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Moving objects segmentation and extraction based on motion blur features☆

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ABSTRACT

In order to restore the spatially-varying blur images whose background is sharp, it is necessary that the moving objects are segmented and extracted from the blur images. So this paper proposes a novel segmentation and extraction method based on motion blur features. Firstly, the blur features are extracted by using contourlet transform and considered as the prior information. Then an energy function is proposed for extracting the moving object from the original images. Moreover, considering that there exists some noise in segmented images, some morphological methods are introduced to remove the noise. The experimental results demonstrate the proposed scheme achieves high-quality segmentation performance and it outperforms the existing methods when used for moving objects segmentation.

1. Introduction

Relative motion between moving object and optical imaging systems may lead to motion blur. Most blind deconvolution algorithms focus on estimating shift-invariant point spread functions [1,2]. However, motion blur estimation remains an extremely challenging problem. It is not completely solved mainly because some blur may be spatially varying and thus cannot be represented by any global descriptor. The example in Fig. 1 shows the cars are blurring but its background images are all sharp. The entire image has no global point spread functions. In order to restore the motion blur objects, they have to be segmented and extracted from the original image.

Segmenting and extracting the moving object quickly and accurately from the background is a basic and key technology of image processing. Existing segmentation and extraction methods can be categorized into three major classes: pixel-based method, region-based method and energy-based method [3–5]. These methods usually generate over-segmentation or under-segmentation problem [6]. Moreover, for the moving object segmentation, the existing segmentation methods have no consideration for motion blur feature. In order to segment accurately, it is necessary to analyze motion blur features.

An approach based on optical flow gives a way to segment and extract the moving object within an image [7]. Schwarz et al. applied depth information of object to estimate the position of object [8]. This depth information is obtained by a Time Of Flight camera. Kim et al. propose motion detection method by combing the optical flow technique and random sample consensus under a free-moving camera [9]. Choi et al. propose visual object tracking method by combining optical flow and FIR filter [10] and Sengar et al. propose moving object area detection method by using normalized self adaptive optical flow [11]. Despite the success of existing optical flow methods, there are still some problems related object detection. For example, some methods do not perform well

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Fig. 1. The spatially-varying motion blur image: the moving objects are blurred and the background images are sharp.

with moving objects of small size; some need special type of camera.

Besides optical flow method, there are some other methods for moving object segmentation. Elder and Zucker [12] use a Gaussian model to generate a focal point spread function and compute the blur characters by using the differential operators, including the first order operator and the second order operator. Focal blur is analyzed and detected by contours of out-of-focus object. They only propose the estimation method of blur extent. But they cannot extract blurry regions from the blurred image. In addition, one method proposes an energy function after inferring the blur kernel so as to segment image into blur and sharp regions [13]. The method only processes severe blur and could do nothing about slight blur. The method in [14], proposed a partial blur analysis and detection framework for automatically classifying whether one image contains blurred regions. But the accuracy rate of the detection is only approximately 2/3. The method in [15], proposed by Chakrabarti and Zickler, proposed a prior model by analyzing the Fourier spectrum of natural images, and then segmented and extracted moving objects. However, due to the limitation of the Fourier transform, the segmentation results are very bad.

In this paper, a new segmentation and extraction method is proposed for the moving objects. Unlike the traditional segmentation methods, we use the contourlet transform for sub-band decomposition, which contributes to generating perfect prior information of the natural image. It has been proven that the contourlet transform is good at describing the image contour and the direction of the texture information. Furthermore, the morphological methods, including morphological erosion and morphological dilation, are all used in the extraction. The use of these methods improves segmentation effects.

The remaining sections of this paper are organized as follows. The model of motion blur is briefly reviewed in Section 2. The sub-band decomposition using contourlet transform is explained in Section 3. Segmentation and morphological method are introduced in Section 4. Experimental results are shown in Section 5 and finally Section 6 discusses conclusions and future research directions.

2. Motion blur model

Image motion blur can be modeled as:

$$g[x] = (h^{*}f)[x] + n[x] \quad x = (x_1, x_2) \in I \tag{1}$$

where $I \subset R^2$ is the support of the image, f and g respectively denote the ideal natural image and the observed motion blur image. h_x is the spatially varying blur point spread function at position x. n represents image noise, assumed to be Gaussian white noise, that is:

$$n[x] \sim N(0, \sigma_n^2) \tag{2}$$

The operation (*) in Eq. (1) represents 2-D convolution, given by

$$(h^{*}f)(x) = \sum_{s \in S} h(s) f(x - s) \tag{3}$$

where $S \subset R^2$ is the support of the PSF.

One of the major problems is the spatial variation of the point spread function. For spatially varying model, there are two common restoration methods at present. The one is that the image is divided into many blocks for making every image block approximate to space invariant model. The other is to convert the spatially varying blurring image into space-invariant blurring image. However, existing spatially-varying blur restoration methods have lots of deficiency. In recent years, a new restoration method is proposed by extracting the moving objects and then restoring it. How to segment and extract the moving object is a critical problem.

In order to segment and extract the moving object from the natural images, it is essential to acquire some moving objects features. Fortunately, recent study in natural features of motion blur image has shown that, although pixels of natural images vary greatly, the distribution of the image gradient obeys heavy tailed. That is, the image gradient distribution has a lot of small values and can approximately fit on a normal distribution. It is in conformity with the fact that natural images include a large number of gentle