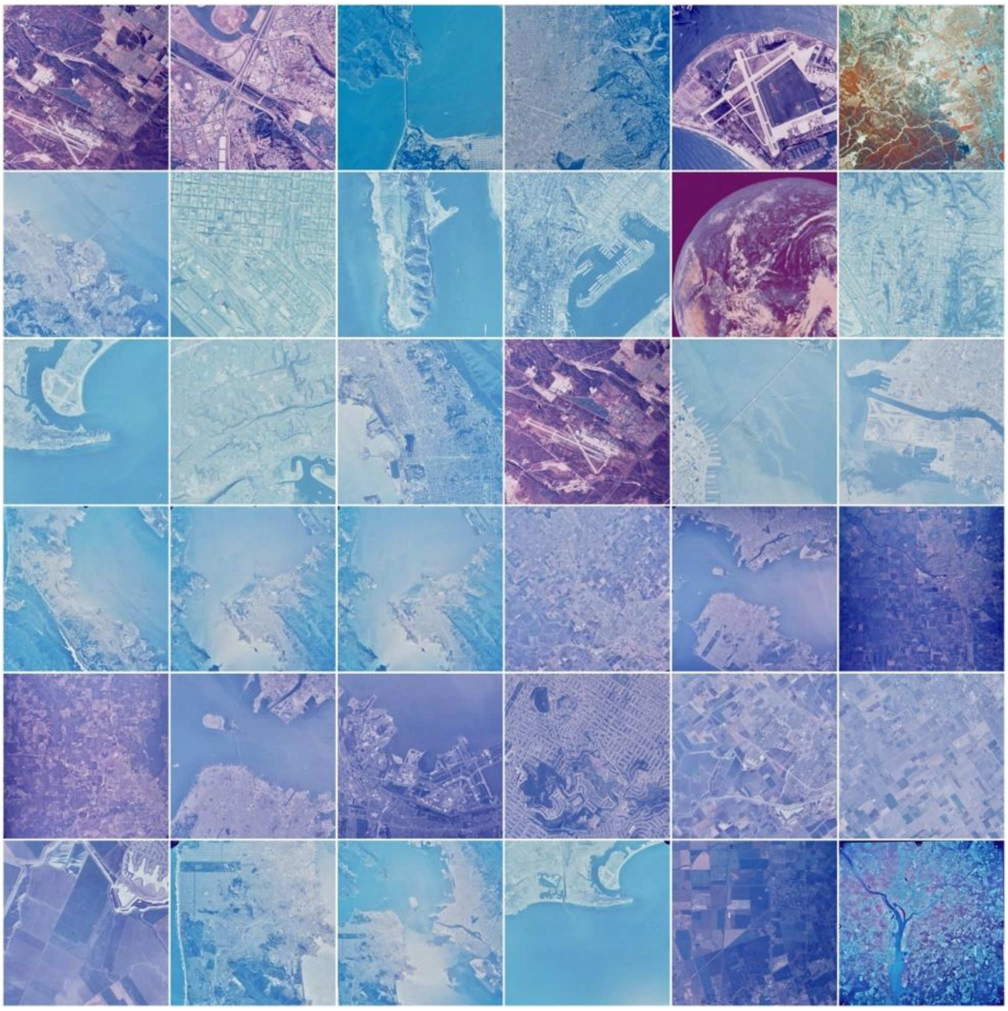
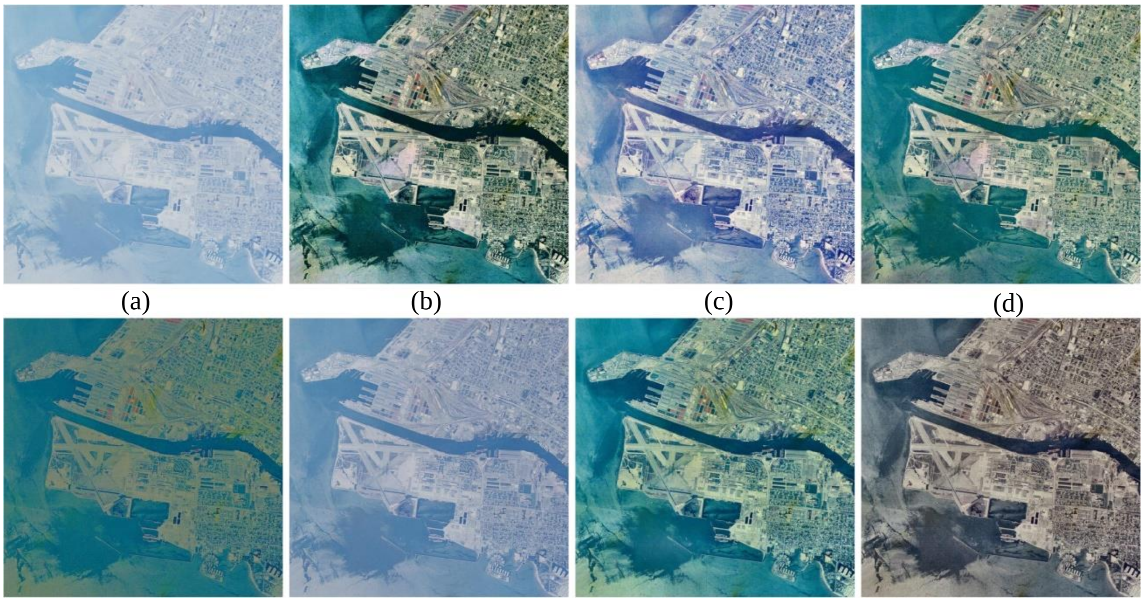


Figure. 3 Aerial image data set [19]

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

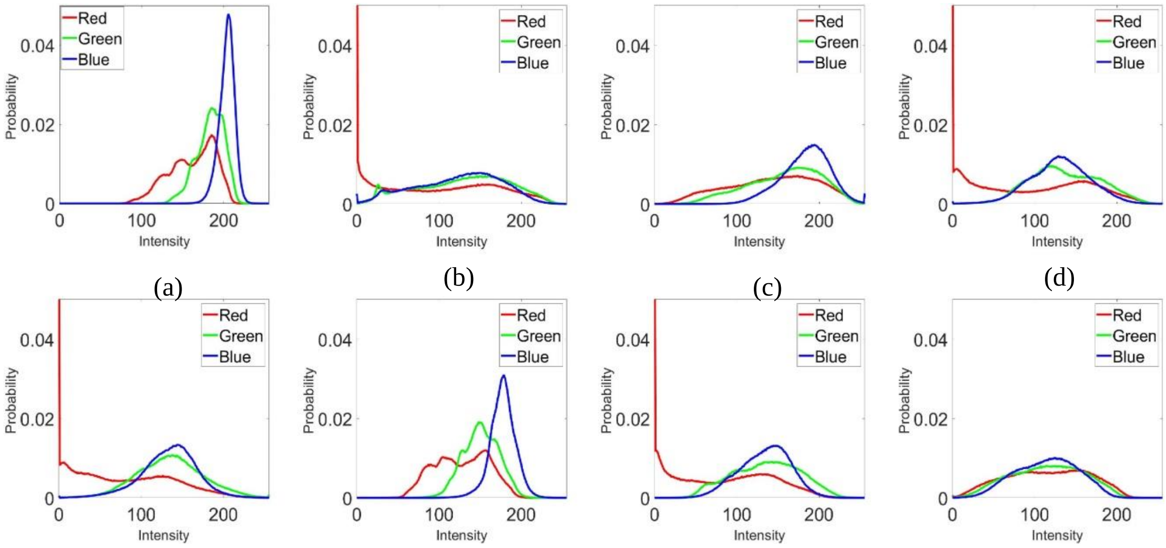
Figure. 4 Selected aerial images as a model from the complete data set



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

(e) (f) (g) (h)

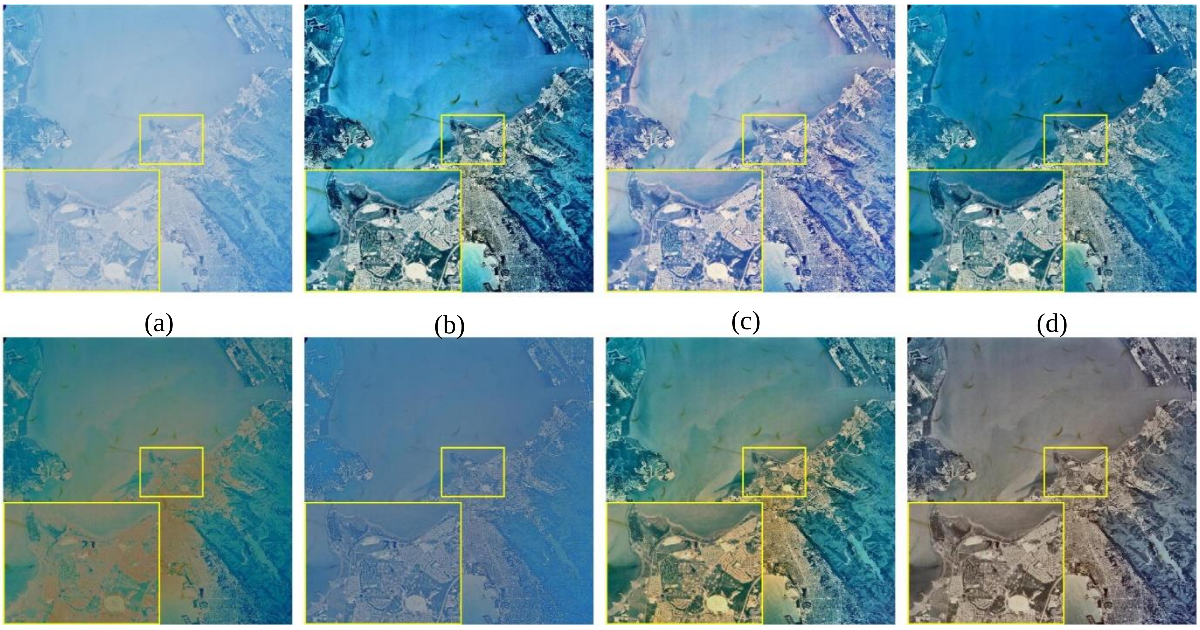
Figure. 5 Enhanced aerial images: in (a) image a in Fig. 4 enhanced using the methods (b) MDCAHE, (c) AHE, (d) DCP, (e) DCPR, (f) MLA, (g) YCBCR, and (h) SEA



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

(e) (f) (g) (h)

Figure. 6 The Histograms aerial photographs in (a) image a in Fig. 4, that enhanced using various methods: (b) MDCAHE, (c) AHE, (d) DCP, (e) DCPR, (f) MLA, (g) YCBCR, and (h) SEA



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

(e) (f) (g) (h)

Figure. 7 Magnified area of an aerial image: (a) image b in Fig. 4 enhanced using the methods, (b) MDCAHE, (c) AHE, (d) DCP, (e) DCPR, (f) MLA, (g) YCbCr, and (h) SEA

Table 2. Quality assessment for image a, b, c, and d

Image _a				**Image _b**			
Method	**EN**	**AG**	**MSD**	**Method**	**EN**	**AG**	**MSD**
MDCAHE	7.618	16.940	40.275	**MDCAHE**	7.662	13.122	32.735
AHE	7.447	9.916	21.729	**AHE**	7.319	5.937	14.407
DCP	7.538	14.052	32.213	**DCP**	7.070	9.561	22.782
DCPR	6.541	3.527	7.045	**DCPR**	6.265	1.963	4.703
MLA	6.862	4.807	9.566	**MLA**	6.935	2.375	4.638
Ycbcr	7.373	12.721	28.471	**Ycbcr**	7.335	8.534	21.765
SEA	7.441	12.859	31.718	**SEA**	7.057	9.032	23.110
Image _c				**Image _d**			
Method	**EN**	**AG**	**MSD**	**Method**	**EN**	**AG**	**MSD**
MDCAHE	7.921	15.764	49.449	**MDCAHE**	7.945	14.500	39.317
AHE	7.883	14.978	46.254	**AHE**	7.704	10.955	28.361
DCP	7.806	13.625	44.496	**DCP**	7.080	8.855	21.464
DCPR	7.371	8.312	25.340	**DCPR**	6.795	3.628	8.378
MLA	6.942	6.578	14.104	**MLA**	6.758	3.057	7.178
Ycbcr	7.784	13.447	43.710	**Ycbcr**	7.295	9.179	24.187
SEA	7.590	11.887	39.176	**SEA**	7.446	12.663	36.118

Conflicts of interest

No conflict of interest.

Author contributions

Hazim G. Daway has contributed to the design and implementation of the research by using Matlab. Nadia A. Khalaf and Baida M Ahmed have supervised the written paper and provided the necessary data.

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