Low ligh and low contrast image enhancement

Shengyin Shen
Civil and Environmental Engineering
shengyin@umich.edu

Abstract—this work is about low light and low contrast image enhancement. In this way, it enhances the performance of low-light images with the daylight images as a reference. First of all, the histogram equalization method is applied to enhance contrast of the low-light images. And then, the luminance of image is also enhanced by the gamma adjustment. And finally the color of the image will be enhanced by mapping color distribution from the daytime images to the low-light images.

Keywords—image enhancement, daylight reference image, histogram matching

I. Introduction

Low light and low contrast images are featured by poor contrast, poor resolution and limited dynamic range. Therefore, images captured in the environment with low light are not clear for human visual system. The poor quality of low light and low contrast images not only leads to confusion of textures and visual illusions but also results in disorientation, user fatigue, poor detection and classification performance [1].

To solve such problems related to the poor quality of low light and low contrast images, it is necessary to create an image enhancement method which should compose a series of images of enhancement processes, such as contrast enhancement, luminance enhancement, color enhancement and denoising. formatter will need to create these components, incorporating the applicable criteria that follow.

II. Colour Model Transformation

A. RGB color model

The RGB is a color representation, which is widely used for the storage of digital images. RGB are the initials of the three primary colors: red, green and blue. The RGB color model is mainly used in electronic systems, such as computers and televisions. The image captured by camera will also be stored in the RGB model.

B. HSV Colour Model

HSV is another model represents the color in electronic systems. H stands for Hue, S stands for Saturation and V stands for Value of light intensity. In the HSV color model, hue determines the hue of color. Saturation describes how it is distributed across the spectrum of different wavelengths. The range of the saturation is from 0 to 100. When the saturation equals 100, it means that the most saturated color is achieved by using just one wavelength at a high intensity. Value ranging from 0 to 1 reflects the subjective brightness perception of a color for humans. When the value is 0, the color is totally black; when the value is 1, the color is almost white.

C. Colour Model Transformation

The HSV model is closer to the perception of the human visual system because it describes the color in the same way with the eye and brain of humanity.

In the contrast enhancement, image processing in HSV model can obtain a better visual performance. In the computer based file storage system, the image is saved in the RGB model, so the transformation from RGB model to HSV model is necessary.

III. Contrast enhancement

The histogram of the images, which plots the number of pixels of each value, represents the tonal distribution. After analyzing the distribution of pixels, some characteristics of the image can be identified. Then, the image enhancement processes can be implemented based on such characteristics. A low light and low contrast image is illustrated in figure 1.

The image is in the RGB model. The histogram of red, green and blue channel can be calculated accordingly in figure 2.

Figure 1 Low light and low contrast image

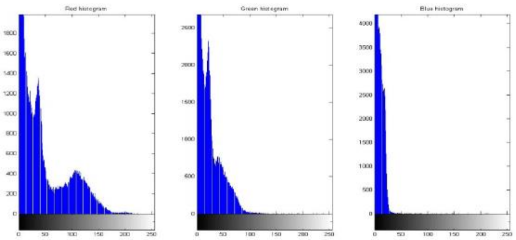

Figure 2 Histograms of low light image in RGB model

In figure 2, the value of red, green and blue is concentrated in a very lower dynamic range, which means the image is very dark. However, the histogram in the RGB model is not suitable for the contrast enhancement. So the image should be converted to HSV model to be used for contrast enhancement. In the HSV histograms, H-channel histogram represents the distribution of different color's hue, S-channel represents the distribution of saturation and V-channel represents for the distribution of lightness [3]. The histogram of three components in HSV model is shown in Figure 3. In the figure 3, it can be seen that the histogram, the values of V-channel is mainly concentrated in a lower region, which means that the image looks very dark.

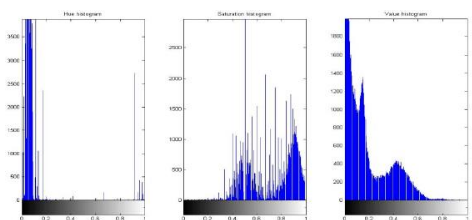

Figure 3: Histograms of low light image in HSV model

Next, we are going to enhance the contrast of the image by adjusting the histogram of the V-channel. Here, the histogram equalization will be applied. It is achieved by redistributing the light intensity to a wider dynamic range. The histogram equalization is applied to V-channel. The figure 4 and 5 shows the result of the histogram after applying the histogram equalization [2].

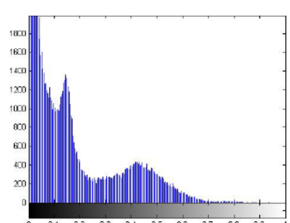

Figure 4 V-channel histogram of low light image

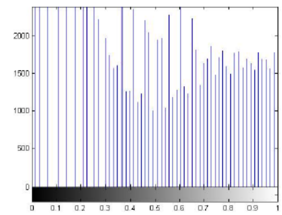

Figure 5 V-channel histogram of low light image after histogram equalization

From the figure 4 and 5, it is found that the intensity on equalized histogram is averagely distributed, which means the contrast has been enhanced. The V-channel component of the HSV model represents a grayscale image. Then, by combining the enhanced V-channel image with H-channel and S-channel and converting the color model from HSV to RGB, we can get the contrast enhanced image. The result is shown in figure 6.

Figure 6 Contrast enhanced image

IV. Luminance Enchantment

After applying the histogram equalization, the contrast of the image is enhanced, but the light intensity is still in a very lower dynamic range. So the luminance enhancement process is implemented.

The technique of image luminance enhancement we applied here is gamma adjustment. The light intensity is adjusted based on the value of gamma and the gamma is defined by function $L = I^{\gamma}$

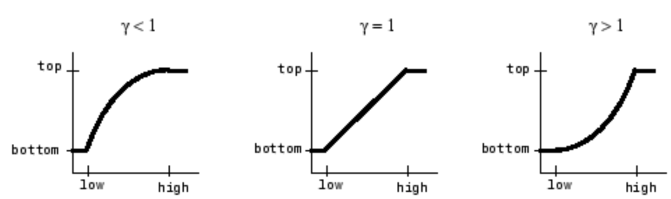

Figure 7 Gamma adjustment function curves [6]

In the gamma function, L is the output luminance, I is input luminance and γ is the gamma value. The value of gamma determines the shape of the curve [5]. If the value of gamma is lower than 1, the curve will be convex and the pixels in the image will be mapped to a higher light intensity. If the gamma is higher than 1, the pixels will be mapped to a darker intensity. Here, the gamma value is selected as 0.5. The result of luminance enhancement is shown in figure 8. We can see that the luminance of the image is greatly enhanced. Some super dark area in the original low light image becomes lighter and clearer.

Figure 8 Luminance enhanced image

V. Denoising

For now, the contrast and luminance of the image is enhanced. However, the image is very noisy. The noise of the image is mainly coming from two sources: the camera capability and the image enhancement processing. So, a noise-removal technique should be used to enhance the overall quality of the image. In this work, a median filter is utilized to remove the noise.

Median filter [2] is a most common noise removal filter for the image processing. It replaces the value of a pixel by the median value of its neighborhood pixels. Median filter has a good effect on random noise, especially on impulse noise which is obvious in our case. Its superiority lies in less blurring so that it is suitable for removing the noise of the enhanced image. In this work, a 3x3 window is used for median filter.

Figure 9 current enhanced image vs. noise removal image

VI. Colour Enhancement by Histogram Matching

For the color enhancement, a reference based method is applied. A reference based method is done by using a day light image which is captured in the normal light environment. The day light image will have the same scene as the low light image but the contrast, luminance and the color will be normal compared with the low light image. And here, a histogram matching technique is applied.

Figure 10 day light image

For the histogram matching, it is conducted in one dimensional histogram first. For the input image, the probability density function (PDF) of histogram is calculated and then by accumulating the PDF, the cumulative distribution function (CDF) of the input image is calculated.

$$I = T(i) = \sum_{j=0}^{n} p_{i(i_j)} \quad j = 0,1,2,3 \ldots n$$

Similarly, the CDF of the low light image is also calculated.

$$R = G(r) = \sum_{l=0}^{n} p_{r(r_l)} \quad l = 0,1,2,3 \ldots n$$

And then we will create a reverse function to map the CDF of the day light image into the CDF of the low light image.

$$G^{-1}(r) \approx G^{-1}(i)$$

And in reality, we use an approximation algorithm to achieve the mapping process: find the n and m which make the following equation has the minimum value.

$$\left| \sum\nolimits_{j=0}^{n} p_{i(i_j)} - \sum\nolimits_{l=0}^{m} p_{r(r_l)} \right| n = 0,1,2,3 \ldots n-1 \quad m = 0,1,2,3 \ldots m-1$$

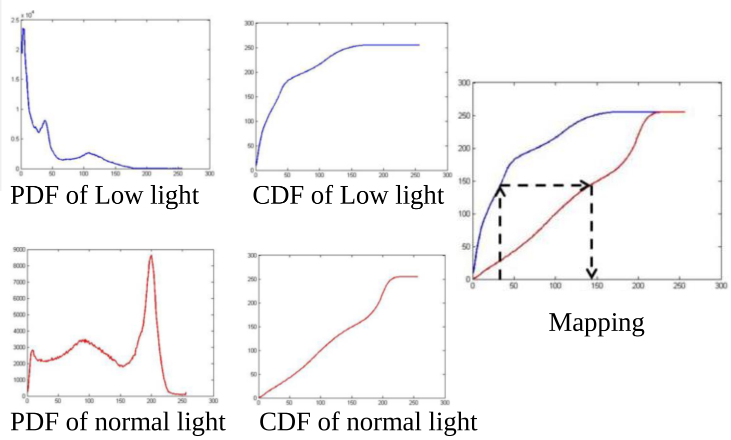

Figure 11 Procedure of histogram mapping

As illustrated in Figure 11, the input image is low light and low contrast, and the referenced image is normal light. By applying mapping the histogram, the distribution of pixel intensity of the original image will be re-mapped into a higher level based on the CDF of the referenced image.
Since a color image contains 3 channels, so each channel will be performed in the same procedure. And then by adding the 3 channels together, the low light color image will be enhanced. Figure 11 shows the enhanced image.

Figure 12 enhanced image

In the enhanced image, it can be seen that the color, contrast and the luminance is enhanced obviously compared with the original low light image. By referring to the color of the day light image, the color of the low light image is recovered. The performance of the low light image is very close to the day light image.

VII. Result and discussion

Here 3 pairs of the result are illustrated: one is captured in the kitchen of the apartment one is captured in the outside of the apartment and the other one is captured in the lab. From the result, the effect of the low light and low contrast image enhancement is quite obvious. The enhanced image performs better in contrast, luminance and color.

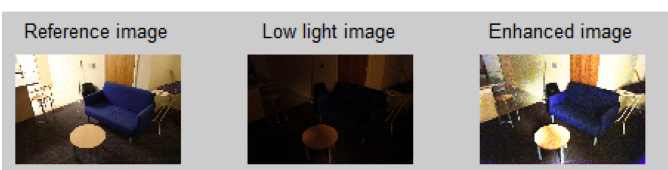

Figure 13 low light image enhancement result 1

Figure 14 low light image enhancement result 2

Figure 15 low light image enhancement result 3

In the first example (Figure 13), the low light and day light image has the same scene. Actually the scene of two images are not required exactly same. If the referenced daylight image has a similar scene with the low-light one, then the obtained enhanced image could also perform very well. In the second and third example (Figure 14 and 15), it can be seen that the viewpoint of the daylight image is different from that of the low light image, but the enhanced image still performs normally and very well.

However, if the scene of referenced day light image is totally different from that of the low light image, it will lead to a deviation in the enhanced image (as shown in Figure 16).

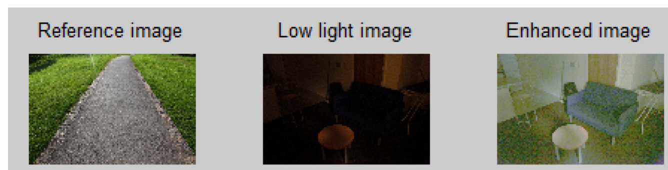

Figure 16 wrong referenced image

Since the color distribution of the low light image will be forced to match to a wrong reference day light image, then the type of color distribution of the "enhanced image" will be different from the original one. The color will not be correctly recovered. So in order to have a better performance of the enhanced image, an appropriate referenced image should be selected. In the future, the similarity of the scene should be checked before applying the histogram matching to have a good performance.

Summary

In this project, I have achieved enhancing the low light and low contrast image in the aspects of the contrast, luminance and color. In particular, the color enhancement is done by referring a day light image. During working on this project, several image processing techniques have been studied, explored and implemented such as color space converting, histogram equalization, gamma correction and also the 2D-filter (2-D convolution) used for removing the noise (learning in class). The performance of the enhancement is significantly obvious. The enhanced image performs as well as the day light image. The object in the original low light and low contrast image becomes lighter and clearer and the color is also recovered based on the referenced day light image. In the future, a region and object based enhancement should be studied since focusing on the region of the interest will bring a better performance.

REFERENCES

[1] Artur Loza, David Bull and Alin Achim, “Automatic Contrast Enhancement of Low-Light Images Based on Local Statistics of Wavelet Coefficients”, Proceedings of 2010 IEEE 17th International Conference on Image Processing, 2010.

[2] Rafael C. Gonzalez and Richard E. Woods. *Digital Image Processing*, Addison-Wesley Longman Publishing Co., Inc.,Boston, MA, USA,2008.

[3] http://en.wikipedia.org/wiki/Histogram_equalization

[4] http://en.wikipedia.org/wiki/HSL_and_HSV

[5] http://en.wikipedia.org/wiki/Gamma_correction

[6] http://www.mathworks.com/help/images/contrast-adjustment.html