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Deblurring MR Images with Two-Step Algorithm

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Abstract: MR images due to the defect of imaging devices or the patient's motion including voluntary and involuntary such as breathing may be blurred. According to the role of these types of images in the diagnosis of disease and therefore person's health, their desirable quality is very important and would be deblurred. Various algorithms have been proposed to deblurring in both frequency and spatial domains but most of these algorithms take into account the limitations on algorithms such that only one type of blur can deblur or consider the blur factor in only one direction. The objective of this study is to propose an algorithm that can address deblurring without restrictions in order to the motion of objects or blured factor. In the proposed algorithm, the sparseness of image edges property is applied in iterative deblurring which uses only one uniform image with unknown blur kernel is uncertain. The experimental results show that due to the good quality of deblurring with this algorithm, the restored images is contained with roughness and smoothing algorithm can improve image quality about 20% and it is comparable with art deblurring algorithms and is a suitable approach to solve the problem.

Key words: Blind uniform, deblurring, convolution, sparseness, MR images

INTRODUTION

Digital image processing is one of the software branches that have two branches image recovery and computer vision itself. One of the challenging issues in the field of image recovery is artifact. One of this artifact is blur. These images is prevented clear sight, in spite of blur, various noises may be added. This causes degradation of the image quality which must be eliminated through the destructive elements in the image to achieve deblurred image. Many applications in various fields have been used such as astronomy, remote sensors, medical imaging (Ma *et al*., 2013), satellite images (Jalobeanu *et al*., 2004), aerial and submarine in daily life to enhance blurred image.

Several methods have been diagnosed to solve the problem of deblurring. From them, these methods are used most commonly: estimation of the Point Spread Function (PSF), iteration, scattering, learning dictionary, Bayesian, configuration of Total Variance (TV). Most of existing algorithms are focused on the edge of detection and is considered as an important part in the most algorithms.

The selected method for deblurring uses the sparsness of image edges to deblur the natural images which this feature has integrated with iterative method in this method different iterations with strong edge detection filter is detected the blur kernel. Due to the sparse edges in medical images this method has been selected for deblurring. On the other hand, due to different types of blurred image that may occur, the algorithm must act to remove all kinds of blur. The deblurred images have some roughnesses and to increase the quality of such images, must be smoothed. Implementation result is shown the increased quality of the deblurred images after smoothing.

LITERARURE REVIEW

Techniques in the blind mode which PSF of the image is not clear, only a blurred image is usually used and blur kernel is supposed as a parametric form, so the blur kernel can be obtained with only estimation of a small number of parameters. The linear model of motion blur which were used in these works are often very simple. In real mode, for a correct linear deblurring is more complex, a pair or some images are used to obtain more information from the blur kernel.

Two common strategies for deblurring complex motion from an image which is recently used are bayesian

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and regularization methods. The bayesian framework is based on algorithms that use some probabilities on the hidden image, blur kernels or distribution of image edges to obtain the blur kernel. A possible limitation of this method is that the possibilities of assumed priorities may change. Another good strategy is formulation of the blind deconvolution issue as a minimization problem. Among the existing methods based on regularization, the amount of TV is usually selected to set the variable (Almeida and Almeida, 2010).

Sparsity show has recently attracted many researchers in the field of image processing to solve some problems such as deblurring, denoising, high resolution and etc. In the Sparsity Model, a small number of dictionary components are used for the approximate signals as a linear combination. The sparsity characteristics in signals display in human understandings have been proved by studies of machine vision (Almeida and Almeida, 2010; Deshpande and Patnaik, 2014).

Deblurring issue is inherently an ill-conditioned that has become one of the most research scope in the field of image processing (Ueno *et al*., 1993; Hirsch *et al*., 2011; Levin, 2006; Whyte *et al*., 2010). This challenge is more difficult in terms of motion blur as researchers work in this scope to be allocated. This is due to the different states of motions are often unpredictable and the relative motion between the camera and objects inside the shooting scene. Researchers have been limited to a small problem to tackle the problem; for example, the motion is considered only in the horizontal direction (Hirsch *et al*., 2011; Whyte *et al*., 2010) or the motion in a certain angle considered for example it is assumed to only be linearly (Cannon, 1976; Ward and Saleh, 1987).

Proposed approach uses an algorithm that is achieved the blur kernel insuccessive iterations and for this execution uses sparseness of natural image edges. The powerful property of this algorithm is known as its ability to remove a variety of the blur factors. Then, the proposed approach eradicates roughness and leads to the high quality of an image.

BASIC DEFINITION

In this study, all concepts that are needed to comprehend will briefly described.

Convolution: It can be said in a general definition that moving pixel by pixel mask on the image to produce the output image has been called convolution (this is the simplest form of definition by the convolution operation). Convolution operation normally has used for image filtering. Degradation of image quality is done in both spatial and frequency domains that has degraded by using the values of neighboring pixels in the spatial domain and by Fourier analysis of the digital image in the frequency domain.

Convolution is written by $x \times H$. This is defined as the integral of the product of two functions, one of them was reversed and has slipped on the other. If x is input image and H is considered blur mask, convolution in frequency domain is defined in the following. That $x \times H$ represents the Fourier transform and k is constant that is dependent on the normalized Fourier transform (Jain *et al.*, 1995). If the image x, convolution equals calculation of total weight of the image pixels:

$$F\{x \times h\} = k.F\{x\}.F\{H\} \tag{1}$$

Blur kernel: It is filter or blured mask that in combination with the original image with the convolution operation leads to the degradation of the image quality. This kernel for operating effectively with the central pixel is considered to odd numbers. For example 3×3, 7×7 or 9×9.

Blur and its factors: Blur, drop in image quality which can be occurred with several factors in image such as motion (Shan *et al*., 2008; Hirsch *et al*., 2011), the focus (Almeida and Almeida, 2010), ambient light shooting and inherent aspects such as camera pixel size, the presence of anti-fracture filters on a camera sensor and limited resolution sensors and atmospheric conditions such as pressure, temperature (Jalobeanu *et al*., 2004), etc. These factors can be seen in Table 1. If the reduction in image quality happens with only one blur kernel, blurred image is uniform and degradation with several blur kernel is diagnosed non-uniform. Blur is shown with following model:

$$f = H \otimes x + n \tag{2}$$

In Eq. 2, his blur kernel, x is deblurred image and n is additive noise in imagethat f is blurred image that is degraded with convolution operator $\otimes$. Deblurred image can achieved with inverse convolution operator calls deconvolution. If the possession of the blur kernel or/and sharp image of the scene of shooting is called non-blind convolution otherwise it is called blind convolution.

Gaussian filter: A method for estimating kernel is use of Gaussian filter this is due to the special character of

Table 1: Varios factors in creation blurred image and their definition

Blur factors	Definition	References
Motion	The relative motion between the camera and objects in the picture arise during the exposure	Ma *et al*. (2013), Shan *et al*. (2008), Hirsch *et al*. (2011), Almeida and Almeida (2010), Levin (2006), Yang *et al*. (2014) and Whyte *et al*. (2010)
By focus	One of the important techniques in image systems such as video cameras because the output image depends directly on the performance focus	Almeida and Almeida (2010)
Light shooting	Low light shooting by the scene is created such as shooting at night	Yongmao
Essence camera such as resolution	Because of the type of camera used in image occurs such as limited resolution or pixel size that is intended for the type of camera	Almeida and Almeida, Szeliski
Atmospheric disturbances	The images created by atmospheric characteristics such as pressure, temperature and etc	Jalobeanu *et al*. (2004)

Gaussian noise it's for the variance of light intensity which is drawn from a normal distribution or Gaussian and is a good model for many types of noise caused by the sensor such as the noises that can occur as a result of electronic camera accessories. Gaussian filter is a good filter for removing noise from a normal distribution. Gaussian function with the mean zero in one dimension is defined as following (Zhang *et al*., 2011):

$$gu(i) = e^{\frac{-i^2}{2\sigma^2}} \tag{3}$$

where, the Gaussian distribution parameter σ specifies the width of the Gaussian. In image processing, discrete Gaussian function with the mean 0 in the case of two-dimensional is defined as following which is used as a Gaussian filter:

$$gu(i, j) = e^{\frac{-(i^2+j^2)}{2\sigma^2}} \tag{4}$$

Strong filter edge detection: A more professional mode for edge detection which uses a series of edges detection filters is that the rotated versions are from a basis filter. Filter rotation is done by rotating PSF of a basic filter using bicubic interpolation. For each pixel, the outputs of edge detection filters for all rotations are calculated according to the following formula that in g_θ, θ is a series of rotations of filter. The detection output is obtained from the following Eq. 2:

$$E = \sqrt{\sum_{\theta\in\Theta} g_\theta^2} \tag{5}$$

The objective function: The objective function is a cost of function which should be optimized by its minimization, the intended parameter (in fact it is the blurred image) can be detected. This is usually repeated in the algorithms based on iteration and it is obtained based on the definition of image blurring model. If the image blur is considered as a Gaussian type in case of the importance of having images with sparse edges and considering PSF, the objective function are used as following (Almeida and Almeida, 2010) which is actually used in algorithms with uniform blurred images:

$$C = \left\|f-\hat{f}\right\|_2^2 + \lambda_x R_g(x) \tag{6}$$

Where:

- f = Observed as blurred image
- $\hat{f}$ = An estimation of the blurred image which is obtained from the relation of $\hat{f} = H \times x$ that x is an estimation of the original image and H is estimated as the blurred filter
- $R_g(x)$ = A regulator that attentions to the image edges
- λ_x = A regulatory parameter of sparsity

The uniform blind algorithm: In the reason of lacking of the information, the algorithm in blind mode is selected due to the difficulty in their solution in the field of blur kernel and in the real possibility of this type of issues is high and in the second place, a blind algorithm is selected because of its performance and ability in deblurring different types of blur such as motion, focusing, etc. is investigated. This algorithm is from the iteration algorithms in deblurring the images which estimates the image and blur filter in various iterations. The main features can be seen in the following Almedia and Almedia:

- The use of sparseness priority in images
- The use of strong filter edge detection

The natural images because of their sparse edges are noted and since the edges have the property of separation have an important role in deblurring the images, for example by detecting the direction of the edge in motion blur, blur kernel is detected. Steps of implementation are presented in the following.

Algorithm implementation steps: In order to achieve the best solution in objective function with a large regulatory parameter of λ which is gradually decreased and started by a priority with lower sparseness then sparsity will be gradually increased to achieve a desired result, the optimization dependent on X and H is done in iteration. In the beginning of optimization with a large amount of λ, only the main characteristics are remained in the estimated image then gradually reduction of this amount in iterations, the image details are considered. With a strong configuration, processing is forced to eliminate high error frequencies for only paying attention to these features and as optimization goes and estimation of blurred filter is better, smaller and weaker properties which can be used gradually to estimate. This method has continued to make a good solution.

For iteration in this algorithm, the maximum of a posteriori method with a new priority is used that the sharp edges are used to stop the generalized TV as its discrete form which is for its implementation, an adaptive version with Increment in Signal to Noise Ratio (ISNR) is used but it has seem that this strategy has not work successfully in combination with this method. Due to this it should be stable for the variances that do not affect the quality of retrieved images. In particular, the calculation should remain constant in these cases: each repetitive conversion of the intensity measurement; small transformations (in opposite) of estimated image and blurred filter which these cases have affected the speed and the performance of this program. For this reason, another criteria based on the amount of whiteness in the image is presented in 2011 to stop this algorithm.

PROPOSED ALGORITHM

The deblurred images by the uniform blind algorithm are rough which in the presented algorithm, smoothing has been used to increase the quality of these images. This algorithm is seen in Fig. 1. The algorithm is described in the steps as followed in bellow.

Step 1: As it is seen in this Fig. 1, the blurred image was placed by the uniform blind deblurring algorithm with estimation of blur kernel and is converted to a deblurred image in this step.

Step 2: This produced from step1 is contained roughness which is converted to a deblurred image with smoothing which flowchart has a higher quality compared to the deblurred image before smoothing.

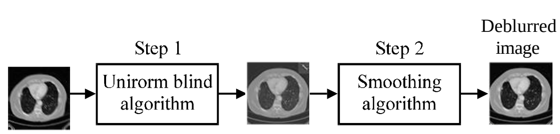

Fig. 1: The proposed strategy flowchart

Smoothing is done by a Gaussian filter. Gaussian filter is often used to reduce noise problems. Gaussian filters have basically the same physical properties because they have a similar standard deviation in the whole two domains. An image can be filtered by a gaussian filter with the similar properties with description of a numerical value for standard deviation (sigma) which this value is considered as 0.5, here.

IMPLEMENTATION AND RESULTS

Used data, implementation environment, evaluation criteria for deblurred image quality with this proposed application is presented in this study.

Evaluation criteria: Different items have been developed for evaluating image quality such as PSNR, ISNR, SSIM, etc. that the maximum signal to noise ratio or PSNR is one of the simplest and most commonly used. When it comes to image quality evaluation as in Gupta come, there is no specific rule for the SSIM or PSNR. Therefore, formal discussion and summary interpretation of numerical values is obtained during the assessment process. According to research, PSNR acts the differentiation of the structural composition badly and vary imposed degradation of the images to the same image can obtained the same amount of MSE but other studies show that MSE and it's' outcome PSNR has the best performance in noise image quality evaluation. So, here, the PSNR is used to measure image quality.

There is an interesting relationship between Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM). That is the values in the same way as the SSIM and PSNR are not independent. As a final result it seems PSNR values can result from SSIM and its' inverse. PSNR and SSIM criteria are primarily different on the degree of their sensitivity to image degradation. In Gaussian noise, SSIM is more sensitive than PSNR while it's opposite for JPEG compressed images and SSIM acts well. However, both will respond well to the gaussian noise and the JPEG images.

Exprimental data: To investigate, one hundred of MR medical selected images which were received from The Cancer Imaging Archive (TCIA) medical images database. This database is a public archive for different cancers which has thousands of different medical images and has a good program to achieve the desired images; it focused on the images which were taken by a special type of imaging device such as CT or MR.

Implementation environment: To perform the smoothed uniform blind algorithm, a 2-cores laptop with 2.13 GHz CPU power in per core is used with MATLAB Software version R2015a run on windows seven.

Result: Figure 2 shows the results of algorithm implementation before and after smoothing. Figure 2a shows images of the brain from three views that has been blurred with a 9×9 filter with an angle of 135 degrees. Figure 2b shows the deblurring results of those three images with the uniform blind algorithm and Fig. 2c shows the results of implementation with the proposed algorithm. Evaluation the results of algorithm with the criteria of PSNR and SSIM for medical images has been done which the evaluation results is shown in Table 2. As it stands, the obtained values for PSNR and SSIM, indicates an increase and improvement in the quality of image with the proposed algorithm which this increase is estimated by 20%.

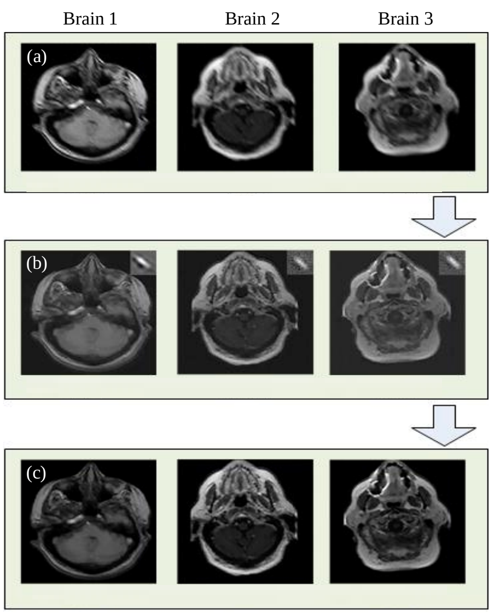

Fig. 2: a) Three views of brain MR which are damaged with 9×9 filter and with an angle of 135 degrees with motion blur; b) Blur-removal results with the uniform blind algorithm of and c) Deblurring results after smoothing

Table 2: Evaluation of deblurring results of three MRI images of the brain before and after proposed algorithm with the criteria of PSNR and SSIM

Images	Kernel size	PSNR (before)	PSNR (after)	SSIM (before)	SSIM (after)
Brain 1	9×9	29.26	31.67	0.72	0.89
Brain 2	9×9	25.45	27.18	0.76	0.84
Brain 3	9×9	25.23	26.67	0.79	0.85

CONCLUSION

Non-use of a powerful approach in solving the deblurred medical images may not diagnose the type of disease for example it is interpreted noise to tumor. Proposed approaches due to the importance of these types of images act desirably and make the deblurred image close to real scene.

A new approach with a uniform blind algorithm was proposed for deblurring the medical images then the results after smoothing was investigated. These results show the quality improvement of MRI medical images which are reduced with motion blur. The deblurred images were assessed and evaluated with two criteria of PSNR and SSIM that each two criteria showed an increase in the quality of the obtained results. Creating an algorithm that can perform deblurring operations more efficiently for medical images and present a better result and also consider speed as its criteria of action will be considered as the future research.

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