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An automatic image fusion algorithm for unregistered multiply multi-focus images

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ABSTRACT

The multi-focus image fusion technique provides a promising way to extend the depth of defocused images by combining multiple images with diverse focuses into a single focused one. In this paper, we present a robust and automated algorithm for the fusion of unregistered multiply multi-focus images. The motivation of our method lies in the fact that the source images are assumed to be perfectly aligned in the majority of previous research. Actually, the assumption is difficult to achieve in many practical situations. Hence, image registration method for multi-focus images is talked in this paper. We choose a multi-focus image as reference one in the image registration process by entropy theory. Speeded Up Robust Features (SURF) feature detector with Binary Robust Invariant Scalable Keypoints (BRISK) feature descriptor is used in the feature matching process. An improved RANdom Sample Consensus (RANSAC) algorithm is adopted to reject incorrect matches. The registered images are fused using stationary wavelet transform (SWT) with sym5 wavelet basis. The experimental results prove that the proposed algorithm achieves better performance for unregistered multiply multi-focus images, and it is especially robust to scale and rotation translation compared with traditional direct fusion method.

1. Introduction

Multi-focus image fusion has emerged as a major topic in computer vision and image processing community since the optical lenses have a limiting focus range [1]. When imaging an object that is thicker than the depth of focus (DOF) of a camera, it is impossible to capture an image of all relevant objects in focus. Multi-focus image fusion provides a promising way to extend the depth of defocused images by combining multiple images with diverse focuses into a single focused one. Nowadays, multi-focus image fusion technique has been widely used in machine vision, targeting, object recognition, medical imaging and military affairs [2]. In the past decade, a number of multi-focus image fusion techniques have been proposed to improve the fusion result [3–8], such as wavelet transform (WT) based algorithm [4,9], shearlets based method [10], Independent Component Analysis (ICA) based algorithm [11], Principal Component Analysis (PCA) based algorithm [12], pulse coupled neural network (PCNN) based algorithm [13], pixel based method [14], and so on. However, in the majority of previous image fusion research, the source images are assumed to be perfectly aligned. Actually, this is difficult to achieve in many practical situations. For example, mechanical imperfections of the microscope or stereomicroscope may introduce systematic progressive displacement in the process of focus adjustment. As shown in Fig. 1, we assume that the object and the image in a different side of the lens. According to the Gaussian imaging formula [15] shown in Eq. (1), when the object distance change, the image distance will change in the opposite tendency. Further, the magnification β in Eq. (2) will change with the variation of object distance u and image distance v. In addition, if we capture a sequence of pictures without use the tripod, we will get a sequence of images with rotation and displacement. Hence, the fusion algorithm should be reliable and robust to imperfections such as misregistration [7], and the "perfect" fused image should contain the salient information from each source image, without introducing artifacts [16].

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \tag{1}$$

$$\beta=\frac{v}{u} \tag{2}$$

There are few literatures to discuss the fusion methods for multifous images with translation and magnification change. Ishita and Bhabatosh [17] presented a fusion method using a morphology based focus measure in a quad-tree structure to against pixel misregistration. Zhang et al. [18] proposed an algorithm based on filtering in frequency domain and synthesis in space domain,

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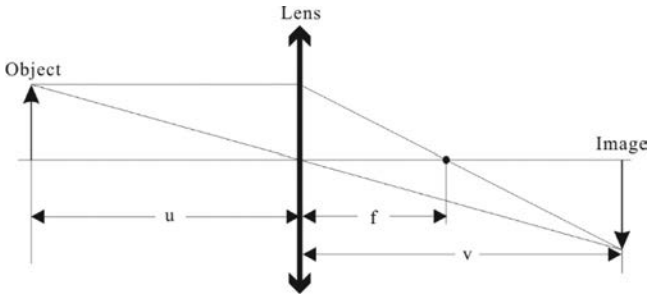

Fig. 1. The principle of lens imaging.

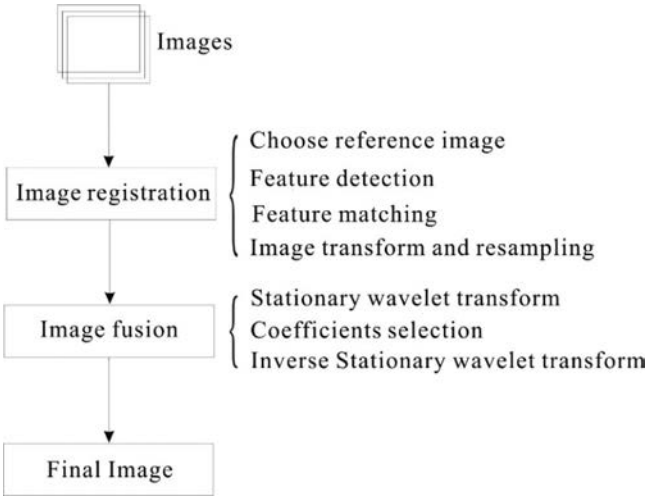

Fig. 2. The flow chart of proposed algorithm.

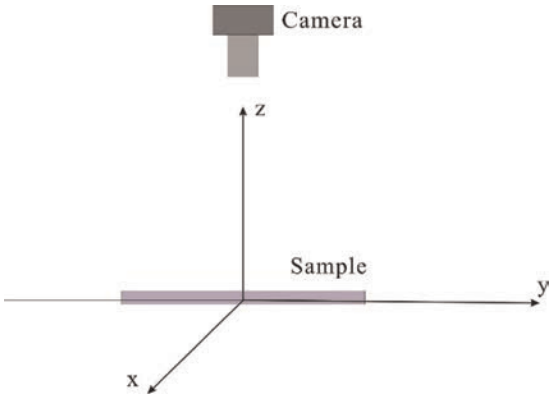

Fig. 3. The coordinates system of focus region adjusting.

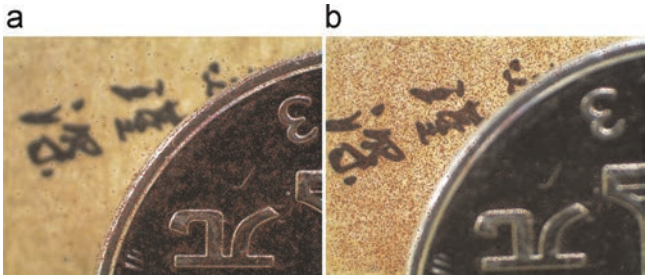

Fig. 4. SURF feature detection result for a pair of multi focus images: (a) image focused on the coin and (b) image focused on the book.

which is insensitive to two pixels misregistration. If we do not fix camera by a tripod or others devices, the captured images may have relative translation, scale, rotation and other geometric

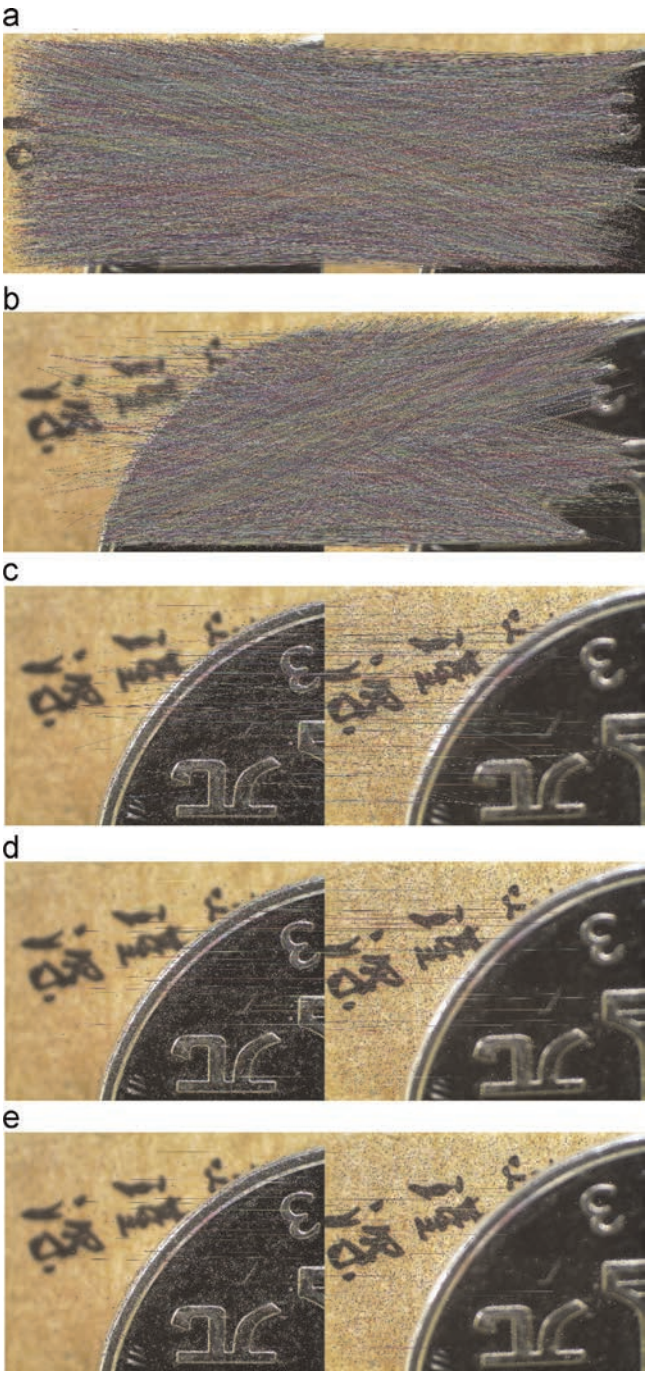

Fig. 5. Image matching process of SURF feature detector and BRISK feature descriptor: (a) image matching result by hamming distance; (b) image matching result by *k*-NN algorithm; (c) image matching result by ratio test; (d) image matching result by symmetrical test and (e) final image matching result by RANSAC algorithm.

transformations. Hence, the fusion results of images with large offset by above fusion schemes will cause artifacts. Zhang and Blum [19] described an edge based registration approach for multi-focus image fusion. However, it only solves the registration problem of two images, and cannot settle the registration matter of multiple images. Image registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, or by different sensors [20]. Hence, image registration can be embedded into multi-focus image fusion algorithm.