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New contrast enhancement approach for dark images with non-uniform illumination[☆]

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A B S T R A C T

Contrast enhancement of dark images with non-uniform illumination is a difficult task, as these images have both dark and bright regions. Hence, we cannot use many of the widely accepted methods of contrast enhancement, which rely on enhancing the contrast of the both of dark and bright regions at equal level, which results in over enhancement and disappearance of the finer details in brighter regions. This motivated us to design an approach for contrast enhancement of dark images with non-uniformly illumination without affecting the details in the bright regions. We are proposing a method which deals with 'YCbCr' model, as by using this color model we can separately use luminance part 'Y'. Then, we enhance the luminance part 'Y' of the image by using a newly developed sigmoid function.

1. Introduction

In many situations an image is taken in extreme light conditions, such as excessive bright or dark environmental conditions the result is low contrast, which produces low dynamic range of intensities in the dark and bright regions. Due to this non-uniform illumination, the details in both dark region as well as in bright region disappear. In such cases, if we use contrast enhancement tools in order to enhance the contrast of dark regions, the bright regions become over enhanced and the details in the bright regions disappear. This situation motivated us to develop a new approach by which we can enhance the contrast in both the regions of the image without affecting the details.

Many techniques are used for image enhancement; histogram equalization (HE) is one of the simplest and widely accepted technique [1]. A number of variations of HE are also available in the literature [2–7], these variants of HE are having their own benefits and drawbacks. Later, various 'adaptive histogram equalization' (AHE) approaches were proposed by Hummel [8], Ketcham [9], and Pizer [10] to overcome the drawbacks of HE. These adaptive approach use a mapping function on each pixel in the histogram to increase the local contrast. Although AHE produces good results, but it suffers with the problem of slow speed and over enhancement of noise in image. The enhancement in the noise causes appearance of the artifacts in the processed image. In [11], K. Zuiderveld proposed 'contrast limited adaptive histogram equalization' (CLAHE) to deal with the drawback of AHE and to remove the artifacts in the processed image. Later, various authors proposed variants of CLAHE, few of them are discussed in [12,13]. The main problem of CLAHE is that it does not use whole dynamic range of histogram.

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To overcome the drawback of HE, Yang et al., [14] proposed 'bin underflow bin overflow histogram equalization' (BUBO-HE). This approach use two frequency thresholds, to control the level of enhancement. The main drawback of BUBO-HE method is that it does not address the decreased local contrast problem.

Later, Chiu et al., [15] proposed another approach for dimmed light images based on adaptive gamma correction (AGC). In this approach, image is enhanced by using weight distribution to modify the pixel intensity of the input image. This approach suffers by over enhancement in bright areas of input image.

In 2011, Kang et al., [16] proposed an approach 'adaptive height-modified histogram equalization' (AHMHE) for enhancing the contrast of images with back-light affect. This approach firstly converts the RGB color image into YCbCr color image and generates a mapping function for Y component based on adaptively height-modified histogram. After that, a local contrast map is defined by difference operation of Y component with blurred Y and then a new chroma correction method is applied. This approach also have the same drawback as all the previous approaches of over enhancement in brighter areas of input image.

In [17] a new enhancement approach is suggested by authors, using the fuzzy methods for enhancing the contrast, of low contrast non-uniform illumination images. They employed modified Gaussian membership function in the enhancement process on gray-scale. Recently few other methods [18,19] have been proposed for contrast enhancement and brightness preservation of all type of images (including dark images with non-uniformly illumination). These methods are able to enhance contrast of all type of images without affecting their original features. But, sometimes these methods preserve mean brightness in the processed image so accurately that it is not possible to measure contrast enhancement by viewing the image.

The drawbacks motivate us to design a new approach by which we can enhance contrast of dark region without affecting the mean brightness of the image and color information of brighter region. In this paper, we propose a new approach for handling dark images with non-uniform illumination using modified sigmoid function. In proposed approach, we deal with the YCbCr color model instead of RGB color model, as our main objective is to archive uniform illumination and hence the contrast enhancement. For this we use modified sigmoid function on the base layer of the luminance component of the input image and obtained new base layer and detail layer of illuminance component Y. Finally, we get the output image after converting new YCbCr image into RGB image. The results of proposed approach are compared with above described approaches used for dimmed light images (AHMHE, BUBO, CLAHE and AGC) and proposed approach overcomes the drawbacks of these approaches.

The organization of this paper is as follows: Section 2 describes proposed method in detail. Experimental results and comparison with other methods are shown in Section 3 and a short concluding remark is given in Section 4.

2. Proposed method

In this section we describe the proposed approach in detail. The block diagram of the proposed algorithm is as given in Fig. 1:

2.1. RGB to YCbCr color space conversion

There are number of color space models available in digital image processing. Some of important models are HSV, YCbCr, YUV, YIQ etc. Every color space model has its own properties and importance. Since we want to enhance the contrast of the image with non-uniformly illumination, it is logical to use YCbCr color model model, as in this model, its Y part contains the detailed information of luminance component and C_b and C_r are the blue-difference and red-difference chroma components. The main advantage of using YCbCr color space model is that we can enhance the luminance by enhancing the Y part only, without affecting the color information contained in Cb and Cr part.

In proposed approach, we initially convert RGB color image into YCbCr color space. To convert RGB color model into YCbCr color model [16] we are using following equation:

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 16 \\ 128 \\ 128 \end{pmatrix} + A \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix}, \tag{1}$$

where,

$$A = \begin{pmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112.000 \\ 112.000 & -93.786 & -18.241 \end{pmatrix}$$

and Y: [16,235], Cb: [16,240], Cr: [16,240].

2.2. Decomposition of Y component

Once, we convert the given RGB image into YCbCr image and get the illuminance component Y. We are interested in decomposing the luminance component Y into its base layer and detailed layer. Base layer contains the smooth part of the