Restoring the Blur Image

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Abstract

The Families, friends, professionals, and enthusiasts take countless numbers of photographs everyday, and inevitably, many images suffer from some sort of distortion, or blurring. In the proposed system of this paper, Fourier based image deblurring is implemented to recover the motion blurred images. For the blurred color images, the motion blur kernel is, first of all, estimated using motion length. The RGB color channels are partitioned into three channels (R, G and B) respectively. For each three channel, the Lucy-Richardson algorithm is separately applied as 2D image. The LR algorithm operate on iterative convolution and deconvolution processes to get the deblur version of the image. In order to speed up the system, the convolution and deconvolution processes are performed in frequency domain by means of Fourier transformation. The main fact of the LR algorithm is ringing artifacts around the strong edges of the image. The post processing stage of the system carries out the deringing by smoothing these ringing regions. Then, finally, the three separate R, G and B channels are superpositioned to get the resultant deblurred color image of the proposed system.

1. Introduction

Motion blur caused by a relative motion between a camera and a scene is inevitable due to the nature of a camera sensor that accumulates incoming light over a certain period of time. Many computer vision algorithms rely on the assumption that a scene is captured without such motion blur. However, this assumption generally does not hold blur from images so that the subsequent algorithms can neglect the effect of motion blur.

Motion deblurring has been studied by many researchers. Most methods solve the problem under an assumption that there is only a single motion blur kernel for the entire image. However, in real-world cases, photographed images often have spatially-varying motion blurs due to multiple relative motions caused by moving objects or depth variations from the camera.

This paper proposed a deblurring system that automatically removes the motion blurs from blurring color images.

The next sections, Section (2) to Section (6) discuss the design of the proposed system with step by step manner. The conclusions and further extensions of the proposed system are stated in the Section (7).

2. Converting the multi dimensional image color image into 2-D images

The blur image to be processed by this system is acquired by a digital imaging device, a digital camera. As can be seen from Figure 1, the acquired image is a motion blurred color image. The color image is 24 bit true color image and each pixel conveys different RGB values, with 256 different intensities for each of these three primary colors.

Figure 1. The blur color image to be tested

Figure 2. Red intensity image

Figure 3. Green intensity image

Figure 4. Blue intensity image

The Lucy-Richardson algorithm applied for the deblurring stage of the system can operate only on 2-D images, that is, the gray or intensity images. In such intensity images, each pixel conveys only a single value, that is, the gray value, and thus such images are of two dimensional. To be able to apply the deblurring algorithm upon the color image, the color image is partitioned into three 2-D images, each of which contains only one of the three composite colors. Therefore, the partitioned three 2-D images are the Red image, Green Image and Blue image as shown in Figure 2, 3, 4 respectively. Each pixel in the red intensity image of a certain color image conveys only a single value, that is, the red intensity, and hence, the Red intensity image is a 2-D image.

3. Estimation of blur kernel

Restoration of blurry images is highly dependent on the estimation of motion blur parameters to define the point spread function (PSF), which describes the response of an imaging system to a moving point source and practically models the blur on the corrupted image. One of the most common degradation functions is linear motion blur. The relationship between the observed image g(x, y) and its uncorrupted version f(x, y) is defined by

$$g(x, y) = f(x, y) * h(x, y)$$

where h(x, y) is the PSF convolved with the original image f(x, y).

Assume that the blur image is motion blur image with uniform linear motion in the x-direction with the rate of $x0(t) = at/T$. At a given time T, also suppose that the pixel in the original image is at distance a in the corresponding pixel in the blur image. The degrading function for the linear motion blur can be formulated as

$$H(u,v) = \frac{T}{\pi ua}\sin(\pi ua)\,e^{-j\pi ua}$$

The deconvolution of the blurred image with the PSF that caused the blur allows obtained the restored blur-free image [4].

4. Deblurring process in the frequency domain

After PSF for input image has been obtained, Lucy-Richardson iterative deconvolution algorithm is applied for image deblurring. The algorithm maximizes the likelihood that the resulting image, when convolved with the PSF, is an instance of the blurred image. Lucy-Richardson algorithm operates as follow:

$$\hat{f}^{(r+1)}(x,y) = \hat{f}^{(r)}(x,y)\left[h(-x,-y) * \frac{g(x,y)}{h(x,y) * \hat{f}^{(r)}(x,y)}\right]$$

Since $\hat{f}^{(r)}$ is necessary to apply an iterative procedure in which $\hat{f}^{(r)}$ be initially estimated. In general, the estimation is obtained using an a priori non-informative distribution. In this system, this estimation is performed by reblurring the input image. The operator '*' denotes the convolution. The convolution with negative coordinates, h(-x, -y), means the deconvolution process. To speed up the system all the convolution and deconvolution processing are performed in frequency domain. Fourier transform is used to convert the image from the spatial domain into frequency domain. The Fourier spectrums of the three intensity images are illustrated in Figure 5 to 7. In the frequency domain, the Fourier transformed image and PSF are multiplied to get the equal result of convolution in spatial domain [3].

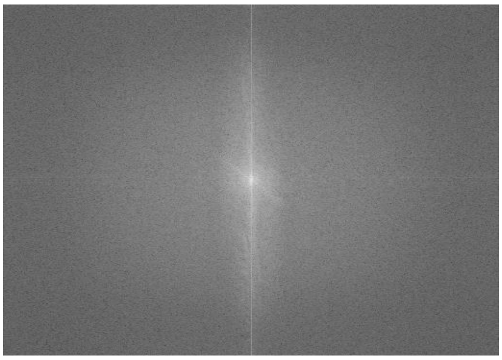

Figure 5. Fourier spectrum of red intensity image

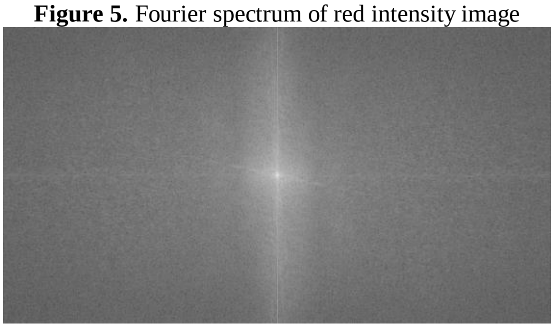

Figure 6. Fourier spectrum of green intensity image

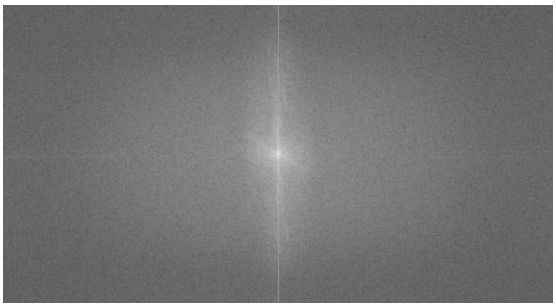

Figure 7. Fourier spectrum of blue intensity image

5. Deringing

The results of applying Lucy-Richardson algorithm are often visually inacceptable due to ringing artifacts that tend to occur near strong edges. The amount of ringings depends on the number of iteration: the more iterations were performed at the deblurring stage, the more ringing will appear along edges. In this system, ringing artifacts suppression is carried out at the last stage.

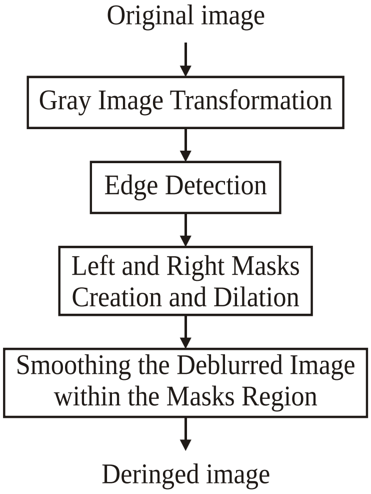

Figure 8. The block diagram representation of the deringing

Artifact locations on the deblurred image depend on two factors: edge closeness and the PSF shape. The motion blur parameters (length and angle) define the PSF shape. In this system, the input blurry images that are caused by horizontal motion are applied. So, the angle of motion blur can be assumed as 0 degree. The artifact locations can be predicted by using the information about edges and blur parameters. Experimentally, it is found out that the ringing is aligned along both sides of the edges at the distance and angle equal to the length and angle of motion blur. Based on the knowledge about this interrelation, the post-processing part of the system has to be carried out.

The post-processing scheme, that is, deringing is divided into three steps, as it is shown on Figure 8. The work flow is as follows [5].

5.1. Edge detection

On the first step, edge detection is performed. Since it is needed to find only long and important edges and omit weak and short ones, the Sobel edge detector is applied to detect the long and important edges. The edge detector produces the binary image in which the pixels in edge region are '1' and the others are '0'. The detected edges using are shown in Figure 9.

Actually the edge detection has to be performed upon the original image since only the edges of the original image are required, not the edges of the edges of the ringings. Therefore, the original blur color image is first of all transformed into gray scaled image and upon the resultant gray image Sobel edge operator is carried out to get the main and important edges of the original image [1].

Figure 9. Edge image of the original image

5.2. Mask creation and dilation

On the second step, two masks are created. These two masks represent the left and right region of the edge image at the distance equal to the length of motion blur. Then, binary morphological processing, dilation, is performed on these two masks to thicken out these masks. In fact, these masks regions are the ringing artifacts will have to occur in the deblurring image. Figure 10 and 11 shows the resultant left and right masks. After the locations of the ringing artifacts can be determined, these ringing artifacts can be eliminated out to enhance the quality of the deblurred image [2].

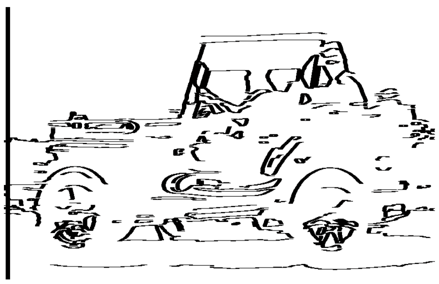

Figure 10. Left dilated mask

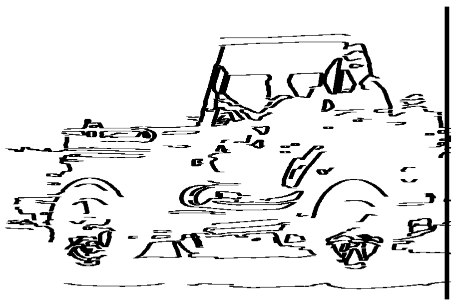

Figure 11. Right dilated mask

5.3. Smoothing

The final step is smoothing the mask regions. The smoothing operation is carried out by mean filtering. Mean filtering is a cornerstone of modern image processing and is used extensively in smoothing and de-noising applications. The mean filter considers each pixel in the image in turn and looks at its nearby neighbors to decide whether or not it is representative of its surroundings. The neighboring pixel values are replaced with the mean of those values. The mean is calculated from all the pixel values from the surrounding neighborhood and then replacing the pixel being considered with the mean pixel value. If the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used [4].

6. Superposition the R, G and B intensity images

The above deringing stage is carried out separately upon the Red, Green and Blue intensity images respectively to eliminate out the ringing artifacts upon these three intensity images. After the deringing has carried out upon the intensity images, the resultant intensity images are superpositioned to get the resultant, deblurred, ringing artifacts free, color image of the system.

Figure 12. Resultant, deblurred, ringing artifacts free, color image of the system

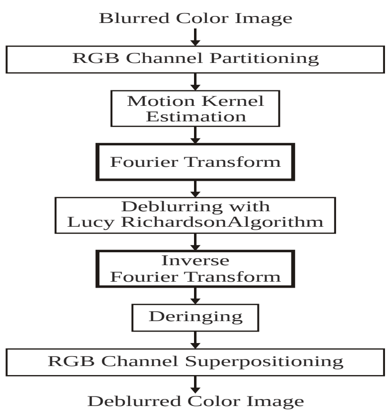

Figure13. Block diagram representation of the system

7. Conclusion, limitations and further extensions of the system

In the proposed system, real camera images, corrupted by linear motion blur are applied. The whole scheme is divided into three main parts: PSF kernel estimation, deblurring, and deringing. For PSF kernel estimation, the blur length is used. This kernel is further used in Lucy-Richardson deblurring scheme, and again, the output image this deblurring scheme is corrupted by ringing artifacts. The third part is intended to remove these artifacts to obtain acceptable quality output image. Applying this scheme to different real images, the resultant, deblurred and artifact-free pictures are obtained from the motion blur images. The main advantage of the proposed system is the use only one blurry image as an input. Many recent works in the area employ several corrupted images of the same scene to combine information and obtain blur-free image.

The main limitation of the system is that the system can treat on the horizontally motion blur images. There are other certain causes of blurring, such as, Gaussian blur and lens blur, etc. The deblurring techniques for such other blurring should be carried out as a further extension of this system.

Although notable image enhancement can be observed from the results, obtained with the scheme, not all the artifacts can be removed from initial blurry image. This fact is also a certain limitation of the system. Another limiting fact to the system is that the blur object with the distinct and non blur background, when deblurring the blur object, the non blur background suffers considerable distortions.

As the future analysis of this system, foreground objects detection algorithms should be materialized. But, such systems certainly will be complicate and lead to memory consumption. Other image processing techniques of deblurring in spatial domain should also be developed as future works.

8. References

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