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Comparative Analysis on Aerial Image Enhancement Techniques

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Abstract

In this paper a comparative analysis on various aerial image enhancement techniques are carried out with that of wavelet based enhancement technique based on certain quality assessments. Paper illustrates wavelet based enhancement algorithm performed in an intelligent manner and the obtained result is compared with other conventional enhancement techniques. From the comparative analysis performed using mean square error, peak signal to noise ratio and structured similarity index measurement the wavelet based enhancement technique is found to give better enhancement result. Since the algorithms proposed are applicable to color images this work can be further extended to other applications like feature extractions of roads and buildings, medical image segmentation and video streaming.

Keywords: Aerial Image, Color Restoration, Enhancement, Histogram Equalization, Mean Square Error, Peak Signal to Noise Ratio, Structural Similarity, Wavelet

1. Introduction

Image enhancement has become one of the main areas of interest of most of the researchers in the recent past[3]. Color image enhancement is mainly a hurdle as it involves three imaging plane of colors namely red, green and blue. Here focus is on aerial color images[2]. Aerial images are taken from imaging instruments deployed on satellites, air/space crafts or balloons. Generally defining images taken from a height above the earth's surface to capture various geographical features of a certain area below the imaging instrument is termed as aerial images[1]. The distance between the target and imaging device is proportional to the noise found in the image generated. This can be either due to natural factors like small clouds, haze[5], dust particles present or can be due to instrumental errors. One of the prominent instrumental errors found is the low dynamic range of imaging device used. This adversely affects the intensity, contrast and even the color of the image generated. Thus enhancement as a whole include enhancement in all the above three above mentioned parameters; intensity, contrast and color. Many traditional algorithms are present in order for color images[10]. In this paper a comparative analysis done on the quality of enhancement performed using these traditional algorithm with that of wavelet based algorithm[11,12]. In wavelet based technique there is absence of independent coefficients that enables quality in denoising when compared with other techniques. Various traditional methods of enhancement that are used for comparison in this paper are Histogram Equalization (HE), Adaptive Integrated Neighborhood Dependent Approach for Nonlinear Enhancement of Color Images (AINDANE)[15] and Modified Histogram Equalization (MHE). The parameters used to check the quality of the obtained image are Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Measurement (SSIM).

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2. Proposed Algorithm

Aerial images are more vulnerable to many kind of noises both caused due to natural as well as instrumental or man made errors. Natural noises include haze, fog, cloud particles or dust particles that causes a small amount of visual blurring in obtained aerial image. Enhancement of such aerial image is the main work in this paper. Here a comparison is performed on various enhancement techniques with that of wavelet based color image enhancement technique. Various enhancement techniques are listed below.

2.1 Wavelet based Enhancement

This method is a non linear technique[6,8,9] used for image enhancement. This application of algorithm can be very useful in television to improve the visual quality of images. The technique is applied to both spatial domain and discrete wavelet domain. This is based on some assumption taken regarding visual appearance and human image formation. From the image obtained from various imaging instruments the intensity and reflectance values are separated as shown in (1).

$$M(x,y) = L(x,y)R(x,y) \quad (1)$$

Intensity of image is then estimated related to each pixel location as shown in (2).

$$I(x,y) = \log(L(x,y)) + \log(R(x,y)) \quad (2)$$

On the luminance[4] part of the image wavelet based dynamic range compression is performed (4). For any color image the intensity part in that image can now be estimated from (3).

$$I(x,y) = \max\left[I_i(x,y)\right] \quad (3)$$

Then the enhancement algorithm is then applied on this intensity image. This is done using a center surround approach using Gaussian kernel (5) that helps in finding the local contrast leading to local contrast enhancement.

$$\begin{aligned} M(x,y) = & \sum_{k,l \in z} p_{J,k,l}\phi_{J,k,l}(x,y) \\ & + \sum_{j \ge J}\sum_{k,l \in z} q^{h}{}_{j,k,l}\psi^{h}{}_{j,k,l}(x,y) \\ & + \sum_{j \ge J}\sum_{k,l \in z} q^{v}{}_{j,k,l}\psi^{v}{}_{j,k,l}(x,y) \\ & + \sum_{j \ge J}\sum_{k,l \in z} q^{d}{}_{j,k,l}\psi^{d}{}_{j,k,l}(x,y) \end{aligned} \quad (4)$$

$$G(x,y,c) = K\, exp\left(\frac{-\left(x^2 - y^2\right)}{c^2}\right) \quad (5)$$

As a final step a color restoration is performed. The obtained image will be close to real world perception compared to the aerial image leading to better enhancement.

2.2 Histogram Equalization (HE)

This is traditional method used in obtaining a uniform intensity value. When compared to wavelet based technique the enhancement is only applied to intensity values in the image and more over it performs intensity normalization irrespective of the value. This is done using the Probability Density Function (PDF) of the lightness level in any given image. Corresponding to the intensity level the value is normalized. Initially we need to know the maximum value of intensity; in case of gray scale it is 255. Then in simple words it can be expressed as ratio of number of pixels with particular intensity to that of total number of pixels. Short coming of the HE algorithm[14] is it may enhance highly intense areas in an image also.

2.3 Modified Histogram Equalization (MHE)

To avoid the above mentioned shortcoming of HE the MHE was developed. This method can produce good outcome for color images. As a starting step the image is converted to National Television System Committee (NTSC) standard. Then on the first plane that lightness component is normalized using sigmoid function given in (6).

$$S_n = 1 \Big/ \left(1 + \sqrt{\frac{1 - I_n}{I_n}}\right) \quad (6)$$

The detailed explanation of the MHE[17] is depicted in Figure 1 where Y represents the image obtained after applying the HE on luminance component. From the next step onwards normal HE is applied to all the 3 planes including the above normalized lightness plane. Then from NTSC space image is converted back to RGB format.

2.4 AINDNE

This algorithm is extremely useful in enhancement of images taken under extremely low or non uniform lightening condition. Initially in this algorithm the luminance values are enhanced which is considered to have the low frequency component and the reflectance of the image is considered to have high frequency component.

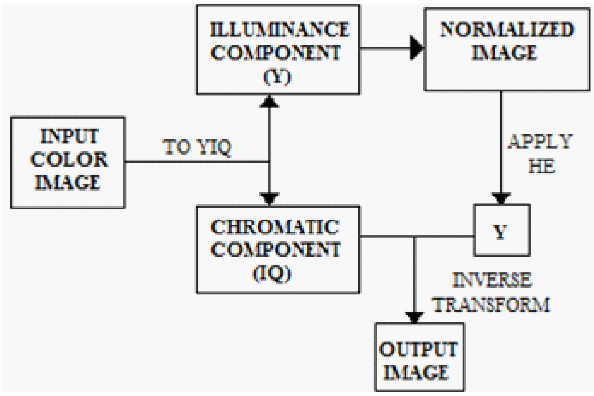

Figure 1. MHE algorithm for color image.

Intensity is image is convoluted with the Gaussian surround function. Then the next step is adaptive range compression which ensures improvement of luminance values of all the darker pixels in the image. Finally on the basis chromatic information present in the original aerial image a linear color restoration is performed. Then the enhanced intensity image is finally shifted back to RGB color image.

3. Comparative Analysis

A detailed study of outputs obtained from all these above mentioned algorithms are performed using certain quality assessment parameters listed below[7]. Each of the enhanced image and the original aerial image is applied to the following quality assessment technique in order to find the better algorithm from the assessment. The algorithm is applied to dataset of various aerial images to improve the accuracy of the result.

3.1 Mean Square Error (MSE)

The MSE calculates the average value of squares of error[16]. Error value represents the difference of the aerial image and the enhanced aerial image obtained from various algorithms. The error can also be between various enhanced images obtained from each of the above enhancement algorithms. The aim should always be to obtain minimum MSE value.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2 \quad (7)$$

In case of image the (7) can be written as shown in (8).

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left(I(i,j) - \hat{I}(i,j)\right)^2 \quad (8)$$

3.2 Peak Signal to Noise Ratio (PSNR)

PSNR value is a ratio that needs to be high value always in optimum cases. That is the denominator or the noise should be less and the numerator or the actual signal strength should be high[18]. This is usually used to identify the quality of image. This algorithm is more effective in terms signals, for finding the amount of noise present in a particular signal knowing the reference signal.

$$PSNR = 20.\log_{10}(MAX_{pixelvalue}) - 10.\log_{10}(MSE) \quad (9)$$

3.3 SSIM

Structural similarity index as the phrase suggests will find out the similarity between any two images. It is method of Human Visual System (HVS) that performs as to how human perceive a scene. If both the image used for finding the similarity is same then SSIM[13] value is 1. It depends on the reference image provided to the SSIM algorithm. The structures present in image are independent of illumination. The structure can be defined as a value independent of contrast and average luminance. Here only the local luminance value is considered. The output obtained after enhancement from above algorithm is used as reference and is compared against the output before enhancement and the similarity index is calculated. The SSIM value depends on the mean and variance of both the images.

All the above analysis performed is related with the noise present in the actual image before enhancement because image obtained from aerial imagery is contaminated with noises in the form of fog, haze and dust particles. The output of the comparative analysis showed that wavelet based enhancement method gives high PSNR value and low value of MSE value when compared with HE, MHE and AINDNE. AINDNE methods give better result than that of HE and MHE as per the analysis.

4. Results and Discussion

All the comparative analysis related to this paper is carried out in Matlab Version 7.10.0.499 (R2010a). It is a software that considers all the image that it reads as matrices, which helps in faster computation. Here aerial image dataset of various developed suburban geography is chosen and applied for enhancement. Another dataset having aerial images of San Diego is also used. The dataset contains total of 38 images of varying resolutions like 512 × 512, 1024 × 1024 and 2250 × 2250. For our work aerial images with

512 x 512 resolution is chosen for enhancement from this dataset. Single image is applied for enhancement using wavelet based, AINDENE, HE and MHE algorithms. The original aerial color image before enhancement is shown in Figure 2. From the output obtained from all these the wavelet based technique is found to yield a better enhancement result. The output of histogram equalization is shown in Figure 5 and output of modified histogram equalization is shown in Figure 6. The output obtained from histogram equalization is not properly enhanced as it improves the intensity value in all the pixels irrespective of the pixel value whether high or low. In MHE even though the intensity values are properly enhanced based on NTSC standards, it does not take into consideration the contrast of the image in total. AINDNE in Figure 4 and wavelet based technique in Figure 3 is found to yield a better in overall enhancement value but comparing the result obtained the wavelet based technique is showing

Figure 2. Original aerial image.

Figure 3. Wavelet based enhancement.

Figure 4. AINDENE.

Figure 5. Histogram equalization.

Figure 6. Modified histogram equalization.

more similarity with that of real world situations. All the quality assessments carried out using above mentioned methods also points that wavelet based technique is giving good improvement and enhancement in terms of contrast, luminance and also in color. The MSE value is found to be minimum in case of wavelet based enhancement when compared with other three methods described earlier. PSNR value is also found high for enhanced image obtained from wavelet based technique. The process of comparative analysis is carried out on various ground truth data of aerial images and result is found convincingly better enhanced in wavelet based technique.

5. Conclusion

In this paper a detailed comparative analysis is performed on various aerial color image enhancement techniques. From the output obtained it is found that the wavelet based technique is found to yield a better enhancement outcome in terms of contrast, luminance as well as color. The algorithm is iteratively performed over various aerial image data set including San Diego and other rural and urban areas. As future work aerial image enhancement using wavelets can be performed as an initial step in most of the image processing algorithms to obtain better result and can also be applied as initial step in feature extraction, segmentation etc. Color image enhancement is also an important area of interest when it comes to video streaming.

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