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Matlab Program for Sharpening Image due to Lenses Blurring Effect Simulation with Lucy Richardson Deconvolution

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Abstract: This research was conducted to simulate digital image sharpening using the Lusi Richardson deconvolution method. Sharpening was then performed by Lusi richardson deconvolution of the pint spread function of the lens effect. This point spread function is modeled mathematically with a mathematical function approach. The results of the convolution between the Digital Image from a photo of an object are then convolved with the point spread function so as to produce a blurry image. The blurry image is then re-sharpened by deconvolution using the Lucy Richardson convolution method. The results of this deconvolution are then compared with the image of an object photo of reference and then the difference is calculated. The slight difference between the deconvolution result image and the original object photo image indicates that the program is running well. Peak Signal to Noise Ratio (PSNR) Is used to determine image sharpening recovery. The optimum sharpening recovery of deconvolution iteration is obtained in the maximum PSNR value.

Keywords: Deconvolution; Image Sharpening; Lucy Richardson

Introduction

Image is a representation (picture), likeness or imitation of an object. The image as output as a data and visual recording system is optical in the form of photographs, analog in the form of video signals such as images on a television monitor, or digital in nature which can be directly stored on a storage medium (Apriliyani, 2017).

Image sharpening or commonly called this transformation is used to increase the contrast of color and light in an image. This process is done to facilitate the process of interpretation and image analysis. Contrast enhancement in an image is a way to improve appearance by maximizing the contrast between lighting and darkening or raising and lowering the value of an image data. Image enhancement is an operation that aims to improve image quality by manipulating image parameters. With this operation the special features contained in the image are more emphasized.

Contrast enhancement is applied to obtain a higher contrast impression. Everything is done by transforming all brightness values and giving the result in the form of an image with a new maximum value that is higher than the initial maximum value, and a new minimum value that is (generally) lower than the initial minimum value. Visually, these results are in the form of new images with variations the black and white is more prominent so that it looks sharper and facilitates the interpretation process. This processing often occurs in color images, both JPEG and PNG type, for this reason, sharpening is often carried out on these images.

With the sharpening of the image aims to clarify the edge of the image on the object in the image. Image sharpening is the opposite of softening operations because this operation removes the soft parts of the image. Image quality with the aim of increasing or improving the image. For sharpening the image, the Fourier Phase Only Synthesis and Blind Deconvolution Methods are needed for Image Sharpening. This method is able to be a solution to the problem above. The Fourier

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Phase Only Synthesis Algorithm is used for sharpening the image by interpreting the objects in the image display. And Blind Deconvolution is a method that can be used to restore images that experience blur effects without having to know the PSF value (Purba, 2020).

In previous research Apriliyani (2017), Perform Analysis of the Lucy-Richardson Method and Blind Deconvolution. Significant results were produced from both methods utilizing knowledge about the process of image degradation, one of which was the PSF value (Apriliyani, 2017). And further research Purba (2020), conduct Image Phase Improvement Application to Sharpen Images Using the Fourier Phase Only Synthesis method. Image results can also be obtained from the sharpening process which is also significant (Sundani et al., 2014).

Recovering a sharp image from a single blurred (possibly corrupted by disturbances) observation is the process of deblurring a grey-scale image. Motion blur or defocus aberration are the causes of blurring artifacts (Lai et al., 2016). The physical process that results in a defocused image is typically modeled by convolution of the original image with a point-spread function (PSF) and additive noise in the case of uniform defocus blur (Bahat et al., 2017). A schematic of this kind can be seen on the left side of Figure 1, where the intensity of the original image is shown by f and the intensity of the blurred image is shown by g (Zhang et al., 2013). Blind deblurring occurs when more than one out-of-focus observation of a sharp image is made. Integration over a light field captured at each time during exposure can be used to model motion blur (Srinivasan et al., 2017).

Several deblurring algorithms can be used to reassemble the original image whenever the PSF is known beforehand; Otherwise, it is challenging to estimate both the PSF and the intensity of the original image simultaneously. The estimation of both the PSF and the original image intensity simultaneously is made possible by a class of algorithms known as blind deblurring methods. In fact, blind deconvolution, a technique for undoing convolution with an unknown function (Fiori, 2004; Levin et al., 2011), is the source of blind deblurring. Astronomy uses deblurring algorithms (Vorontsov & Jefferies, 2017) to deal with photographic images taken by terrestrial telescopes whose quality is affected by atmospheric turbulence. Processing of barcodes and QR codes also includes blind deblurring of recorded images that are out-of-focus (Brylka et al., 2020; Lou et al., 2014).

Basic Theory

Improving image quality is an initial process in image processing which aims to perform image processing in order to have results with better relative quality than the initial image. Image quality improvement is carried out because the existing image has poor quality, for example the image has noise, the image is too dark/light, the image is less sharp, the image looks blurry and many others that cause the image to experience quality improvements.

Image quality improvement is the process of obtaining images that are easier for the eye to interpret Image improvement operations include image smoothing, image sharpening, dark/light contrast correction, edge enhancement, pseudo-coloring and noise filtering. The image sharpening operation aims to clarify the edges of objects in the image (Putra, 2010).

Sharpening image is the opposite of image softening (blurring) operation because this operation removes the soft part of the image. The sharpening operation is carried out by passing the image through a high-pass filter (HPF = high-pass filter).

A high-pass filter will miss (or amplify) high-frequency components (e.q edges or edges of objects) and will reduce low-frequency components. As a result, the edges of objects appear sharper than their surroundings. In addition to sharpening the image, a high-pass filter is also used to detect the presence of edges (edge detection). In this case, edge pixels are displayed brighter (highlighted), while non-edge pixels are made dark (black) (Sutoyo, 2010).

Image is a representation (picture), likeness or imitation of an object. The image as output as a data and visual recording system is optical in the form of photographs, analog in the form of video signals such as images on a television monitor, or digital in nature which can be directly stored on a storage medium.

Fourier is one way of representing the shape of a signal to the frequency domain. The Fourier series only applies to periodic signals. Discrete Fourier Transform (TFD) is a way to represent periodic and non-periodic signals to the frequency domain.

In phase-only Fourier synthesis is not in magnitude only Fourier synthesis. In particular, let f (x) denotes an n-dimensional signal and F(o) = IF (o) lep (") the n-dimensional Fourier transform where x = (XI, x 2, *, xn) is a vector of independent variables o = (a1w , 2,*, oni) the frequency variable vector, and IF(o)l are the magnitude and phase of F(o) respectively. Fourier synthesis f ,,, (x) is defined as a signal with Fourier Transform IF(o) l, that is 3 {fm (x) 1 = IF (w) l. Accordingly, the phase-only synthesis fp(x) is has S {fp(x)} = M(u)EFL ("). Where M is either unity or perhaps more generally a power function which is in some way representative of the class of signals but not derived from knowledge of the specific fp signal. The first context in which the similarity between the f(x) signal and the phase-only fp(x) synthesis has been recognized and demonstrated in the Fourier synthesis of crystallographic structures.

Joseph Fourier, is an integral transformation that restates a function in a basis-sinusoidal function, namely a sum or integral sinusoidal function multiplied by several coefficients ("amplitude"). There are many closely related variations of this transformation depending on the type of function being transformed. There are two kinds of Fourier analysis, namely for periodic functions using the Fourier Series, while for non-periodic functions using the Fourier Transform.

Blind Deconvolution is the same as the Lucy-Richardson method, the types of blurs used for testing are Gaussian blur and Motion-blur. The edge detection process is used to reduce the noise in the image blur, then multiply the iteration value or process repetition because there are several images if the iteration is too large, the image can cause artifacts or noise streaks as a result of the image repair process (Sundani et al., 2014).

Method

The research was conducted in several stages. The first stage is taking an image of an object using a digital camera which is then stored in bmp format. The second stage is the creation of a lens defocus simulation which is a compound function. Or often called the point spread function. This point spread function is modeled mathematically with a certain function which is then used as a convolution operator for image defocusing. The results of the convolution between the Digital Image from a photo of an object are then converted with a point spread function so as to produce a blurry or blurry image. The blurry image is then re-sharpened by deconvolution using the Lucy Richardson convolution method. The results of this deconvolution are then compared with the image of an object photo that is not blurry and then the difference is calculated. The slight difference between the deconvolution result image and the original object photo image indicates that the program is running well.

The blurring function or point spread function is made with certain mathematical functions. In this study, the mathematical function used is the mathematical function for defocusing a positive lens at a certain distance. The positive lens is a lens that is commonly used for almost all types of positive lens cameras. This is also an imitation of the eye lens which is located behind the cornea of the eye with the strength of the cornea lens + 10 diopters, while the power of the eye lens varies according to the object to be seen. This point spread function is then converted with photographic image data consisting of three layers of colors, namely red green and blue. The dataset is converted with the Spread function, the green data is also converted with the spread function, so is the blue data.

The convolution result of a digital image with pixel size m * n converted with a Point function with pixel size k times l will produce a digital image with size M plus k-1 multiplied by N + l - 1. The size of the data resulting from this convolution is larger than the final result so that at the edges of the image you will see errors in the image. This is what is called the edge effect.

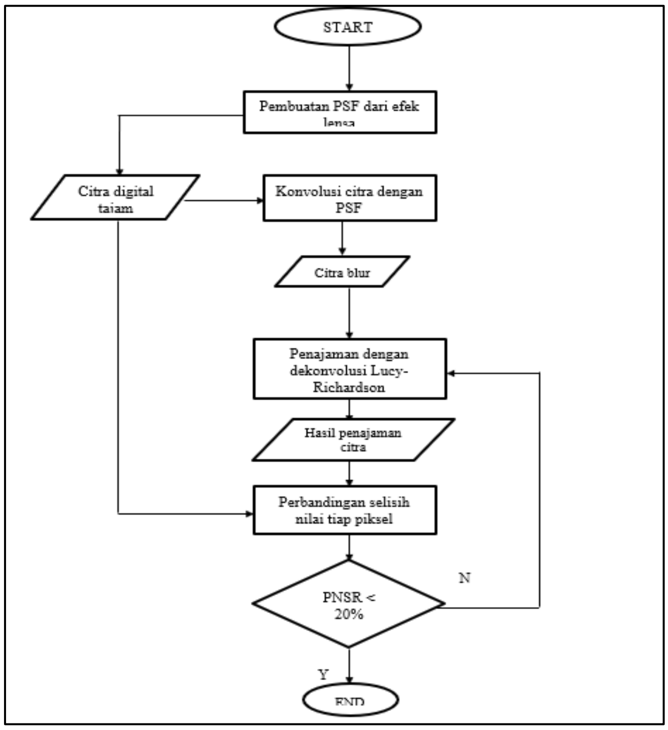


Figure 1. Algorithm flowchart

The point spread function will have a defocusing radius of R. With this size, the size of the point spread function is 2R * 2R. It should be noted that the point spread function must have a data edge that is zero, if the data edge of the spread function is not zero then an image formation error will occur due to the edge effect of the point spread function. Figure 2 shows Gaussian PSF Kernel generated from Gaussian function consist of 30 x 30 pixels.

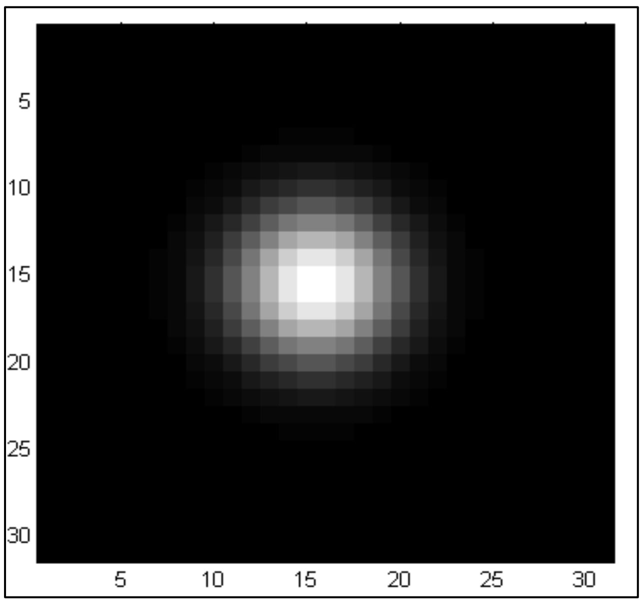


Figure 2. Gaussian PSF Kernel

Digital photographic image results data has a size expressed in pixels. One pixel is one digital data which is a color point of a digital image data. The number of pixels determines the image quality of a digital image, the more the number of pixels, the higher the quality of the image, and the smaller the number of pixels, the lower the quality of the image. Digital images in Matlab are composed of matrices consisting of pixels.

One digital image has 3 layers of data, namely red or red data, green or green data, and blue or blue data, so it is often abbreviated as red green blue (RGB). The white color represents the three colors of RGB light with the maximum intensity of these three components, while the black color represents the day of presentation of the color of RGB light with the minimum intensity of the three RGB components.

Images in Matlab each pixel has a size of 8 bits for each color with a minimum value of 0 and a maximum value of 255. The red color will be represented by the value of the red layer with an intensity of 255 and the green layer 0 and the blue layer 0. The blue color will be represented by the value of the red layer with an intensity of 0, green with an intensity of 0 and blue with an intensity of 255. The green color will be represented by a red layer with an intensity of 0, a green layer with an intensity of 255 and a blue layer with an intensity of 0. Image color combinations can be seen as figure 3.

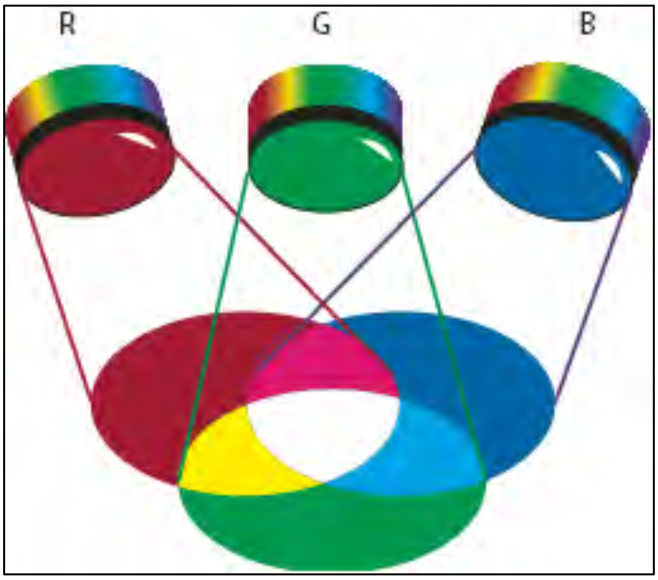


Figure 3. RGB color combination

The process of deconvolution is the reverse process of convolution. If the convolution process is a blurring process, then the sharpening process is a deconvolution process. In this study the deconvolution process used is the Lucy Richardson deconvolution method.

The quality value of the sharpening result can be calculated by comparing the value of each pixel from a good image with the deconvolution result image The percentage difference between the values of each pixel indicates errors that still occur in image sharpening. The smaller the percentage difference in the value of each pixel, the higher the quality of the sharpening that has been done.

Quantitatively, the calculation of the difference between the sharpened image and the reference image can be calculated using MSE or Mean Square Error. Mean square error is the average squared error of each image pixel. In image sharpening, image quality calculations can be performed using PSNR, which stands for peak signal to noise ratio.

Mean Square Error (MSE), Root Mean Squared Error (RMSE), and Peak Signal-to-Noise Ratio (PSNR) are examples of parameters commonly used as indicators to measure the similarity of two images. These parameters are often used to compare the results of image processing with the initial image or the original image. The equation used to calculate the three parameters is as follows:

$$MSE = \frac{1}{m \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} [f(i,j) - g(i,j)]^2$$

$$RMSE = \sqrt{\frac{1}{m \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} [f(i,j) - g(i,j)]^2} \quad (1)$$

$$PSNR = 10 \log_{10} \frac{255^2}{MSE}$$

where I_{max} is maximum intensity and MSE is Mean Square Error, RMSE is Root Mean Square Error and PSNR Is Peak Noise to Signal Ratio.

MSE and RMSE do not have units while the units for PSNR are decibels. The more similar the two images are, the closer the MSE and RMSE values are to zero. Whereas in PSNR, two images are said to have a low level of similarity if the PSNR value is below 15 dB.

Results and discussion

In this study, image sharpening was carried out on 5 images that had been blurred before, then re-sharpened with Lucy Richardson deconvolution. Sharpening of the 5 pictures is done with iteration up to 20 times. The PSNR of each iteration is calculated separately and then the maximum PSNR value is examined which indicates that the image has the best quality compared to the previous or subsequent iterations. The greater the PSNR value, the better the image quality means that the signal has a greater value than noise.

From table 1 it can be seen that the PSNR value for the first iteration is smaller than the second iteration. The PSNR value for the third iteration is greater than the

PSNR value for the second iteration. This value continues to increase until the maximum value is in the 10th iteration. Then it appears that in the 6th iteration the PSNR value begins to fall, this indicates that the deconvolution in the 6th iteration has decreased in quality compared to the previous iteration.

From the table above, it appears that the highest PSNR is in the sixth iteration, so quantitatively the best image can be determined at the sixth iteration. From these images shown in figure 4, visually, the best image quality may not appear, but quantitatively the best image is the sharpened image in the 6th iteration, this is based on the PSNR value which is the highest among the other 20 PSNRs. The PSNR value from the deconvolution results compared to the reference image is shown in Table 1.

Table 1. Value of PSNR due to Iteration number (N)

Iteration (N)	PSNR	Iteration (N)	PSNR
1	19,02297	11	18,19846
2	19,20952	12	18,27123
3	19,34818	13	18,37468
4	19,46458	14	18,46860
5	19,55515	15	18,53860
6	19,56565	16	18,59025
7	19,33908	17	18,63177
8	18,79882	18	18,66572
9	18,30445	19	18,69464
10	18,19206	20	18,72025

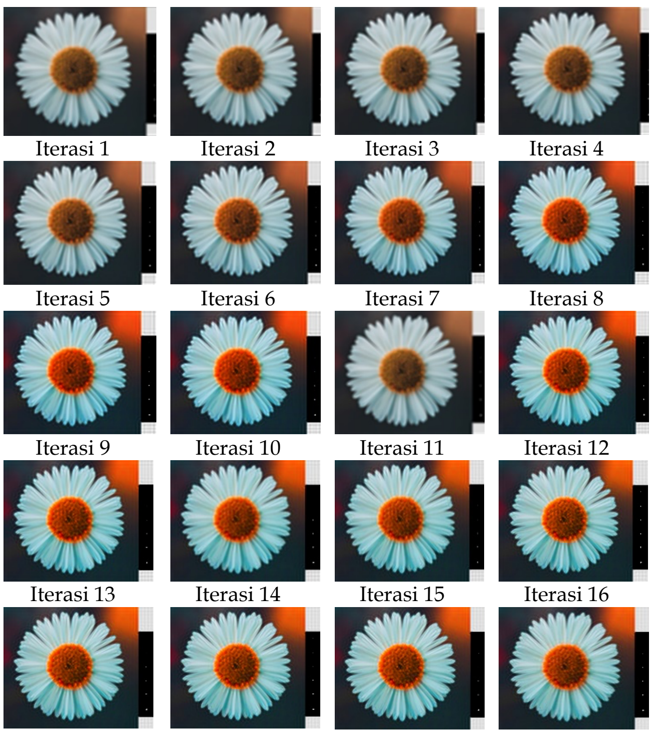
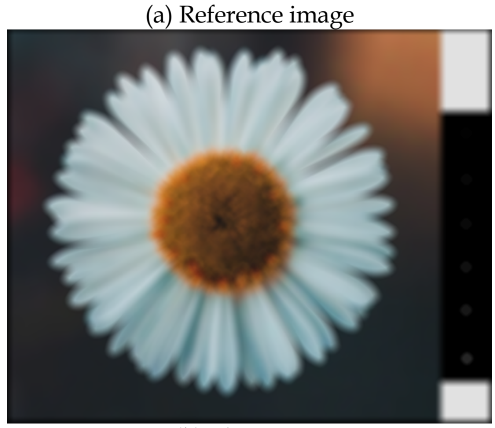


Figure 4. Results of sharpening with 20 times iteration

From Table 1, it appears that in the first iteration the PSNR value is 19.02297. The PSNR number increased until the 6th iteration with a maximum value of 19.5656 56. After the sixth iteration the PSNR value then decreased gradually until it had a minimum value of 18.19206 in the 10th iteration. After that, the PSNR values in the 11th to 20th iterations fluctuated in the range of 18.19846 to 18.72025.

Figure 5 shows the reference image, the blur image and the maximum sharpening image resulting from Lucy Richardson's deconvolution. From these Images it appears that the sharpening results have much better quality than the blurred image and are close to the quality of the reference image, although not perfect. This shows that image sharpening with the Lucy Richardson deconvolution method produces a significant sharpening.


(a) Reference image


(b) Blur image

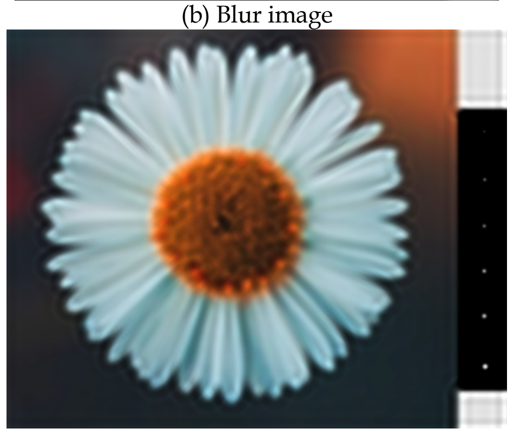

(c) maximum sharpened image

Figure 5. (a) Reference image, (b) Blur image and (c) maximum sharpened image

Conclussion

From this study it can be concluded that Lucy Richardson's deconvolution is good enough for image sharpening due to the defocusing effect of the lens. The PSNR value in the first iteration is always lower than the PSNR in the next iteration, however, at a certain limit in the nth iteration the PSNR value will be maximum. Then in the N + 1 iteration the PSNR value drops again and even decreases. The image with the maximum PSNR through PSNR calculation data.

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