

TWO-PASS ADAPTIVE HISTOGRAM BASED METHOD FOR RESTORATION OF FOGGY IMAGES

V. Agarwal¹, S. Khandelwal¹, D. Goyal¹, J. Sharma² and A. Tiwari³

¹The LNM Institute of Information Technology, Jaipur

²Microsoft India R&D Pvt Ltd, Hyderabad

³Indian Institute of Technology, Jodhpur

vinit.agarwal@lnmiit.ac.in, shubham.khandelwal@lnmiit.ac.in, goyalldushyant@gmail.com,
jatinsha@microsoft.com, akt@iitj.ac.in

In this paper, we present a Local Histogram Equalization (LHE) based method to improve the visual quality of foggy images. From the fog-degraded image we separate all three color components and apply the enhancement algorithm to each of these components. To mitigate the issue of blocking artifacts generated from Local Histogram Equalization with non-overlapping blocks, we propose to process blocks by overlapping them. Processing smaller block size yields better visual quality at the expense of relatively higher processing time, therefore, we also propose to use statistically optimal block size to obtain a good visual quality in reasonable time duration.

Introduction

In practice, it is often observed that visual quality of images gets deteriorated due to various natural phenomena. Fog or haze is one such phenomenon, caused by presence of suspended water droplets in the air. Fog removal or defogging of an image is, therefore, an important requirement that applications ranging from navigation, outdoor surveillance etc.

The visual quality degradation of an image due to fog, is a function of fog density and the distance of the scene. Quality of visibility depends on the extent of scattering caused by water droplets present in the fog. All the methods available in literature can be broadly classified into two categories - Physical model based methods [1]-[6] and Image Processing based methods [7]-[10]. In the first category, Huang et al. [2] proposed a bilateral filtering based method for fast recovery of foggy images. Shwartz et al. [3] suggested a method to remove spatially varying contrast by stray radiance (airlight) method. The key claim in their method is that a hazy scene recovery is only possible by subtraction of airlight. Kim et al. [4] proposed to estimate airlight using a cost function based on human visual model. They subtracted the estimated airlight map from

degraded image to enhance its quality. The luminance component of image is employed for airlight estimation. Oakley et al. [1], [5] suggested a simple correction for contrast loss in foggy scenes. They restored scene contrast by approximating distribution of radiance in the scene. This is done by a Gaussian function with known variance and mean. Their method does not use any estimate of weather information. Robby T. Tan et al. [6] estimated the color of skylight and the values of airlight. In the second category i.e. Image processing based methods, Z. Xu et al. proposed Contrast Limited Adaptive Histogram Equalization (CLAHE) [7]. Major drawback of this method is that, often, noisy pixels also get enhanced along with enhancement of the foggy pixels. However, the same method when applied on medical images yielded good results in improving visibility of such images. They also proposed Bilinear Interpolation Dynamic Histogram Equalization [9] method. The given image is divided into sub-images of some smaller size and then partitioned into corresponding sub-histograms without domination in Jia et al. [10] who proposed using Content Adaptive Local Contrast Enhancement algorithm (CLAHE) and non-overlapping block processing only on luma component of YCbCr part of image. We propose a similar algorithm in this paper.

They applied their method in YCbCr color space with non-overlapping blocks whereas we apply the CLAHE algorithm on each of the RGB color spaces using overlapping blocks. We call this as pre-processing stage. Due to the overlapping, some of the pixels get equalized by its neighborhood pixels and haze is significantly removed. This causes much better nearer vision than obtained by methods reported in literature. Moreover, in the second stage we applied the CLAHE algorithm [7] for post-processing. The post-processing is applied on intensity component of the image processed in the first stage. This is done because intensity component also gets enhanced after reducing the noise level in the pixels of image.

Proposed Algorithm

In this paper, we present an overlapping block-by-block, contrast limited adaptive histogram equalization (CLAHE)-based method. This is intended to overcome limitations of CLAHE algorithm. The proposed method is based on the general observation that human vision system is highly sensitive to noise. The proposed method is described as follows.

The foggy image captured by camera is divided into blocks and these blocks are taken in such a way that they overlap over a small number of columns. Each block of the image is split into R, G, B channels respectively. Now each channel of the block is processed by CLAHE. Finally, the block processed in each component is converted back to RGB block image. The above procedure is followed for processing of all the overlapped blocks.

Now the processed image is converted from RGB color space to HIS color space. The reason of conversion in HIS representation is the fact that the human eye color sensation matches with HIS representation. After this conversion, the intensity component of the image is processed by CLAHE while Hue and Saturation components are left unchanged. Finally, the image processed in HIS color space is converted back to RGB color space. By using the block segmentation of an image for each region, as in the case of an image with various depths, the contribution of

airlight vary according to region. The small region can be considered to have approximately same fog density in that region. Thus, processing a block according to its surrounding pixels.

Overview of CLAHE

In general, local histogram of a pixel, x , is the same as the histogram of pixels in a rectangular window with the pixel x into its center. Only the pixels within the local area are considered. But according to the characteristic of human vision, the visual systems change with the region and these systems are affected by the surrounding environment. To solve these problems, S.M. Pizer [8] proposed a method which is called contrast limit Adaptive histogram equalization (CLAHE). The CLAHE method applies histogram equalization to a contextual region. Each pixel of original image is in the center of the contextual region. The original histogram is clipped and the clipped pixels are redistributed to each gray level. The new histogram is different from the original histogram, because each pixel intensity is limited to a user-defined maximum. So CLAHE limits the noise enhancement. The algorithm proposed in this paper is intended to overcome the limitation of CLAHE algorithm.

Improved CLAHE

CLAHE establishes a maximum value to clip the histogram and redistributes the clipped pixels equally to each gray level. It limits the noise while enhancing the contrast. By increasing ClipLimit, the noise in the dark background is enhanced to an extent that the image starts looking messy. The parameter ClipLimit sets a limit for the contrast enhancement. The higher value of ClipLimit gives higher contrast and a more flat histogram. To brighten the foreground and to prevent a highly noisy background, the parameter value of ClipLimit is statistically obtained as 0.05 by experimenting on large number of images. CLAHE operates on small regions in the image, called tiles, rather than the entire image. If the number of tiles is increased by powers of 2, we will get higher

value of number of tiles, dividing the image into smaller regions for local histogram equalization. On increasing number of tiles, it gives a better contrast in the foreground. However, when the number of tiles is too large, the data points in each tile would be too few for equalization to do a good adjustment.

The method proposed in this paper has the following advantages over other local adaptive histogram equalization methods.

1. Processing image by overlapping blocks increases level of enhancement. Histogram is equalized on a pixel by pixel basis as each pixel characteristics is dependent on its surrounding i.e. overlapping block.
2. The level of enhancement for each region of the image is determined by local image statistics. These statistics are estimated on a block-by-block basis.

Detailed Procedure

The detailed steps of the proposed method are as follows:

- 1 The image is split into smaller blocks and the blocks are divided into R, G and B parts respectively. Apply CLAHE method on them. Then by overlapping the blocks, we take the smaller size of block and then divide each block image component into different tiles for local enhancement.
- 2 In addition, we perform post-processing to further improve the image quality by adjusting the illumination of the image.
- 3 In HIS color space, keep the H and S part unchanged and process Intensity part with the same clipping limit of CLAHE method.
- 4 After processing Intensity part of image, the H, S and processed I part are combined and converted back to RGB color space.

Experimental Results and Discussions

In order to evaluate performance of our method, we tested it on different types of images degraded by fog. Some results are shown in Fig 1. Fig. 1.d shows the original foggy image. Fig. 1.e shows the result by

CLAHE [7]. The result is enhanced but the distant visibility still needs improvement. Fig. 1.f shows the result by Haze removal [11], but in this algorithm, the artifacts are also added which were not initially present in the given image. For instance, Fig. 1.f.ii shows that the output intensities are lowered giving black artifacts. Similarly, Fig.1.g is the result of Visibresto [12] which enhanced the image but the distant vision is still not clear. But Fig. 1.h shows the results of the proposed algorithm which are better than various methods compared. As we decrease size of the blocks, we found that haze removal capacity of our algorithm improves. In this algorithm, we have used 64x64 size of the block that results into a total of 81(9x9) number of tiles for the images of dimension. The proposed block size is obtained statistically.

Conclusion

In this paper, we present a contrast limited Content Adaptive Histogram Analysis that sets the visibility restoration from a single image without using any extra information and enhances the contrast of images. Our aim in this work is to improve the visual quality of distant objects. From the figures, we can see that most of the fog has been removed from the images. This gives better contrast enhancement and brightness compared to other techniques. We believe that our method can be very useful in various fields/systems such as outdoor surveillance systems, intelligent vehicle systems, remote sensing systems, graphics editors etc. Encouraged by good results of the system, the proposed method can be used for real time applications related to fog removal.

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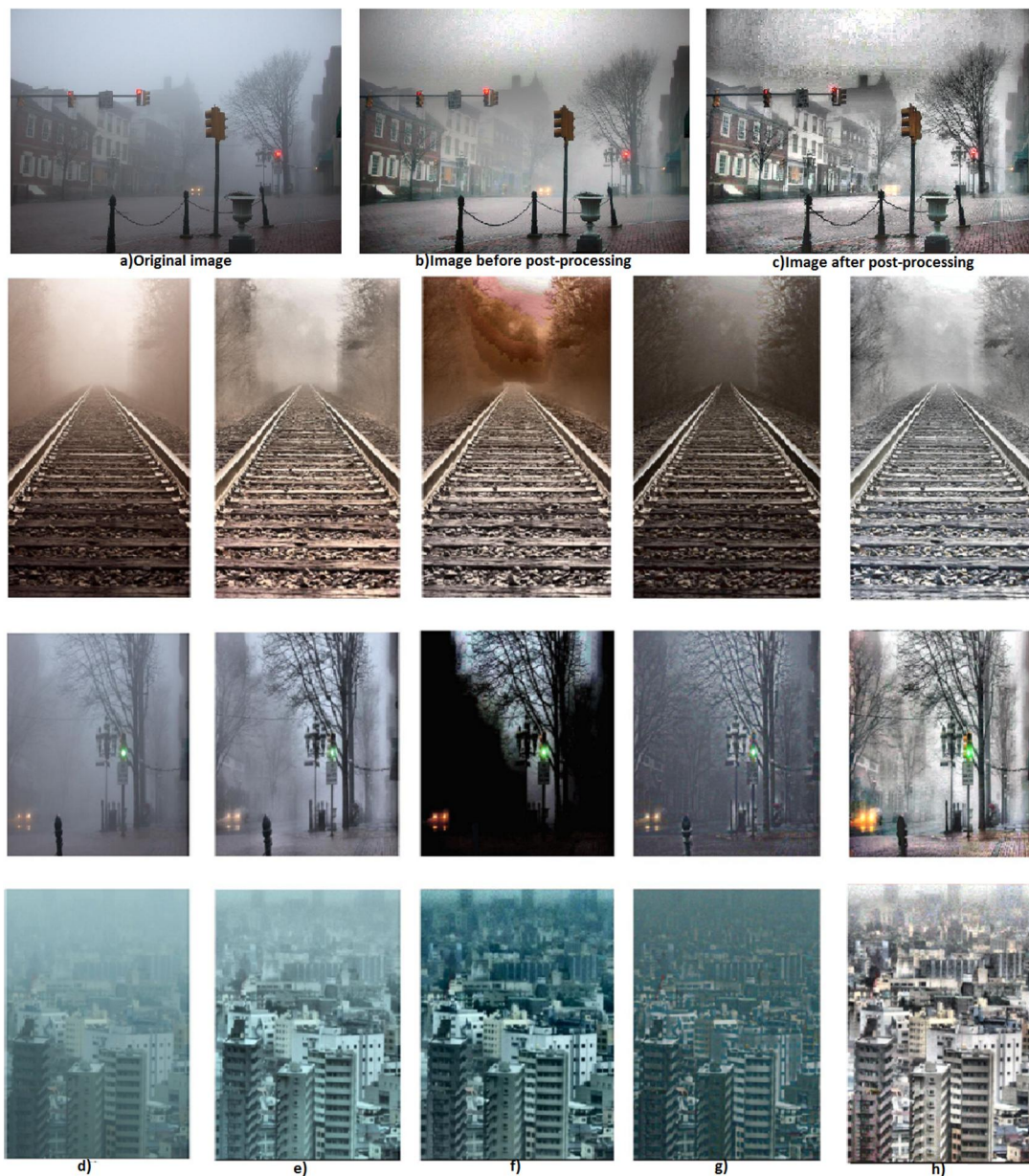


Fig.1. d) Input Image e) CLAHE [7] f) Haze Removal [11] g) Visibresto [12] h) Our Result