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A new multifocus image fusion based on spectrum comparison

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ABSTRACT

In this paper, a spectrum comparison based multifocus image fusion algorithm is proposed. A distinctive feature of the proposed algorithm is that it constructs a global focus detection algorithm, which makes it get free of block artifacts and reduces the loss of contrast in the fused image. In this algorithm, source images are first transformed into Fourier space, in which we adopt the Bayesian prediction algorithm to smooth the log spectrum of each source image. By comparing the difference between the original log spectrum and its smoothed version, we can get the saliency region of each source image. Then image segmentation based on Sobel operator is employed to identify the smooth regions that may be affected by edges or textures, finally a sigmoid function is utilized to map the saliency comparison results to focus detection results in which affected smooth regions are treated in a different way. Experimental results demonstrate the superiority of the proposed method in terms of subjective and objective evaluation.

1. Introduction

Due to the limited depth of field of lens, the existing cameras can hardly get a picture in which all the objects are explicit, especially when the objects differ largely with each other in terms of their distances from the camera [1,2]. Such phenomenon may affect human observation or further computer processing. One method that might be useful to address this problem is to extend the depth of focus. In [3], the authors proposed a method to extend the depth of focus for a particle field using a single-shot digital hologram. Another alternative is multifocus image fusion [4]. With the technology, we need to capture multiple images from the same scene with different focal distances first, then explicit parts from source images are abstracted and injected into one image. It has been proven valuable in many applications such as biomedical imaging and camera manufacturing [5,6]. Until now, many image fusion algorithms have been invented. According to the fields in which visual information is combined, the existing algorithms can be roughly grouped into two catalogs: transformed field based and spatial field based procedures.

The former ones refer to such algorithms: source images are transformed to other fields from spatial field, then coefficients are combined by comparing the saliency map in transformed field, and finally fused coefficients are transformed back to spatial field. Such algorithms include Pyramid transforms [7,8], Discrete Wavelet Transform (DWT) [9–11], Shift-Invariant version of DWT (SIDWT) [12], and Complex Wavelet Transform (CWT) [13–15]. In recent years, some sophisticated image transformation methods have been designed, such as Curvelet transform [16–18] and

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subsampled/nonsubsampled Contourlet transform [19–21], to get more directional information. More recently, some data driven image decomposition methods are invented: Looney proposed a fusion algorithm based on complex extensions of empirical mode decomposition [22]. Sharma et al. proposed a hybrid fusion scheme combining self-fractional Fourier function decomposition and multivariate empirical mode decomposition [23]. Meanwhile, the theory of compressive sensing is brought into image fusion. Liu et al. proposed a multimodal medical image fusion based on compressive sensing [24]. In [25], the authors proposed a new fusion approach for low spatial resolution multi-spectral and the high spatial resolution Panchromatic (Pan) image. The theory has also been used in visible/infrared image fusion [26,27]. Liu et al. presented a general image fusion framework by combining multi-scale transform and sparse representation [28]. The underlying goal of this kind of algorithms is to decompose source images into several layers with different frequency components. Such operation makes it possible to build individualized fusion rules for different frequency components. Generally, the fusion rule for low-frequency layers is the averaging method, while the one for high-frequency layers is maximum absolute value selection. Nevertheless, it is necessary to be aware of the limitations of these methods. Nearly all of them are time-consuming, which makes it difficult to be incorporated into digital cameras. In addition, these algorithms tend to reduce the contrast of fused images.

The other catalog of algorithms fuse visual information in spatial field, and they rely on focus detection measures. Namely, focus detection is a key point [2]. The basic assumption of the multifocus image fusion is that focused objects seem sharper than the defocused objects, and the sharpness is linked to some easily computed measures [29]. Until now, a variety of measures have been developed, such as Spatial Frequency (SF) [1,30], sum-modified-Laplacian

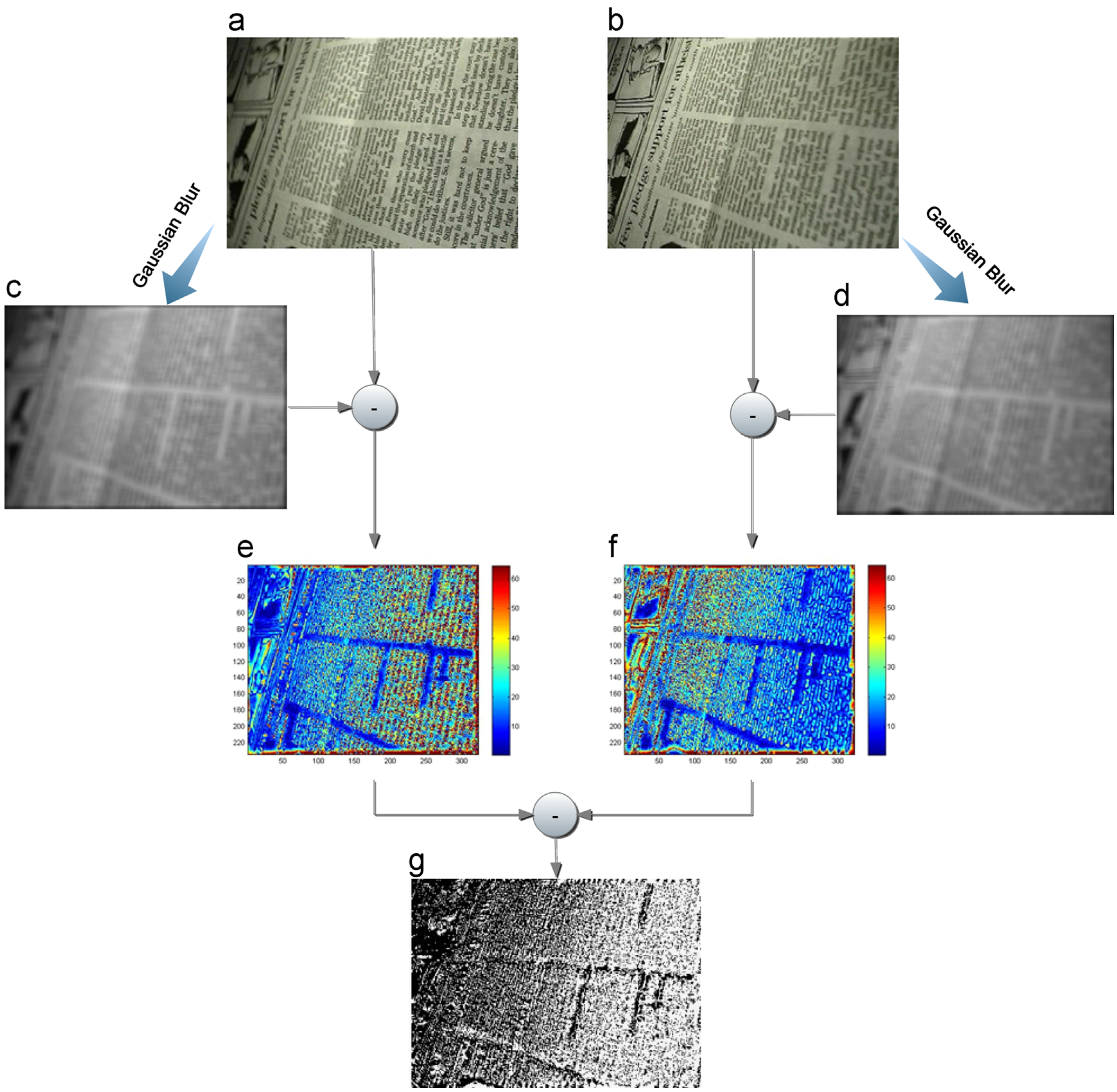

Fig. 1. “Newspaper” image set: (a) source image A; (b) source image B; (c) blurred image $\overline{A}$; (b) blurred image $\overline{B}$; (e) error image between image A and $\overline{A}$; (f) error image between B and $\overline{B}$; (g) focus detection map.