A Stereo Micro Image Fusion Algorithm Based on Expectation-Maximization Technique

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Abstract. Due to the limitation of Depth Of Field (DOF) of microscope, the regions which are not within the DOF will be blurring after imaging. Thus for micro image fusion, the most important step is to identify the blurring regions within each micro image, so as to remove their undesirable impacts on the fused image. In this paper, a fusion algorithm based on an Expectation-Maximization (EM) technique is proposed for stereo micro image fusion. The local sharpness of stereo micro image is judged by EM technique, and then the sharpness regions are clustered completely. Finally, the stereo micro images are fused with pixel-wise fusion rules. The experimental results show that the proposed algorithm benefits from the novel region segmentation and it is able to obtain fused stereo micro image with higher sharpness compared with some popular image fusion method.

Keywords: Stereo Microscope, Image Processing, Image Fusion, Expectation-Maximization technique.

1 Introduction

With the development of digital signal processing, micro-images have widely been used in many applications such as materials, metallurgy, pharmacy, biology, chemistry, food, and so on[1]. But, the Depth of Field (DOF) of microscope is limited, and as a result, only the regions which are close to the focal plane can be seen clearly, while the other regions may be blurring. In order to obtain clear image, image fusion processing must be taken [2, 3]. Some image fusion techniques had been proposed and mainly used to make micro-image more informative or try to provide convenience for human in observing the stereo micro images.

Image fusion algorithms mainly include multi-resolution analysis [4, 5], wavelet transform [6-8] and other improved algorithms, which have their respective advantages and disadvantages for different specific images. For common images, traditional image fusion algorithms can be used to meet the requirements, but the micro image fusion for a particular task may require complementary fusion technique. For an efficient micro image fusion technique, the fused micro image is required not only to have the local contrast and global contrast, but also well combine the edge and contour information of source micro-images, so as to improve the details of micro image and its visual

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effect [6]. Burt presented a combined algorithm with an averaging and choosing in low-frequency components [7], Nevertheless, in Burt's algorithm a fixed threshold is used, which is not good enough to be relative to the uncertainty of image. In order to overcome this disadvantage, a wavelet transform based image fusion algorithm was presented in Ref. [8]. After wavelet transforming of multi-focused images, the matching degree of images is computed as an adaptive threshold to decide whether the maximum selection or weighted average to be used. But this algorithm still cannot get better fusion results for texture regions in micro images.

This paper presents an EM (Expectation-Maximization) technique according to the features of the stereo micro image, and a new stereo micro image fusion algorithm is further proposed. The EM technique used for blurring region identification and the corresponding fusion algorithm for micro image are presented in Section 2. The experimental results in Section 3 show the effectiveness of the proposed algorithm, and a conclusion is given in Section 4.

2 The Proposed Stereo Micro Image Fusion Algorithm

For the stereo micro image fusion, the most important step is to identify the blurring regions within the monocular micro-image and to correspond exactly to the information of the binocular micro images, so as to remove their undesirable impacts on the fused image. The basic idea of the proposed stereo micro image fusion algorithm is to judge the local sharpness of micro-image by EM technique [9, 10], then the feature points are detected by the SIFT (Scale Invariant Feature Transform) [11, 12], and the feature matching is taken. Finally, the binocular micro images are fused with fusion rules. Fig. 1 shows the diagram of the stereo micro image fusion algorithm based on the EM technique.

2.1 The EM Clustering Based on the Definition Feature Values

To further provide a quantitative measurement on how blurring the image is, the key issue in this work is how to formulate the probability density function of the feature values distribution. The information of the definition feature values has been gained based on the TenenGrad function. The statistical model of the down-sampling image was shown in Fig. 2.

Fig. 2(a) is the monocular stereo micro image of papaya fruit. Fig. 2(b) is the statistical model of the definition feature values information. The definition information was gained by normalized feature values and count frequency within the range of these feature values. In view of the above fact, the distribution is proposed to be modeled using the following two-component Laplacian mixture model.

$$p(w)=\frac{\alpha}{\sigma_1\sqrt{2}}e^{-\sqrt{2}|w|/\sigma_1}+\frac{1-\alpha}{\sigma_2\sqrt{2}}e^{-\sqrt{2}|w|/\sigma_2} \tag{1}$$

where α is a mixing coefficient, each component yields a Laplacian distribution with a zero mean and standard deviations σ_1 and σ_2, respectively; and furthermore, σ_2 is assumed to be larger than σ_1.

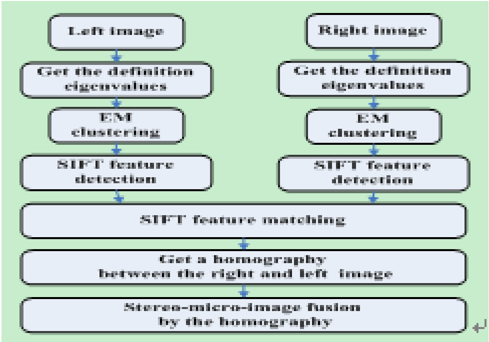


Fig. 1. The diagram of the stereo micro image fusion algorithm based on the EM technique

(a) The monocular stereo micro image of papaya fruit (b) The statistical model

Fig. 2. The statistical model based on the stereo source micro image feature information

To evaluate the local information of input micro images, the proposed Laplacian mixture model is proposed to be locally adaptive; that is α, σ_1 and σ_2 in (1) are locally adaptive for each feature values (denoted as $w(k)$) to be $\alpha(k)$, $\sigma_1(k)$ and $\sigma_2(k)$. The EM technique [9] is exploited to conduct the maximum-likelihood estimation of these parameters iteratively, as follows. In each iteration, the estimation process is updated via two steps [10]: expectation step and maximization step, which are iterated until the convergence is reached.

2.2 Feature Point Detection and Matching by SIFT

The SIFT has the following steps in feature point detection [11]:

Step 1: The Gaussian kernel is build for the image scale space transform. The image scale space is denoted by $L(x, y, \sigma)$, which is gained by convoluting between the variable metric Gaussian function $G(x, y, \sigma)$ and the source image $I(x, y)$. In order to detect the stable key feature point in the scale space, this paper introduces the Difference of Gaussian function $D(x, y, \sigma)$. The relationship between them as shown in Equation (7):

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y) \qquad G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$$
$$D(x,y,\sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) = L(x,y,k\sigma) - L(x,y,\sigma) \qquad (7)$$

Step 2: The local key points are posited precisely. Once the extreme points are detected, the following is to refine the feature points and to find extreme points in the image Gaussian pyramid each layer of the difference image.

Step 3: The directions are allocated based on the precise positioning of the local key points. This indicator can reflect the rigid rotation of the SIFT descriptor.

Step 4: A description symbol is set for each local key point, and the 128 dimensional SIFT feature vectors are represented for each key point. These mean that the description symbol can not be impacted by deformed geometry or other factors such as the size changes.

Step 5: The Euclidean distance is calculated in the local key points of the binocular micro images. The distance used to characterize the similarity evaluation criteria among the key points. If the ratio of the adjacent distance values is lower than a certain threshold, then they are a pair of matched key points.

2.3 Stereo Micro Image Fusion

The x point of the image demand for fusion according to the homographic matrix is mapped to the point x' of the reference image, which has four adjacent points x_1, x_2, x_3, x_4. The most accurate point can determine by the similarity function. If the best matching point is x_4, then the pixel value of x_4 assigns to the point x of the image demand for fusion, as shown in Fig. 3. The equation is the similarity function.

$$D(p,q) = \exp(-\frac{\Delta g_{pq}}{\sigma}) \tag{11}$$

where p and q are the pixels position, respectively. Δg_{pq} presents the differ of Euclidean distance between p and q. $D(p,q)$ means that the definition of similarity with the visual aggregation principle defined in the Gestalt psychology. σ is a constant and is closely related to the resolution of the image.

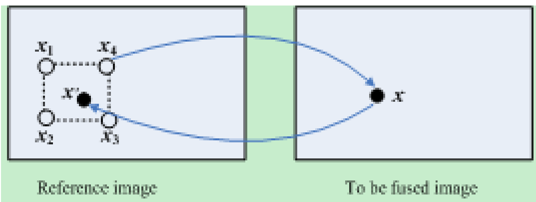
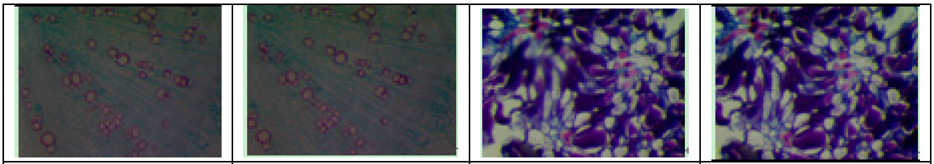


Fig. 3. The diagram of stereo micro-image fusion based on the homographic

3 Experimental Results and Discussions

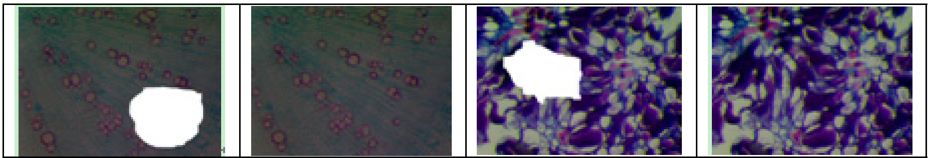
In order to evaluate performance of proposed stereo micro image fusion method, the images of “Carrot Root” and “Papaya Fruit” with 1024×768 pixels are taken as the tested stereo micro images shown in Fig. 4. They are showed that each of left images has some blurring regions. Figs. 4(a) are binocular micro images of Carrot Root, Figs. 4(b) are binocular micro images of Papaya Fruit. It is seen that the binocular micro images are related closely with each other.



Left Image	Right Image	Left Image	Right Image
(a) Carrot Root		(b) Papaya Fruit	

Fig. 4. The test stereo micro images

The proposed EM technology method is presented for identifying blurring regions within a micro image. In the experiments, the blurring region in micro image is identified by using TenenGrad evaluation function with block size of 129×129 or 127×127, then, the sharpness regions are clustered completely. Finally, the stereo micro images are fused with pixel-wise fusion rules. The results were shown in fig. 5.



clustered image of the left image	fusion image of the left image	clustered image of the left image	fusion image of the left image
(a) Carrot Root		(b) Papaya Fruit	

Fig. 5. The experimental results of the stereo micro image fusion algorithm

Figs. 5 are the clustered results obtained by the EM technology and the fusion image of the left image by the stereo micro image fusion algorithm. It is seen that the sharpness of the fused images obtained with the proposed algorithm is higher than that to be fused images. The high quality benefits from relatively more accurate region segmentation achieved by the EM clustering based blurring region identification. Except the visual analysis of these fused images, Table 1 gives some objective evaluation results of the fusion micro images and the source micro images. For these indicators, the larger the values are, the clearer the micro-image is.

Table 1 gives the objective sharpness evaluation results with respect to the source images and fused images obtained with the stereo micro image fusion algorithm. It is clear that whether evaluating with spatial domain or frequency domain the fusion micro images show its superiority compared with the source micro images.

Table 1. The objective evaluation results of the information and clarity comparative experiments

Indicator		Variance	TenenGrad	SobelGrad	Hadamard	DCT
Carrot Root	To be fused of the left image	3.7399	1.8438	1.1328	1.3447	6.1017
	fusion image of the left image	3.8852	2.0137	1.2263	1.3819	6.2935
Papaya Fruit	To be fused of the left image	1.1978	1.1153	2.5544	3.1471	1.2345
	fusion image of the left image	1.2274	1.2025	2.6625	3.3601	1.3425

4 Conclusion

The captured micro images may have clear regions as well as blurring regions due to the depth of field limit, which significantly decrease the image quality. Image fusion is helpful to solve this problem. In this paper, a fusion algorithm based on the EM technology is proposed for stereo micro image. With the help of EM technology, the blurring regions in monocular micro image can be accurately clustered, so that the blurring regions will be excluded in the fusion. The proposed algorithm is able to retrieve the details existing in the binocular micro images and fuse them as an image with high sharpness. Experimental results show the effectiveness of the proposed algorithm. Future works may focus on more effective fusion rules so as to improve the performance of fusion greatly in stereo micro image.

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