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A Literature Survey on Blur Detection Algorithms for Digital Imaging

Boon Tatt Koik
School of Electrical & Electronic Engineering,
Engineering Campus, Universiti Sains Malaysia,
14300 Nibong Tebal, Penang, Malaysia
Email: btkoik@gmail.com

Haidi Ibrahim
School of Electrical & Electronic Engineering,
Engineering Campus, Universiti Sains Malaysia,
14300 Nibong Tebal, Penang, Malaysia
Email: haidi_ibrahim@ieee.org

***Abstract*--Development of blur detection algorithms has attracted many attentions in recent years. The blur detection algorithms are found very helpful in real life applications and therefore have been developed in various multimedia related research areas including image restoration, image enhancement, and image segmentation. These researches have helped us in compensating some unintentionally blurred images, resulted from out-of-focus objects, extreme light intensity, physical imperfection of camera lenses and motion blur distortion. Overview on a few blur detection methods will be presented in this paper. The methods covered in this manuscript are based on edge sharpness analysis, low depth of field (DOF) image segmentation, blind image de-convolution, Bayes discriminant function method, non-reference (NR) block, lowest directional high frequency energy (for motion blur detection) and wavelet-based histogram with Support Vector Machine (SVM). It is found that there are still a lot of future works need to be done in developing an efficient blur detection algorithm.**

Keywords-component—Digital image, blur detection, literature review, literature survey, image restoration, image enhancement, image segmentation, blur classification

I. INTRODUCTION

Studies on characterization and detection for blur regions from digital image have become one of the important research branches in recent years. In addition to the use as a part of de-blurring process, automatic detection and classification of the blurred regions from digital image are very functional in order to understand the image information, and also useful for evaluating image quality [1] for further enhancement processes.

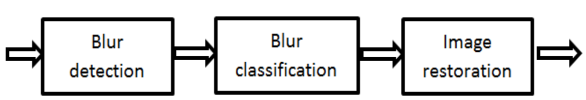

Figure 1. Block diagram to relate blur detection, blur classification, and image restoration.

Researches regarding blur phenomena in digital image can be narrowed down into three main branches. These branches are blur detection, blur classification, and image restoration. However, we can also describe these three research branches as a series of consequence processes, as shown in Fig. 1. The initial process is the blur detection, where the blurred regions are identified. Then, it is followed by blur classification, where the blurred regions are categorized and classified according to their blurring nature. Finally, image restoration will take place, where the blurred image will be processed by de-blurring operation, in order to obtain a sharper image.

Being the first branch or the initial stage in improving the quality of digital image that suffers from blur, blur detection algorithm is very useful because it is used as the preliminary processes to detect the specific regions which require de-blurring operations. Many blur detection algorithms have been proposed by researchers in recent years. The research presented by Rugna and Konik [2] had showed that blurry regions are more invariant to low pass filtering process. As a consequence, this interesting fact has been chosen as one of the features to classify image regions into either blurry or non-blurry areas.

Algorithm proposed by Levin in 2006 [3], on the other hand, uses a method based on inferred blur kernel. This kernel is used to build an energy function to divide the image into two distinctive layers; which are the blur layer, and the non-blur layer. On the other hand, in works by Elder and Zucker [4], only the blur extent is being measured; without designing a method that distinctly labels the image's region into blurry or non-blurry areas.

Blur classification is the second branch of the research related to blur in digital images. This research branch's objective is to classify the blur areas according to their characteristics, or types. The two common studied classification of the blur type is near-isotropic blur, which includes out of focus blur, and directional motion blur. Hough transform and error-parameter can be used to estimate the blur parameter for linear motion blur. Other directional motion blur is curve motion blur, which is using curve fitting approach and polar transformation to estimate the motion parameter values [5]. Blur detection algorithms are also useful in segmenting the digital image into a few regions, based on blurring characteristics.

The third research branch is the blur image restoration, or de-blurring process. The main objective of this research branch is to improve or repair the blur image by using various algorithms and methods. This research branch is very useful for real life applications. For example, they are applicable to forensic or crime solving, by restoring blurred digital images captured by the mostly low-cost, low-quality surveillance camera into a clearer picture of the criminal.

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Besides, image restoration can be used in image enhancement researches. For example, blur image restoration algorithms can be used as a preliminary process in an advanced image enhancement algorithms to increase the contrast of a digital image captured from consumer electronic products, such as digital camera, smart phones, and video camcorder.

The work by Razligh and Kehtarnavaz [6] proposed an image de-blurring method for the use in cell phone. This de-blurring method takes considerations on the brightness and the contrast of the blurred input images and also corrects low exposure images. Other examples of de-blurring algorithms are the works by Fergus et. al [7] and Shan, Jia, and Agarwala [8]. These methods show reasonable results of de-blurring process, and robustness to noisy image. However, algorithm processing in [7] and [8] are computationally expensive and time consuming which adding disadvantages to their algorithms.

Based on the above mentioned facts, as the research related to blur in digital images are very wide and active, this paper will give more attention and review on blur detection methods. This review is limited only to the methods used for digital images and digital video sequences. The review will be presented in the next section.

II. BLUR DETECTION METHODS FOR DIGITAL IMAGE

Researches on blur detection are very useful for improving the digital image quality, possible aiding in crime solving with video quality improvement and restoration of some precious images in our daily life. Based on our readings, in general, we can divide blur detection methods into seven main categories, which are:

- Edge sharpness analysis.
- Low depth of field (DOF) image segmentation.
- Blind image de-convolution.
- Bayes discriminant function method.
- Non-reference (NR) block.
- Lowest directional high frequency energy (for motion blur).
- Wavelet-based histogram and Support Vector Machine (SVM).

Each of the category will be explained briefly in the following subsections.

A. Blur Detection using Edge Sharpness Analysis

Fig. 2 presents an example to show the effect of blur towards the slope of the object's edges in the image. Sharp images contain step edges. However, when the image become blurred, the step edges become ramp edges. The slope of the edge is depending to the degree of blurring. Therefore, the blur detection can be carried out using the information of the object's edges.

Blur detection and estimation using this method aim at measuring the blur extend by inspecting the object edges inside the image. In the work by Chung et. al [9], gradient magnitude and edge direction are fitted to a normal distribution. The gradient magnitude, with the standard deviation of the normal distribution is regarded as the blur measure[10].

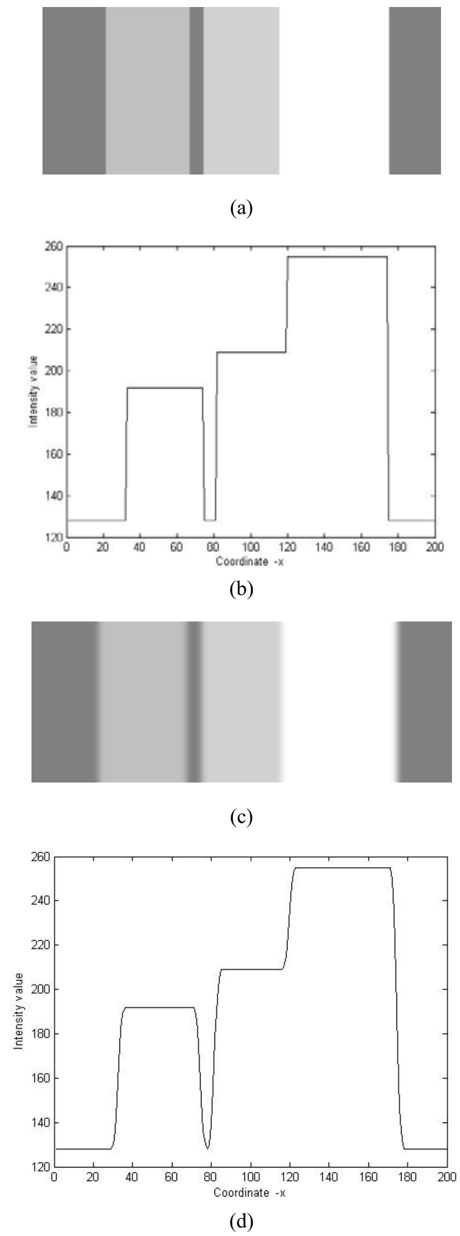


Figure 2. Example of blur edges. (a) The original, sharp image. (b) Horizontal profile of image (a). (c) The blur version of image (a). (d) Horizontal profile of image (c).

On the other hand, the degree of blur which is measured through thickness of object contours is made in the work by Elder and Zucker [4]. This is done by modeling focal blur by a Gaussian blur kernel and calculations of the response using the first and second derivative order of steerable

Gaussian basic filters [11]. Similar to first derivative of the Gaussian, the works by Zhang and Bergholm [12] defines a Gaussian different signature to measure the diffuseness of out-of-focus object in digital images.

B. *Blur Detection using Low Depth of Field (DoF.)*

This blur detection method is suitable for low DoF image, where center image containing focused object with out-of-focus background. An example of an image with low DoF is shown by Fig. 3. Object of interest (OOI) focusing, which is a photography technique by photographer, can be extracted through works by Kim [13] and Wang et. al [14]. As expected, these methods work on images with low DoF.

Other researches that detect the low DoF images using a low DoF indicator shown in works in [15]. The indicator is defined using the ratio of the center region's high frequency wavelet coefficient of the input image. This method is suitable to be used to extract focal image that is done intentionally by photographer for further refining process. However, implementation of only this method without integration of other methods such as edge based segmentation method often resulted in incomplete classification of interest object [16].

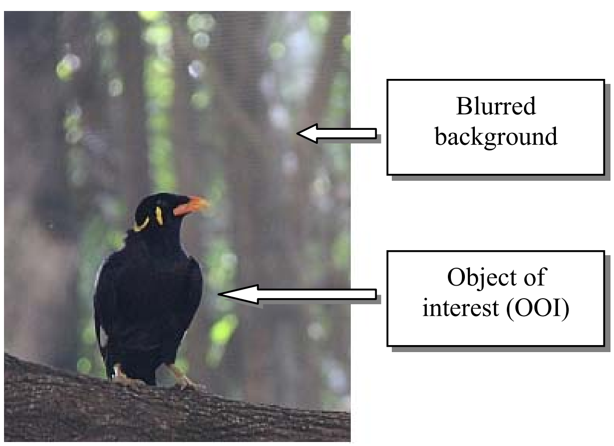


Figure 3. Example of image, with sharp object of interest (OOI) located at the centre of the image. The image contains out-of-focus background.

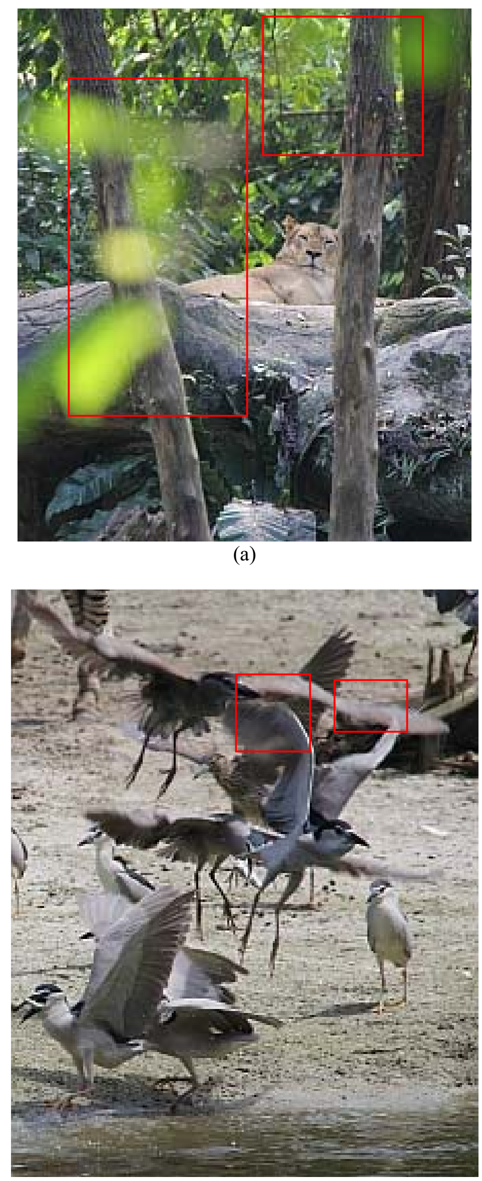
C. *Blur Detection using Blind Image De-Convolution*

Methods by Fergus et. al [17] and Jia [18] use blind de-convolution methods in their works. Estimation of the blur filter and latent un-blurred image is the main objective of these works. In the work by Kovacs and Sziranyi [19], un-blur regions are extracted out in order to distinguish them from blur regions.

In the proposed works in Bar et. al [20] and Levin [21], user interaction or blur kernel assumption is used to solve the partial blur issues. Example of image with partial blur problem is shown in Fig. 4. Estimation by user interaction is subject to the number of sample data being taken and the object data. Blind de-convolution works with satisfactory results with correctly estimated Point Spread Function (PSF) and kernel structures.

D. *Blur Detection using Bayes Discriminant Function*

In the works by Ko and Kim in 2009 [22], Bayes discriminant function is constructed based on the statistic of the gradients of the input image. Mean and standard deviation's statistic are taken for all blur and sharp regions. Blur image tends to have a smaller value of mean and standard deviation in the distribution compared with sharp image. By utilizing this concept, blur region in images can be detected for further de-blurring processes.



(a)

(b)

Figure 4. Example of images with partial blur problem (region bracketed by red rectangular frame).

E. Blur Detection using No Reference (NR) Block

Sometimes, in researches regarding to digital image processing, we need to measure the degree of blur introduced into the image after we applied certain type of processes. Therefore, blur degree can become one of the qualitative measures to evaluate the quality of an image. Therefore, the degree of blurring is important for researcher to evaluate the robustness and effectiveness a few of the image processing algorithms. If the measurement requires both the processed and the original sharp image, this measurement method is known as full-reference (FR) method.

No reference block based blur detection method does not require the original signal information which is more convenience in real scenario, compared with full-reference (FR) and reduced-reference (RR) block based. Image blur region is obtained via averaging the local blur of macro blocks in the images. Texture influence of the image is reduced via a content dependent weighting scheme. This method has lower complexity, higher robustness for variety of image contents compared with traditional edge based blur metrics [23].

F. Motion Blur Detection using Lowest Directional High Frequency Energy

The proposed direction estimation is based on measurement of lowest directional high frequency energy [24]. Motion blur detection based on lowest directional high frequency energy has less computational cost without usage of point spread function estimation. The main contribution of this paper is that a closed-form solution is derived. This method detect the blur motion blurred region by analyzing high frequency energy and estimate the motion direction of the image, making it more accurate and more robust compared with other learning-based methods [25].

The closed form solution that stated above is based on concept that high frequency energy decrease significantly along the motion direction in blurred image. Energy is regarded as sum of the squared derivative of image. The closed-form solution is developed based on this concept. This method has efficiently detect blurred regions without performing simultaneous algorithms of point spread function and de-blurring, which are advanced optimization normally used to restore motion blurred image. The advantages of this method over the stated advanced optimization method is that this method has less computational cost and still can detect blur region effectively.

G. Out-Of-Focus Blur Detection using Wavelet-Based Histogram and Support Vector Machine (SVM)

The main idea of algorithm of wavelet-based histogram and support vector machine is on discrimination of the gradient distributions between blurred and non-blurred image regions [26]. The proposed algorithm does not need the prior knowledge about the input image and is oriented to out-of-focus blur, unlike motion blur detection as described in section 2.6.

This algorithm works on feature extraction in wavelet space by applying wavelet decomposition of input image, calculating wavelet gradient map and construction of gradient histograms. Fig. 5 shows an example of gradient distribution of blurred and non-blurred images.

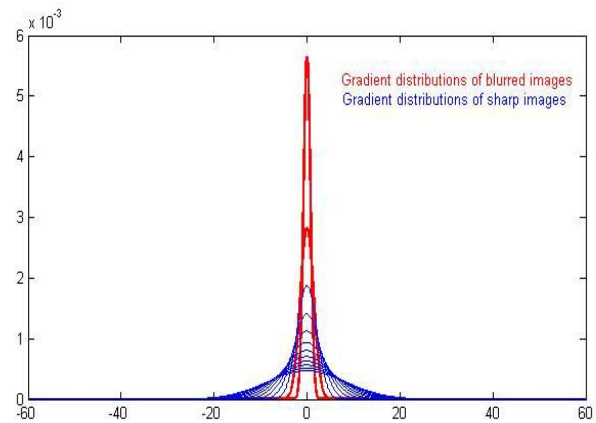


Figure 5. Example of gradient histograms of blurred and non-blurred images. The thick red lines are the areas where high probablility of gradient distribution of the blurred images being located, while thin and scaterred blue lines indicate the areas where high probability of gradient distribution for sharp images. (Modified from [26].)

Probabilistic SVM is used to apply on each patch of the gradient histogram to further analysis and generate a global probability map with SVM predicted probability value. Laplace distribution [27] has been used to model the wavelet gradient histogram and the kernel parameter of SVM is estimated by cross validation applied only to the training set. This proposed method has achieved its objective in detecting out-of-focus blur, which closely related to Gaussian blur.

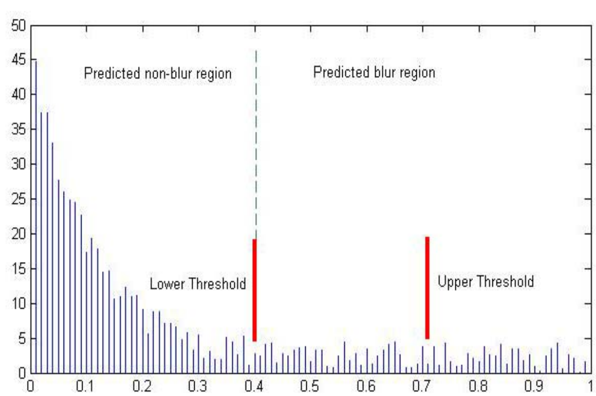


Figure 6. Example of histogram level of probabilistic SVM predicted value of image patches. X-axes:SVM predicted values of image patches, Y-axes: Distribution of SVM probability

TABLE I: TABULATION FOR ALL THE REVIEWED METHODS

Method	Application	Advantages	Disadvantages
Edge sharpness analysis [9][10][11][[12].	Blur extent measurement based on image intensity profile.	Lower computational cost and time.	Not effective for complex image.
Low depth of field (DOF) image segmentation [13][14][15][16].	Photography.	OOI (object of interest) able to be identified effectively.	Only effective for low DoF (Depth of field) image.
Blind image de-convolution [17][18][19][20][21].	Preliminary step for de-blurring process.	Potential blur region in image can be detected effectively.	User interaction is needed for correctly estimated PSF and kernel structure.
Bayes discriminant function method [22].	Preliminary step for de-blurring process.	Fast computation and effective blur identification.	Sampling of large database needed prior to detection.
Non-reference (NR) block [23].	Blur measure.	Lower complexity and does not need original signal information.	Not very effective for complex image.
Lowest directional high frequency energy (for motion blur) [24] [25].	Motion blur detection.	A robust closed form solution is derived for motion blur detection.	Only effective to motion blur image.
Wavelet-based histogram and Support Vector Machine (SVM) [26] [27].	Out of focus blur detection.	Effective and robust in detecting out of focus blur.	Only effective to out of focus image.

III. SUMMARY

This literature review can be summarized as given by Table I. From the review, we can observe that most of the methods deal with specific type of blur and cannot work efficiently if the input image contains complex feature. Therefore, there are still a lot of future works needed to be done in developing blur detection algorithms. Through variety of techniques and methods such as high-level image segmentation, object extraction, content-based image retrieval and image enhancements, many of the researches have provided foundation and improvement for solving many blur-oriented and region based computer vision area. Future researches will be done to develop more robust blur detection methods and also new approaches to have a more effective processing in terms of quality, computing time and cost.

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