Journal of Engineering and Applied Scientific Research
ISSN: 2384-6569
Volume 9, Number 4, 2017

IMAGE DEBLURRING USING WIENER'S FILTER

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Abstract: Image blur is difficult to avoid in many situations and can often ruin a photograph. Thus Image deblurring and restoration is necessary in digital image processing. Blur is a form of bandwidth reduction of an ideal image owing to the imperfect image formation process. This is due to the fact that there is a lot of interference in the environment as well as movement during the image capture process, by the camera or, the when long exposure times are used, by the subject, Out-of-focus optics, use of a wide-angle lens, atmospheric turbulence, or a short exposure time, which reduces the number of photons captured and scattered light distortion in confocal microscopy. This work seeks to reduce the possibility of taking blurry images by developing a Wiener filter algorithm for image deblurring process using MATLAB

Received for Publication on 12 December 2017 and Accepted in Final Form 19 December 2017

INTRODUCTION

Digital images are electronic snapshots taken of a scene, which typically composed of picture elements in a grid formation known as pixels. (Singh etal., 2013). Pixel values of the processed image depend on pixel values of original image, according to Christian et al. (2006), each pixel is assigned intensity, meant to characterize the color of a small rectangular segment of the scene. A small image typically has around $256^2 = 65536$ pixels. Some of this pixels spills over to neighboring pixels blurring occurs, leading to loss of some information, but the actual fact is that some of blurred information on lost details is indeed present in the blurred image, although hidden and can only be recovered if we know the details of the blurring process (Christian et al., 2006)

A clear image is one that entire object can be perceived, for example, a face image is clear if the lips, eyes, nose, etc, is recognizable. The shapes of contained objects can also be recognized from its edges. (El-Henawy et al). Thus, blur in images is an unwanted reduction in bandwidth which degrades the image quality. Image enhancement or deblurring is necessary to reduce blur amount from the image. Image deblurring is a process used to reduce the blur quantity in a blurred image and make the degraded image into sharpened and clear image. Vankawalw at el. (2015). Image deblurring therefore is fundamental in making pictures sharp and useful.

The blurring, or degradation, of an image can be caused by many factors:

- **Slow Shutter Speed**

With a slow shutter speed, the slightest movement will introduce blur to the image, since the information the lens receive changes during lens opening, this happens in low light.

- **Hand Shake**

Most problems in photography blur are due to handshake, tripod are usually employed to hold camera in place

- **Misplaced Focal Point**

If the focus is misplaced, the subject may not be clear, because the camera lens is focused on an area thus all other areas will be blurred while the background is sharp.

In using blurred image to get useful information for some applications, it is necessary to deblur the images. Image deblurring is used to make images sharp and retrieve as much as detailed information from the actual scene. Therefore the objective of image deblurring, is to recover the original, sharp image by using a mathematical model of the blurring process, to achieve this effectively, the Point spread function (PSF) also called the distortion operator (blur operator) has to be known. In fact the quality of the deblurred image is determined by knowledge of the PSF. Taking a closer look as the PSF, Sabah Fadhel et al., in 2016 explained that in the spatial domain the PSF describes the degree to which an optical system blurs (spreads) a point of light. The PSF is the inverse Fourier transform of the optical transfer function (OTF).

In the frequency domain, the OTF describes the response of a linear, position-invariant system to an impulse. The OTF is the Fourier transform of the point spread function (PSF). The distortion operator, when convolved with the image, creates the distortion. Although distortion caused by a point spread function is just one type of distortion. When the PSF is not known, the Blind deconvolution method is applied. Blind deconvolution works blindly as its name indicates. In this method, an initial estimation of the degradation function is calculated. Then the system carries out an iterative process of blind deconvolution until an accurate estimation is obtained which minimizes the mean square error.

El-Henawy et al. (2014), explained that there are two basic approaches for blind deconvolution. The first is called projection based blind deconvolution and the second is the maximum likelihood restoration. The first approach makes an initial estimation of the point spread function (PSF) followed by an initial estimation of the true image. Then the process is repeated until a predefined convergence criterion is met. The advantages of this approach are that it is robust against inaccuracies of support size and it is insensitive to noise, while the disadvantages of this approach is that it is not unique and can lead to errors if unsuitable local minima has been initiated. While the second approach uses the maximum likelihood to estimate parameters such as PSF and covariance matrix. Since the estimation of PSF is not unique, the approach can consider parameters such as size, symmetry, and other parameters. The advantage of this approach is low computational complexity. It can obtain blur, noise and power spectra of the sharp image, while the disadvantage of this approach is that it converges to local minima of the estimated cost function.

Restoration process of images focuses on reconstruction of proper images from the blurred one, since noise also corrupts the image so we need to denoise the image. Image denoising is also a part of deblurring procedure. Three main types of blur in digital image are:

1. Average blur: Average blur can be scattered in both directions; Horizontal or Vertical. Average filter will remove this type of blur and it is useful when noise affects the whole image.
2. Gaussian blur: Blur which is simulated by Gaussian function. Effect of Gaussian blur produced through a filter that follows a bell-shaped curve by unifying a definite no. of pixels incrementally. Such type of blurring is impenetrable in the centre and at the edge side blur will fluffs.
3. Motion blur: Motion blur occurs due to comparative motion between the camera and the scene. Motion blur effects can be simulated in an image using motion filter in a specific direction then the resulted image will appear to be moving

AIMS AND OBJECTIVES

The aim of image deblurring is to improve the visual appearance of an image, or to provide a "better transform representation for future automated image processing.

The focus of this work thus is to develop a MATLAB application that can deblur and enhance images thus making images sharp and useful in terms of reduced blurriness, improve visual appearance and provide a better transform representation of the original scene

Scope of Work

Blur image is generally an issue in image processing and it is hard to avoid. This work focuses on debluring and restoration of images such that shapes of all objects can be perceived correctly, that is taking any image that is not sharply focused and processing it to make it more clear to the viewer.

Motivation

It is well known that an image is clear if we can perceive the shape of all its objects correctly. For example, a face image is clear if we can recognize lips, eyes, nose, etc. The prime motivation of this research mainly focuses on making image restoration and recognition. Many images like medical images, satellite images, aerial images and even real life photographs suffer from poor contrast and noise. It is thus necessary to enhance the contrast and remove the noise to increase image quality. Image stabilization in terms of deblurring and denoising are necessary to reduce blur amount as well as noise from the image.

LITERATURE REVIEW

The work done by different researchers are discussed in this section. The work presented by Lu Yuan et al., proposes an image deblurring approach using a pair of blurred/noisy images, their approach took advantage of both images to produce a high quality reconstructed image, and this they achieved by formulating the image deblurring problem using two images and then developed an iterative deconvolution algorithm which can estimate a very good initial kernel and significantly reduce deconvolution artifacts, special hardware was required and their work uses off-the-shelf, hand-held cameras.

Henawy et al. (2014), was concerned about the blur kernel and the deblurred image. They also introduced the blur type, noise model and different deblurring techniques. He explained that image blur may occur due to many reasons such as camera shake, object movements etc. After that he obtained image degrades that cannot be seen clearly. They observed that all captured images are less or more blurry, and there are lot of factors for degrading the quality of an image.

Fagun Vankawala et al. (2015), surveyed different literatures and simulation results analysis on various image deblurring algorithms proposed by different researchers, they concluded that Richardson Lucy gives comparatively better results and also observed that Richardson-Lucy and Van Cittert have same number of operations where as Poisson Map has highest number of operations and Laplacian has lowest number of iterations Moreover, they observed that Laplacian gives poor result because convolution on image use PSF instead of using PSF according to blur. He concluded by observing that based on the study carried out on a noisy image, the algorithms perform poorly in presence of noise in an image.

S.S. Bedi et al. (2013), observed that Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. He said that choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions. He proposed that Image enhancement techniques in Spatial domain is one of the most important and difficult component of digital image processing, he observed that based on the type of image and type of noise with which it is corrupted, a slight change in individual method or combination of any methods further improves visual quality. They focused on surveying the existing techniques of image enhancement, which are spatial domain enhancement and Frequency domain based enhancement discussed the advantages and disadvantages of the algorithms.

Singh and Sahu purposed a method for deblurring images using transformation spread functions (TSFs). Quality measurement parameters are also calculated in this. Deblurring is said to be a method used to sharp and clear the image. In this paper, the PSF is estimated for blurry image. They concluded that Restoration or deblurring average blur from images is a very difficult problem to resolve.

Minu Poulose et al. (2013), observed that though the subspace analysis and blind image deconvolution finds result to some extent it is prone to errors and is more or less like a probability method. They suggested that the local phase quantization technique is accurate but not robust to different types of blurs and lighting problems can make the deblurring difficult.

Oliver Whyte et al. ,proposed a new model for camera shake, derived from the geometric properties of cameras, and applied it to two deblurring problems within the frameworks of existing camera shake removal algorithms. The model can capture non-uniform blur in an image due to camera shake using a single global descriptor, and can be substituted into existing deblurring algorithms with only small modifications, however, is not applicable for non-static scenes, or nearby scenes with large camera translations where parallax effects may become significant.

Ghassan Hajj (2013), implemented a new algorithm capable of restoring a good image, using a pair of Blurred/Noisy image, instead of using a single blurred or noisy image to get the restored image. He explained that it took the advantage of the two images to produce a high quality image although no special hardware was needed, however he observed that the limitations of the technique was that it requires taking two images at the same moment of the same scene.

METHODOLOGY

In this chapter, techniques and algorithms for image deblurring is discussed. MATLAB is an excellent environment in which to develop and experiment with filtering methods for image deblurring. Image deblurring algorithms in Image Processing Toolbox include blind, Lucy-Richardson, Wiener, and regularized filter deconvolution, as well as conversions between point spread and optical transfer functions, but for the purpose of this work the wiener's method of deblurring images is employed. These functions help correct blurring caused by out-of-focus optics, movement by the camera or the subject during image capture, atmospheric conditions, short exposure time, and other factors. All deblurring functions work with multidimensional images. Step by step techniques involve in Deblurring an image using the wiener's Algorithm to deblur an image is displayed.

1. Load image using the imread command.
2. Display the image.
3. Simulate a blur.
4. Restore blurred image.
5. Simulate an additive noise.
6. Restore blurred and noisy image with noise-signal ratio (NSR)

Degradation Model

According to degradation model represented by fig.1, original image will convolve with degraded function i.e. point spread function using convolution operator which work like a multiplication operator. Then we get degraded image or blurred image noise is also present in the degraded image. An image may be defined as a two –dimensional 2(D) function represented by f(x,y), where x and y are plane co-ordinates, and the amplitude of F at any pair of the co-ordinate (x,y) is known as the intensity or gray level of the image at any point. Thus a image can be said to be digital when x,y and the amplitude value of f are all finite, discrete quantities.

Dejee et al.(2013), visualized the degradation model as represented below

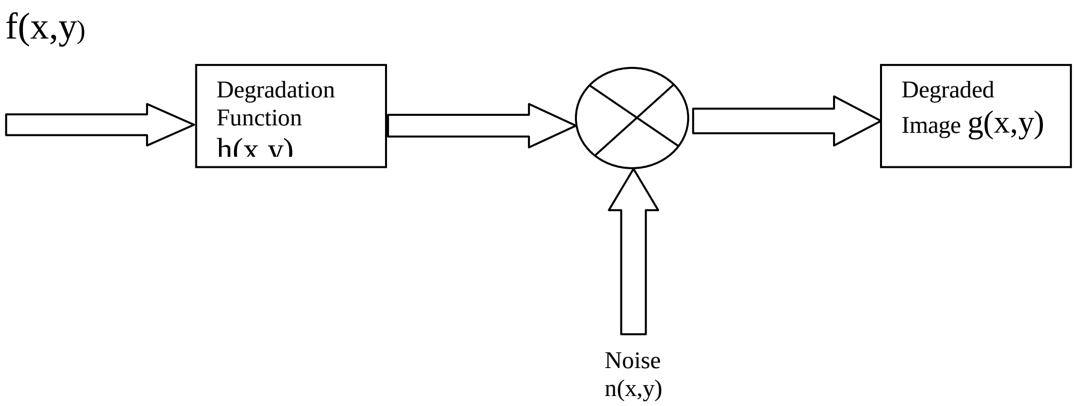

Fig 1: Degradation model

When the image is operated on by the system h(x.y) and noise n(x, y) is added, the degraded image g(x,y) is obtained. Thus trying to obtain an approximation to the original f(x,y) may then be viewed as image restoration.

The blurred image may be described using the following equation.
$g(x,y) = h(x,y) * f(x,y) + n(x,y)$

Thus when the original image is convoluted with the blur kernel (PSF), the result is a blurred image as shown in fig. 2

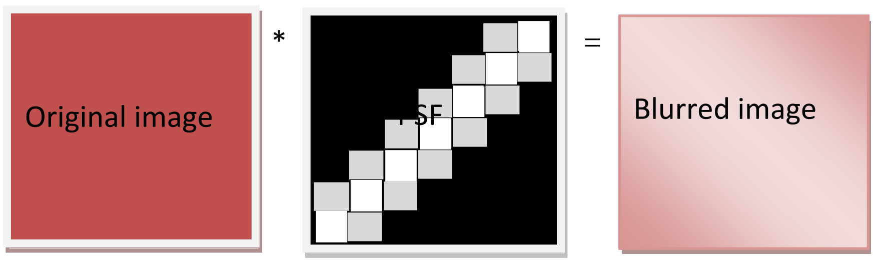

Fig. 2: Process showing how image gets blurred

Deblurring Techniques

There are various image deblurring techniques in image processing but the four basic techniques are classified as shown in fig 3 below

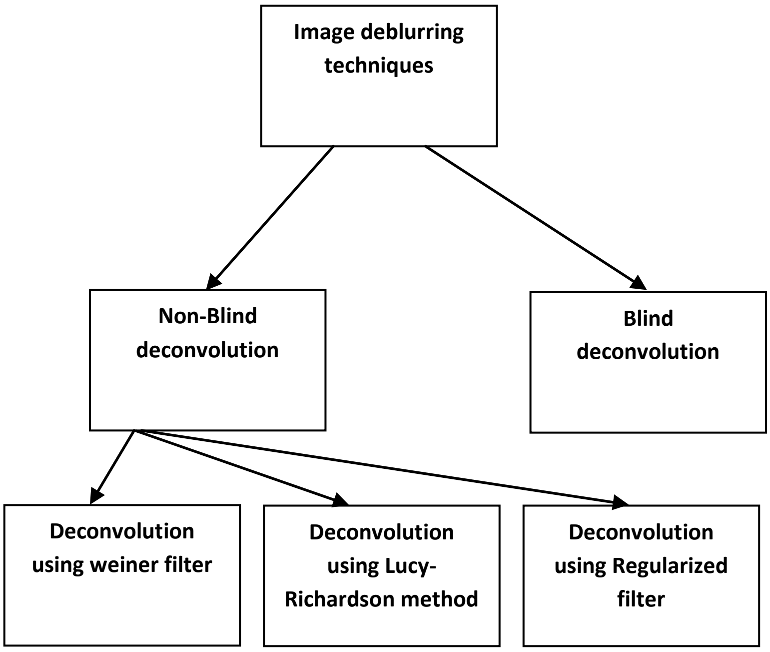

Fig.3: Image deblurring techniques.

One of the most common techniques for image deblurring is wiener filtering and has a large ability to remove the blur in images caused by linear motion or unfocussed optics. Thus this work focuses on the Minimum Mean Square Error (Wiener) Filtering, whose goal is to find the restored image such that the mean square error (MSE) between them is minimized. Wiener filter is used when the PSF and the noise level are known and can be estimated. Sudha Yadav et al.(2016), observed that in the absence of noise, the Wiener filter reduces to the ideal inverse filter and have been used with Fast Hartley Transform (FHT) to increase the speed of deblurring process.

Also according to El-Henawy et al. (2014), Wiener filter performs an optimal trade-off between inverse filtering and noise smoothing because it removes the additive noise and inverts the blurring simultaneously.

The easiest and most obvious way to fix image blur is to look at this formula in the frequency domain (by doing the DFT):

$$G(w_1, w_2) = H(w_1, w_2) X\, F(w_1, w_2) + N(w_1, w_2)$$

Then by dividing out by $H(w_1, w_2)$, we get:

$$\frac{G(w_1, w_2)}{H(w_1, w_2)} = F(w_1, w_2) + \frac{N(w_1, w_2)}{H(w_1, w_2)}$$

The Wiener filter is an important tool in image processing and it essentially performs deconvolution. The formula for the Wiener filter reduces to

$$G(w_1, w_2) = \frac{F(w_1, w_2)}{H(w_1, w_2)} X \frac{H(w_1, w_2)}{H(w_1, w_2)^2 + \frac{1}{SNR(w_1, w_2)}}$$

Where $G(w_1, w_2)$ is the deblurred image, $F(w_1, w_2)$ is the blurred image, $H(w_1, w_2)$ is the blur kernel, and $SNR(w_1, w_2)$ is the singal-to-noise ratio. If there is no noise then the equation reduces to:

$$G(w_1, w_2) = \frac{F(w_1, w_2)}{H(w_1, w_2)}$$

RESULT AND DISCUSSION

Deblurring Approach

The goal of this work is to restore or reconstruct a blurred image to its original image using a weiner deconvolution algorithm.

J = deconvwnr(I,PSF,NSR) deconvolves image I using the Wiener filter algorithm, returning deblurred image J. Image I can be an N-dimensional array. PSF is the point-spread function with which I was convolved. NSR is the noise-to-signal power ratio of the additive noise. NSR can be a scalar or a spectral-domain array of the same size as I. Specifying 0 for the NSR is equivalent to creating an ideal inverse filter.

The algorithm is optimal in a sense of least mean square error between the estimated and the true images. Image I can be uint8, uint16, int16, double, or single data type. Other inputs have to be double. J has the same class as I.

```
I=im2double(imread('joseph.jpg'
));
imshow(I);
title('Original Image');
```

imread command is used to read an image. **I=imread('joseph.jpg'):** this reads sample image included with the toolbox, joseph.jpg and stores it in array named I.

im2double converts the intensity image I to double precision, rescaling the data if necessary. If the input image is of class double, the output image is identical.

imshow(I) displays the image I in a Handle Graphics figure, where I is a grayscale, RGB (truecolor), or binary image. For binary images, *imshow* displays pixels with the value 0 (zero) as black and 1 as white.

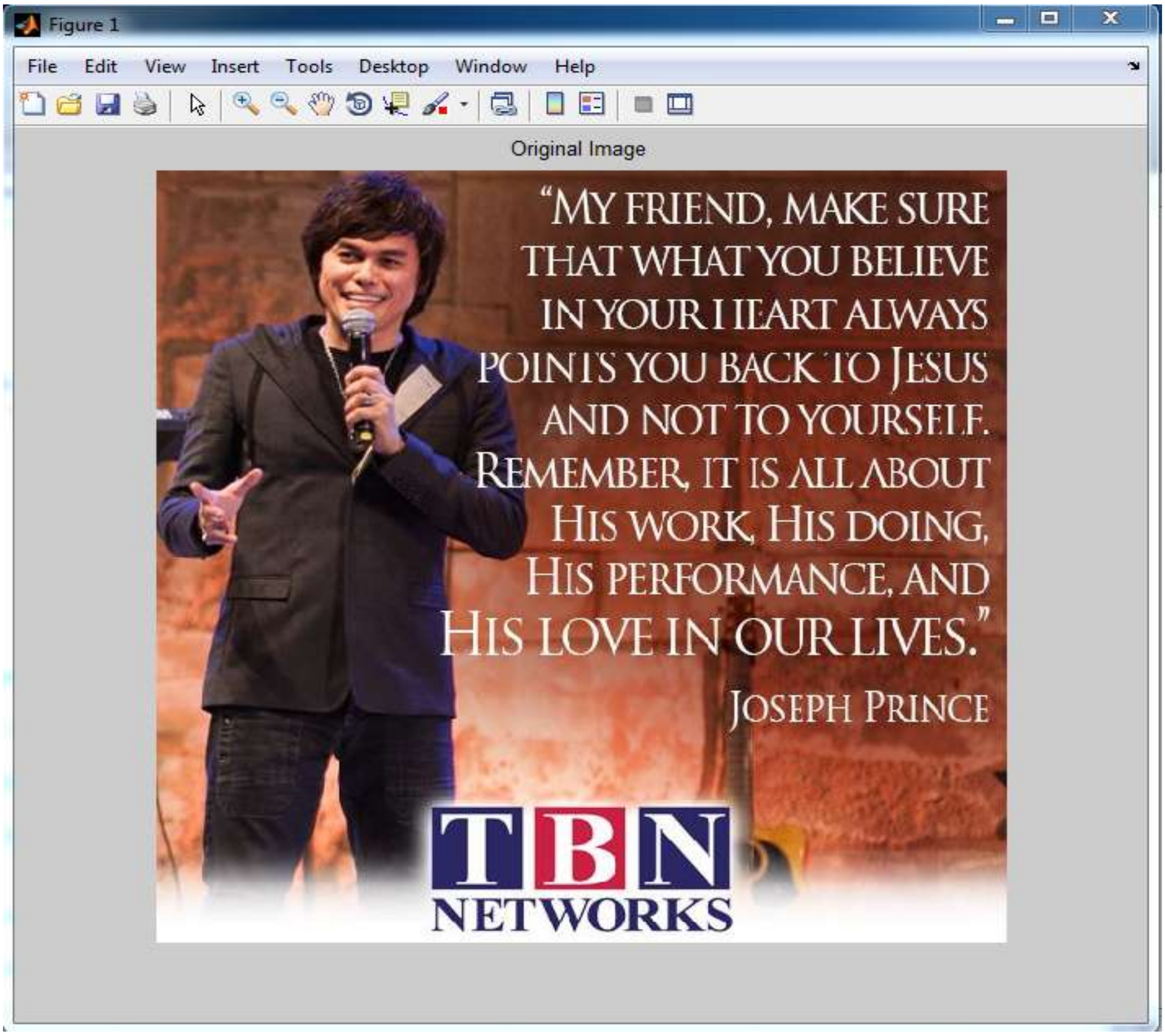

Fig 4.1. Original image

```
LEN= 45;
THETA= 15;
PSF=fspecial('motion', LEN, THETA);
blurred=imfilter(I,PSF, 'conv', 'circular');
imshow(blurred);
figure();
```

PSF = fspecial('motion', LEN,THETA) returns a filter (2D filter) to approximate, once convolved with an image, the linear motion of a camera by LEN pixels, with an angle of THETA degrees in a counterclockwise direction. The filter becomes a vector for horizontal and vertical motions. The default LEN is 9 and the default THETA is 0, which corresponds to a horizontal motion of nine pixels. To compute the filter coefficients, PSF, for 'motion':

imfilter computes each element of the output, ***blurred***, using double-precision floating point. If image I is an integer or logical array, imfilter truncates output elements that exceed the range of the given type, and rounds fractional values.

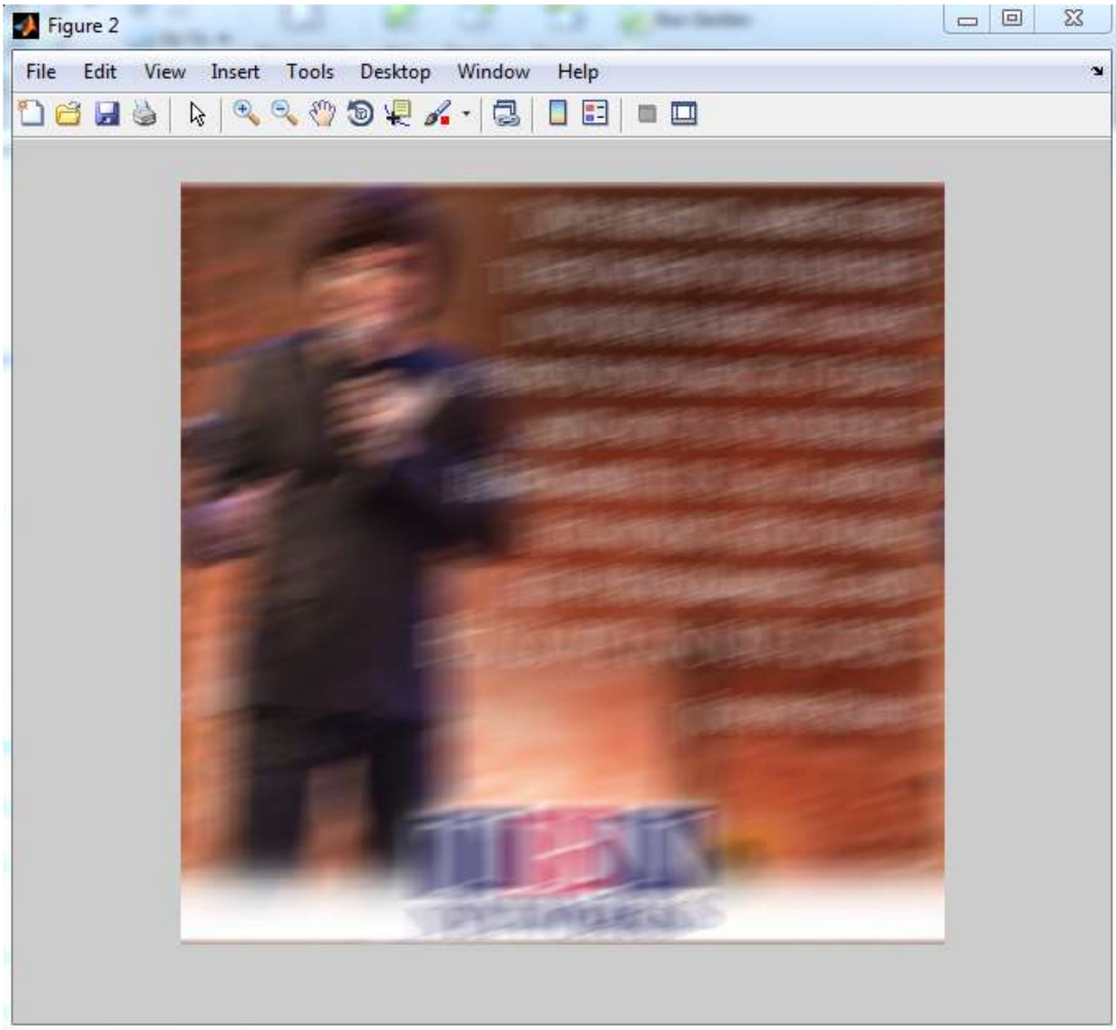

Fig 4.2 Motion blurred image with LEN =45 and THETA=15

The motion blur PSF is created with a width of 45 pixels, and rotated at an angle of 15 degrees clockwise

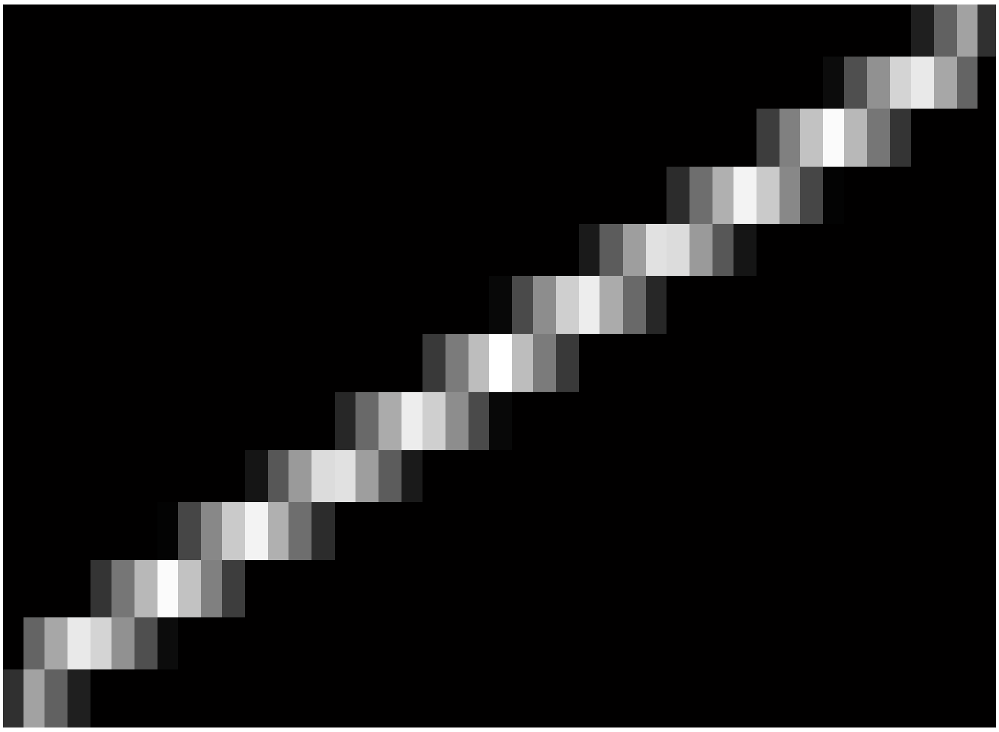

Fig 4.3 Motion blurred PSF with NSR =0

As we have mentioned before, blurring is an operation of a convolution in spatial time. To recuperate the original image, we should do the operation of deconvolution.

*wnr1= deconvwnr(blurred,PSF,0);*deconvolves image blurred using the Wiener filter algorithm, returning deblurred image wnr1. Image blurred can be an N-dimensional array. PSF is the point-spread function with which blurred was convolved. NSR is the noise-to-signal power ratio of the additive noise. NSR can be a scalar or a spectral-domain array of the same size as I. Specifying 0 for the NSR is equivalent to creating an ideal inverse filter.

The algorithm is optimal in a sense of least mean square error between the estimated and the true images.

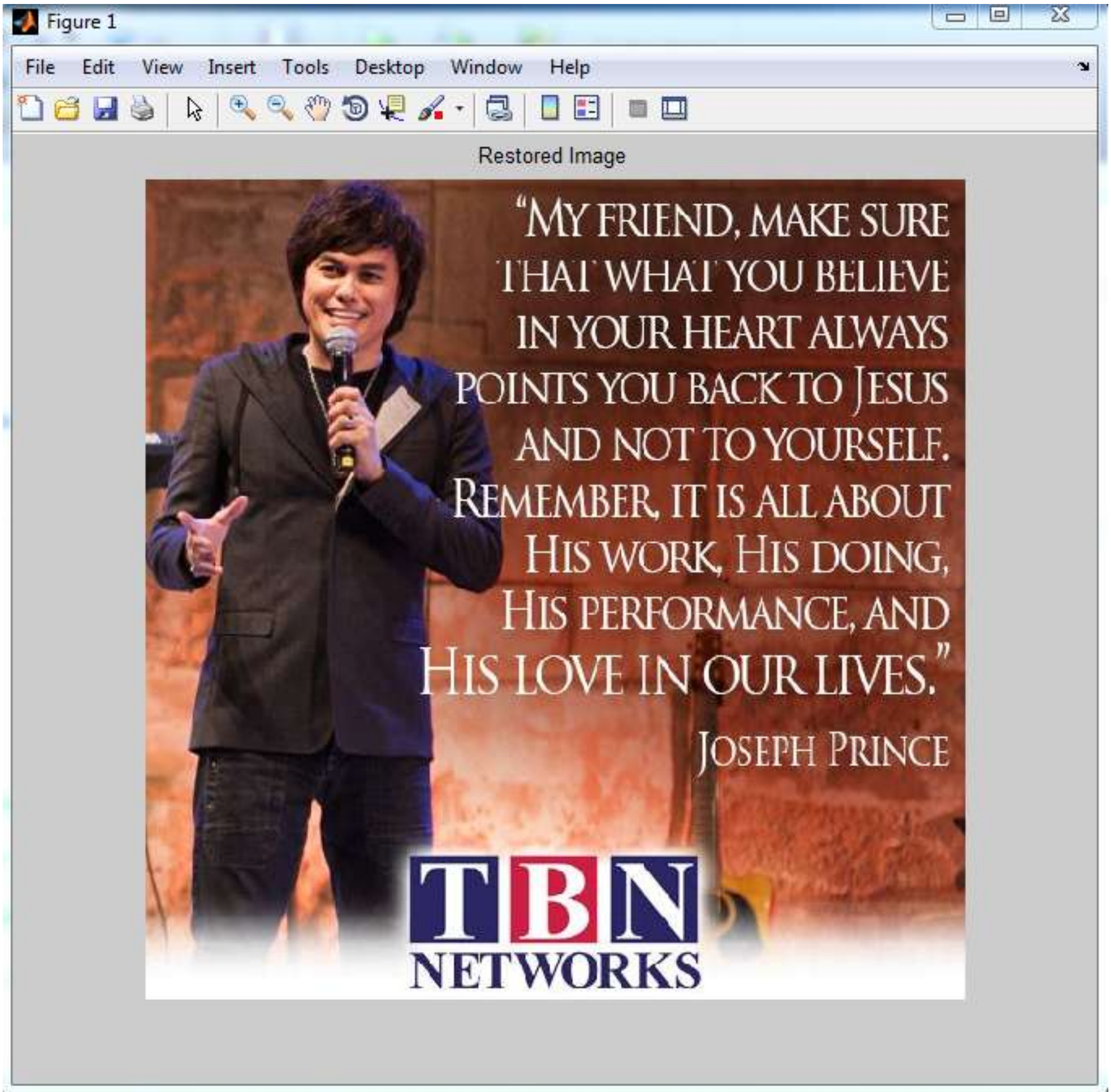

Fig 4.3 Restored Image

CONCLUSION

This work exposed the image processing capabilities in MATLAB. How an image can be processed with the help of MATLAB and how an image can be affected by noise and how that noise is partially removed from image through the use of wiener filter. This filter minimizes the mean square error between the estimated random process and the desired process. It also incorporates both the degradation function and statistical characteristics of noise into the restoration process. It is very important and widely used process in which images are processed to retrieve information that is not visible to the naked eye. Thus using the Wiener filter algorithm to deblur images gave rise to good results summarized as thus:

- Improvement of its pictorial information for human interpretation
- More suitable for autonomous machine perception
- Obtaining and enhancing the edges, to make it appear sharper
- Removing noise from an image and removing of motion blur

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