Image Deblurring Using Fusion Technique Based on Inverse Filtering

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Abstract: Blur can be defined as unsharp image region that happen through camera motion, object motion and through image acquisition. This study introduced restoration of Gaussian blurred images by inverse filtering. This filter is done on the spatial domain for image restoration. The key objective of this research is fusion process based on peak signal to noise ratio measure. The main idea is compared PSNR value between sub image with other sub image of another image. In the beginning convolveinverse filter with image to get on the blurred image. After that convolve the blurred image with inverse of filter that remove blur from image to obtain on the deblurred image. Finally fuse the optimal sub images based on peak signal to noise ratio measure that has higher PSNR.

Key words: Blurring image, inverse filter, image fusion, peak, Iraq

INTRODUCTION

Image restorationis process reconstructing an image that has been corrupted by corruption phenomenon. The objective of restoringis making image after itlike the original image. Image restorationneeds to the inverse process that used to restore the original image.

Inverse filter is one of the deblurring techniques that used to restore the deblurred image after adding blur on image. This filter is one of the types simplest of these techniques. The disadvantage of this filter is sensitive to the noise (Suseela *et al.*, 2016).

Unfortunately a signal or an image is corrupted by blur from through Camera motion, object motion, an optical system that is outside of concentrate and the disturbance in atmospheric (Umbaugh, 2016).

The formula for this filter without noise presence on the spatial domain is followed:

$$B(x, y) = f(x, y) \times h(x, y) \tag{1}$$

Where:
$B(x, y)$ = Degraded image by blur
$f(x,y)$ = Original image
$h(x,y)$ = Blur mask

While the noise presence the formula can be represented as follow:

$$B(x, y) = f(x, y) \times h(x, y) + n(x, y) \tag{2}$$

Where:
$B(x, y)$ = Degraded image by blur
$f(x,y)$ = Original image
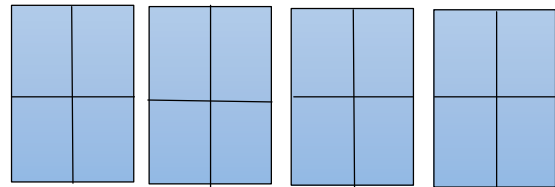$h(x,y)$ = Blur mask
$n(x,y)$ = Additive noise

Fig. 1: Inverse filtering method

Inverse filtering can be represented on the frequency domain by using discrete Fourier transform (Fig. 1):

$$B(x, y) = F(x, y) \times H(x, y) \tag{3}$$

Where:
$B(x, y)$ = Degraded image by blur
$F(x, y)$ = Original image
$H(x, y)$ = Blur mask

The deblurred image $F\hat{}(x, y)$ can be obtained by using inverse DFT according to the following formula:

$$F^{(x,y)=B(x,y)} / H^{(x,y)} = B^{(x,y)^{\frac{1}{H(x,y)}}} \tag{4}$$

Where:
$B(x, y)$ = Degraded image by blur
$F\hat{}(x, y)$ = Restored image
$H\hat{}(x, y)$ = Inverse of blur mask

The Eq. 4 refers that the original image can be acquired by division the blur image on the blur filter or multiplying blurred image with inverse of blur mask. The pseudo inverse filter is handled put zeros in $H(x, y)$ as in Eq. 5 (Umbaugh, 2016):

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$$R_{PI}(x,y) = \frac{1}{H(x,y)} \qquad H \neq 0, H = 0 \qquad (5)$$

Image fusion is the process of blending relevant information from more than one image original into a single image that is more informative than any of the sources images. The main goal of fusion is enhancement original images and providing a result image with more useful information than either original image. In our research study is fused the optimal sub images from set of images that has less blur than other sub images in order that getting on the optimal image (Heba, 2013).

Blurring: Blur has been occurred in images caused by irregularities that happen through image acquisition. There are different types of blur as shown in Fig. 2.

Motion blur occurs due to camera motion or object motion through time of the camera exposure. The defocus blur results from photographing images that out the concentrate of the camera. Gaussian blurs caused by atmospheric disturbance or errors of lens. The shake blur can be happen for example when person takes a picture and his hands is shake (Losch, 2009).

Types of blurring: There are different types of blur in digital images like average blur, Gaussian blur and motion blur as explained in below:

Average blur: It is one of types that has been used to remove blur from an image. This type of blur distributes in vertical and horizontal directions as in following equation:

$$R = \sqrt{hr2 + vr2} \qquad (6)$$

Where:
hr = The size blurring of horizontal direction
vr = The size blurring of vertical direction
R = The radius volume for circular average blur

Gaussian blur: It is that weights of pixel are not equal. The effect of Gaussian blur is a candidate that mixes a particular number of pixels increasing. The blurring was incensed in the center and the edge. It applies to an image when we need extra control over the blur.
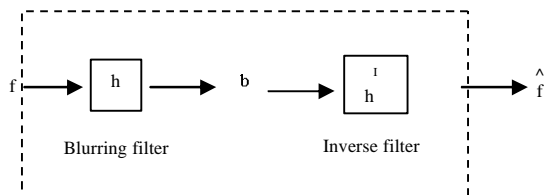
Fig. 2: Some common types of blur

Motion blur: The effect of motion blur is a candidate that makes an image seems in moving by appending a blur in a particular side. The control of motion can be performed by angle (0-360°) or direction (−90 to +90) and/or by density in pixel values (0-999), based the software utilized (Amri and Kalyankar, 2010; Karan, 2016).

MATERIALS AND METHODS

The key idea of applying blur on the spatial domain is convolving inverse filter with image to get on the blurred image. Then apply inverse of this filter that remove blur from image and it convolved with blurred image to obtain on the deblurred image. After that has been calculated PSNR value between sub image of one with other sub image and then summed PSNR of each sub image to get on the optimal sub image. Finally select PSNR value of optimal sub image based on peak signal to noise ratio measure that has higher PSNR and then fused optimal sub images to obtain on the fused image. The Fig. 3 illustrates the global structure of this method that contains many of steps:

Input set of images: The images have been used in this proposed are blur images that gained by appending blur to the different parts of original images. These images will be converted to 2D array with size M×N. These images are of same size and same scene.
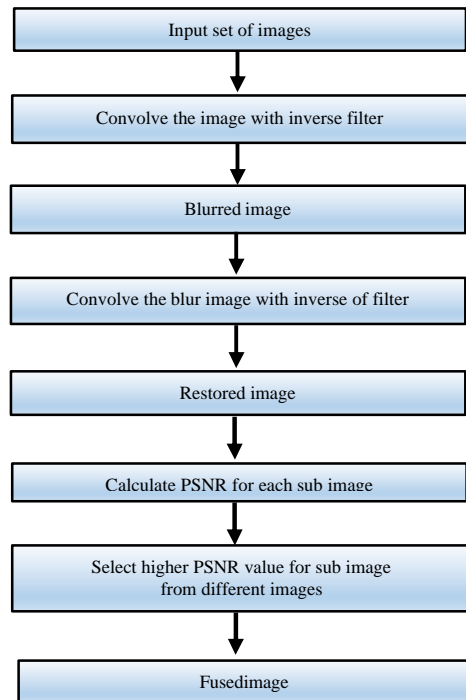
Fig. 3: Block diagram of the proposed method

Convolve the image with inverse filter: Each image is convolved with filter according to the Eq. 1. The coefficients of blur filter are positive value as follow:

$$\begin{matrix} 5 & 7 & 11 \\ 6 & 1 & 3 \\ 13 & 8 & 5 \end{matrix}$$

Blurred image: By applying the Eq. 1 will get on image distorted by blur is blurred image.

Convolve the blur image with inverse of filter: Blurred image is convolved with inverse of filter according to the Eq. 4.

Restored image: By applying the previous equation will get on deblurred image that distorted by Gaussian blur.

Calculate PSNR for each sub image: The selecting process of optimal sub imageshave been performed based on peak signal to noise ratio (PSNR) measure between one sub images with another sub image. Then sum PSNR for each sub image. The resulted image is the image that has the higher PSNR.

For example we have four original images and is computed PSNR for sub image in the upper corner of image:

Motion blur   Defocus blur   Gaussian blur   Shake blur
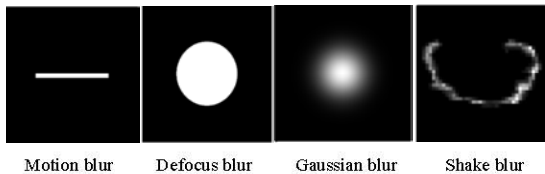
- PSNR between (sub image 1 and sub image 2) = 10
- PSNR between (sub image 1 and sub image 3) = 20
- PSNR between (sub image 1 and sub image 4) = 30
- PSNR between (sub image 2 and sub image 3) = 40
- PSNR between (sub image 2 and sub image 4) = 50
- PSNR between (sub image 3 and sub image 4) = 60

Now calculate sum PSNR for each sub image as follow:

- Image 1 = 10+20+30 = 60
- Image 2 = 10+40+60 = 110
- Image 3 = 20+40+60 = 120
- Image 4 = 30+50+60 = 140
- The higher PSNR is 140

The image 4 is better for selecting upper corner of image. The same steps is computed the rest of parts of image. Select higher PSNR value for sub image from different images: In this step is selected the sub image from several images according to the higher PSNR value.

Fused image: By selecting the optimal sub image from different images and then is fused to consist fused image, the image that gives large value is the better. For example the resulted image after PSNR are computed for each sub image is following:
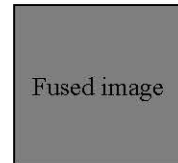
RESULTS AND DISCUSSION

In this study the experiments of this work are performed on 4 images with different parts of blur as given in the Fig. 4 and 5.

Figure 4 is selected four images that corrupted by various parts of blur for images as clarified in Table 1 that compute PSNR value between two sub images. Table 2 finds sum PSNR for each sub image to get on the optimal sub image that has higher PSNR for forming fused image.

Figure 5 also is selected four images that degraded by various parts of blur differ from Fig. 4 as clarified in Table 3 that compute PSNR value between two sub images. Table 4 finds sum of PSNR for each sub image to get on the optimal sub image that has higher PSNR for forming fused image.
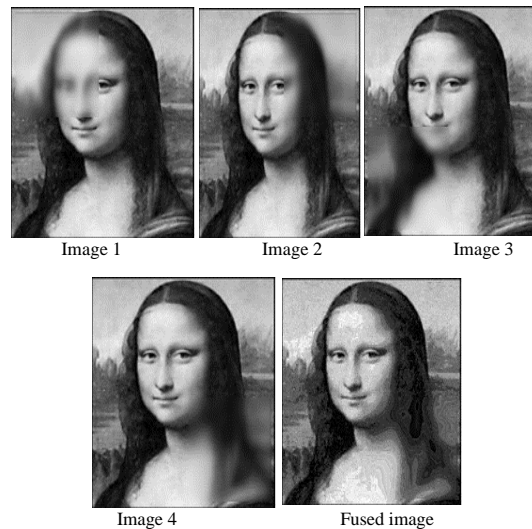

Image 1   Image 2   Image 3

Image 4   Fused image

Fig. 4: The original images and fused image(255×255)

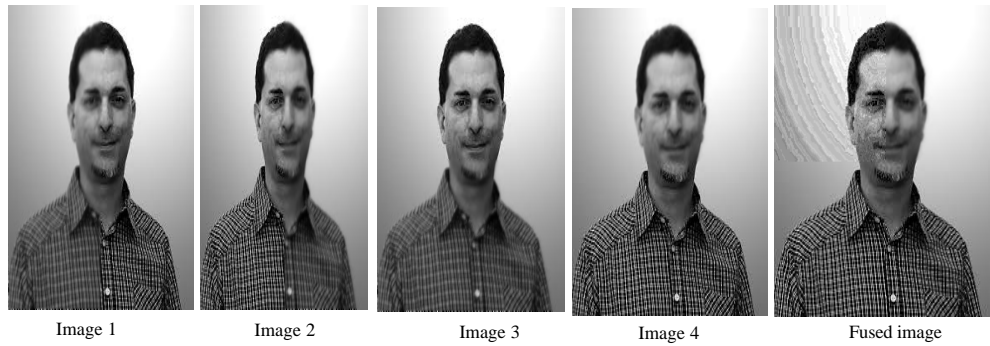| Image 1 | Image 2 | Image 3 | Image 4 | Fused image |

Fig. 5: The original images and fusedimage (400×400)

Table 1: The results of PSNR between two sub images for Fig. 4

Sub images for left upper corner	PSNR value	Sub images for right upper corner	PSNR value	Sub images for left lower corner	PSNR value	Sub images for right lower corner	PSNR value
Sub Image 1 and 2	19.833	Sub Image 1 and 2	21.144	Sub Image 1 and 2	48.130	Sub Image 1 and 2	48.130
Sub Image 1 and 3	19.833	Sub Image 1 and 3	48.130	Sub Image 1 and 3	21.028	Sub Image 1 and 3	48.130
Sub Image 1 and 4	19.833	Sub Image 1 and 4	48.130	Sub Image 1 and 4	48.130	Sub Image 1 and 4	22.122
Sub Image 2 and 3	48.130	Sub Image 2 and 3	21.144	Sub Image 2 and 3	21.028	Sub Image 2 and 3	48.130
Sub Image 2 and 4	48.130	Sub Image 2 and 4	21.144	Sub Image 2 and 4	48.130	Sub Image 2 and 4	22.122
Sub Image 3 and 4	48.130	Sub Image 3 and 4	48.130	Sub Image 3 and 4	21.028	Sub Image 3 and 4	22.122

Table 2: The sum of PSNR for each sub image for Fig. 4

Sub Image no for left upper corner	Sum PSNR of sub image	Sub Image no for right upper corner	Sum PSNR of sub image	Sub Image no for left lower corner	Sum PSNR of sub image	Sub Image no for right lower corner	Sum PSNR of sub image
1	59.501	1	59.501	1	59.501	1	59.501
2	116.095	2	116.095	2	116.095	2	116.095
3	116.095	3	116.095	3	116.095	3	116.095
4	116.095	4	116.095	4	116.095	4	116.095

Table 3: The results of PSNR between two sub images for Fig. 5

Sub images for left verticaldirection	PSNR value	Sub images for right vertical direction	PSNR value	Sub images for left horizontal direction	PSNR value	Sub images for right horizontal direction	PSNR value
Sub Image 1 and 2	26.220	Sub Image 1 and 2	26.372	Sub Image 1 and 2	15.640	Sub Image 1 and 2	17.826
Sub Image 1 and 3	41.334	Sub Image 1 and 3	26.296	Sub Image 1 and 3	15.640	Sub Image 1 and 3	48.130
Sub Image 1 and 4	26.220	Sub Image 1 and 4	48.130	Sub Image 1 and 4	36.770	Sub Image 1 and 4	17.808
Sub Image 2 and 3	26.150	Sub Image 2 and 3	38.639	Sub Image 2 and 3	48.130	Sub Image 2 and 3	17.826
Sub Image 2 and 4	48.130	Sub Image 2 and 4	26.372	Sub Image 2 and 4	15.612	Sub Image 2 and 4	34.743
Sub Image 3 and 4	26.150	Sub Image 3 and 4	26.296	Sub Image 3 and 4	15.612	Sub Image 3 and 4	17.808

Table 4: The sum of PSNR for each sub image for Fig. 5

Sub image no for left vertical direction	Sum PSNR of sub image	Sub image no for right vertical direction	Sum PSNR of sub image	Sub image no for left horizontal direction	Sum PSNR of sub image	Sub image no for right horizontal direction	Sum PSNR of sub image
1	93.774	1	93.774	1	93.774	1	93.774
2	100.501	2	100.501	2	100.501	2	100.501
3	93.635	3	93.635	3	93.635	3	93.635
4	100.501	4	100.501	4	100.501	4	100.501

CONCLUSION

This research presents removing blur from images using inverse filtering method. The results show that higher PSNR is the better for selecting sub image to consisting fused image. The fusion process is given better results than deblurring techniques without fusion process.

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