

Image Mosaic Algorithm and Its Application to the Microimage of Grass Seeds

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Abstract. This paper presents an image mosaic algorithm and its application to the microimage of grass seeds. The following main steps are involved, firstly in the registration stage, the scale invariant feature transform (SIFT) is employed to obtain initial matches. Then the Random Sample Consensus (RANSAC) is used to remove incorrect matches effectively. Finally in the fusion stage, fade-in and fade-out method is applied to smooth seams which exist in the stitched image. Since the effect is not obvious, the adaptive Gamma correction method is used to weaken illumination effect on image quality to obtain a stitched image, which contains more information than each of the original images. Experimental results demonstrate that the proposed approach achieves good performance for grass seeds microimage mosaic in both subjective and objective evaluations.

Introduction

Nowadays, image mosaic using automatic image registration and fusion technique has become increasingly attractive in computer vision [1]. It is a mechanism through which intelligent matching calculation and spatial matching alignment algorithm, combining a group of mutually associated image sequentially to form an image which contains all information of the image sequence and high-resolution [2].

Among the existing image mosaic methods, the Scale Invariant Feature Transform (SIFT) algorithm based on multi-scale space theory is widely used, because the SIFT features can effectively maintain invariance to the rotation, scaling and even affine transformation; moreover, maintain a certain degree of stability and adaptability [3, 4]. SIFT algorithm was originally proposed in 1999 by David G. Low, and further improved in 2004 by the same author [4]. The main purpose of SIFT is to extract distinctive invariant features from images between different views of an object or scene. Mikolajczyk pointed out SIFT is the robustness and the distinctive character after evaluating and comparing the various widely used detectors and local descriptors [5]. Generally, the initial matching always contains some incorrect matches. Fischler and Bolles presented a simple and highly robust method named Random Sample Consensus (RANSAC) to remove incorrect matches [6]. Compared to other methods, RANSAC has been proven to be remarkable by experimental evaluation [7]. In this paper, RANSAC algorithm was used to eliminate the false matches. In the fusion stage, fade-in and fade-out method is applied to smooth seams which exist in the stitched image, but the effect is not obvious, so the adaptive Gamma correction method is used to weaken illumination effect on image quality. Finally, a stitched image is obtained, which contains more information than each of the original images.

The rest of the paper is organized as follows. Section 2 presents the method of image mosaic. Experiment results and discussions are conducted in Section 3. Finally, conclusions are highlighted in Section 4.

Image Mosaic Algorithm

SIFT Feature Extraction. In order to generate the SIFT feature, generally, SIFT feature extraction can be divided into the following four steps:

Scale Space Extreme Detection. In this step, the scale space of an image is defined as a function, $L(x, y, \sigma)$, which is got from the convolution of a variable-scale Gaussian and an input image $I(x, y)$. By using the difference-of-Gaussian (DOG) function in all scales and image locations, it can efficiently identify potential interest point invariant to scale and orientation. DOG function is computed from the difference of two nearby scales separated, as shown below:

$$\begin{aligned} D(x, y, \sigma) &= (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y) \\ &= L(x, y, k\sigma) - L(x, y, \sigma) \end{aligned} \quad (1)$$

$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$ is the Gauss kernel function, which is proven to be the only linear kernel function. Where $*$ is the convolution operator, σ is the scale-space factor, k is the multiplicative factor.

Key Point Localization. In this step, by using a detailed model, we can determine location and scale of each candidate points, and then select key points based on measures of their stability. To ensure that the local extreme can be detected both in DOG space and two-dimensional space of image, each point of scale space should be compared with a total of 26 points, including its eight neighbors in its own area and nine neighbors in the up-area and down-area. It will be considered as the extreme point only when it is maximum or minimum. Among the candidate extreme points detected in scale space, there are a lot of low-contrast edge points and unstable response points. These points need to be filtered to obtain accurate positioning as a key point of the extreme points.

The Amplitude and Direction of Key Points. This step aims to assign a consistent orientation to the key points based on local image properties. Firstly, the gradient magnitude $m(x, y)$ and orientation $\theta(x, y)$ of each key point should be calculated depending on the distribution of the gradient magnitude on the pixels surrounding by extreme points. The gradient magnitude and orientation can be calculated:

$$\begin{aligned} m(x, y) &= \sqrt{(L(x+1, y) - L(x-1, y))^2 + (L(x, y+1) - L(x, y-1))^2} \\ \theta(x, y) &= \tan^{-1} ((L(x, y+1) - L(x, y-1)) / (L(x+1, y) - L(x-1, y))) \end{aligned} \quad (2)$$

Where L is the scale of each keypoint. Secondly, an orientation histogram is formed from gradient orientations of sample points. At last, peaks in the orientation histogram correspond to dominant directions of local gradients. The highest peak in the histogram is detected, that's as the feature point's orientation. In the gradient orientation histogram, when there is another equivalent to 80% of the energy of the peak, it will be the feature point's auxiliary orientation. A feature point may be specified with multiple orientations (a principal orientation, more than one auxiliary orientation). This can enhance the robustness of the matching.

Descriptor of SIFT features. After an image location, scale and orientation have been assigned to each key point, the next step is to compute a descriptor for the local image region [8]. Firstly, rotate the coordinate to the orientation of the feature point in order to insure the rotation invariant. Secondly, to describe the feature points, its adjacent region of 8×8 pixels are usually proposed. This region could be evenly divided into four 4×4 sub-regions. After calculating the gradient histogram of 8 directions for each sub-region and make the vectors of 8 directions for each point in an orderly sort, thus a feature vector of $4 \times 4 \times 8$ equal to 128-dimensions is constituted.

Feature matching. When the SIFT feature vectors of two images have been generated, the best candidate match for each key point in the reference image is obtained by identifying its first nearest neighbor and second nearest neighbor with Euclidean distance in all the descriptors of sensed image. If the distance between key point and its first nearest neighbor is $d1$ and the value between key point and its second nearest neighbor is $d2$, the ratio between $d1$ and $d2$ is less than r , the key point with first nearest neighbor is considered as the best match point. After the above steps, the

initial one-to-one matching between key points of the reference image and the sensed image is obtained, that is, $Q = \{q_i\}$ and $Q' = \{q_i'\}$, $i=1, 2, \dots, N$ (where q_i matches q_i') [1].

Removing Incorrect Matches. If some incorrect correspondences occur, this might lead to wrong results. Random Sample Consensus (RANSAC) algorithm is used to purifying the matching set, while catching the optimal perspective transformation matrix H . The RANSAC algorithm has the following steps [8]:

Strike a maximum sampling frequency N based on probability, repeat sampling N times randomly;

Select four pairs of matching points randomly, in which any of three are not collinear, then calculate the transformation matrix H ;

Calculate the distance between each matching point after they have been transformed to the corresponding matching point;

Calculate the number of inner points whose distance is less than the threshold value, screen interior point out from dataset which contains many outer points and correctly estimate model parameters;

Compute the optimal perspective transformation matrix H by using the matching points which have eliminated false matches.

Image Fusion

Using the above stages to realize image mosaic, the stitched image has obvious seams in overlap region, for we ignored the difference of illumination. The fade-in and fade-out method is used in this paper. This method is based on the weighting method, and its weight is determined by the distance from the pixels to the border of the overlap region [7].

$$I = \frac{d_1}{d_1 + d_2} I_1 + \frac{d_2}{d_1 + d_2} I_2 \quad (3)$$

Where d_1 is the distance between the pixel to the left margin, d_2 is the distance of the pixel to the right margin. I , I_1 and I_2 is the pixel of point in the image. From right to left in the overlap region, the percent of I_1 grades from 0 to 1, and I_2 grades from 1 to 0, as to transition smoothly in the overlap region, but the effect is not obvious. So the adaptive Gamma correction method is proposed to weaken illumination effect on image quality. A complete stitched image can be attained by the above steps.

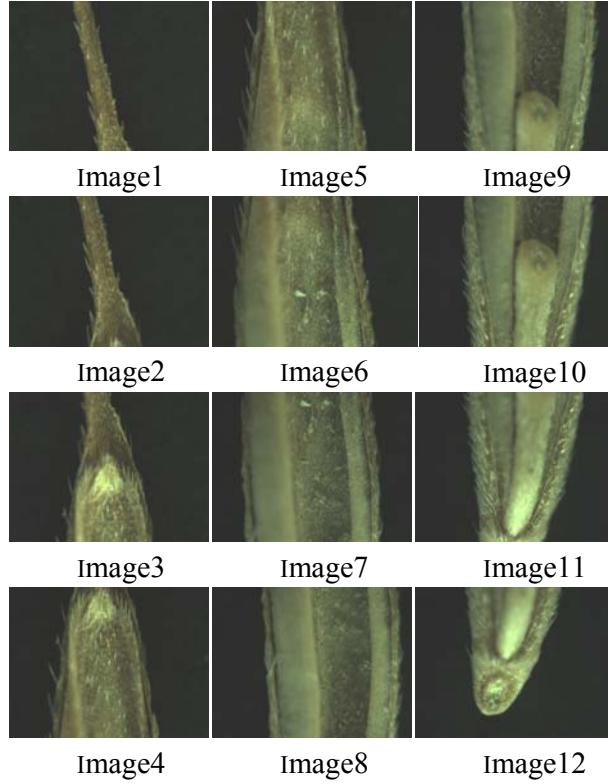
Experimental Results

Morphological characteristic is one of the important factors of grass seed variety recognition. However, in grass seed recognition experiments, it is difficult to acquire high resolution images of both details and overall appearance of the grass seed due to the limitations of microscope and the unsmooth specimen surface at the same time [9]. The purpose of writing this article is to solve this problem.

The images used in this paper are grass seed data recorded by the microscope and CCD camera. 12 images are established as Image sequence, and the images are coded with the figures, such as Image 1, Image 2, etc. Here are some examples with uniform size of 512×384 are shown in Fig.1. The image (a) is an overall image captured by a common digital camera with a macro lens whose resolution of the local details is often insufficient. The local microscope image sequence (b) show detailed different sections of a seed. It is clear that there is an overlap field between the two images, which is crucial to feature matching based on SIFT, and can used as images similarity to exact feature points. If we integrate information from the image sequence into a resultant image, it will improve the efficiency and facilitate the work for experts who want to identify the grass seed.



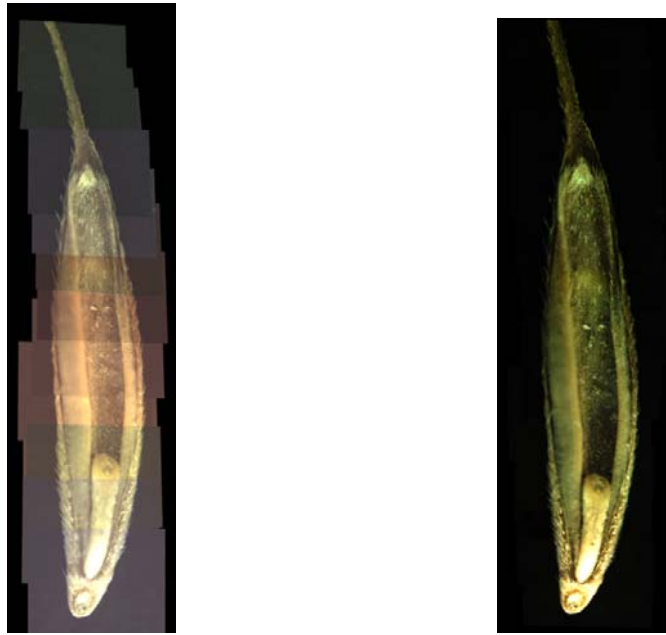
(a) Original overall image



(b) Original seed image sequence

Figure1. Original seed images (*Elymus nutans* Griseh)

Image should be pre-processed before the feature matching, this is important for different pictures with different focus and brightness. After image fusion stage, experiments show that the seams in the image still exist. In response to this problem, an adaptive Gamma correction method [10] is applied to weaken illumination effect on image quality in this paper. Firstly, a mapping between pixel values and Gamma values is built. The Gamma values are then revised using two non-linear functions to prevent image distortion. Finally, pixels are corrected adaptively using the readjusted Gamma values. The panorama grass seed image after stitched is shown in Fig.2. The obvious seams that are smoothed by Gamma correction method from Fig.2 (a) and (b) can be found.



(a) Without Gamma correction

(b) With Gamma correction

Figure2. The panorama grass seed image. Note that large changes in brightness between the images are visible if Gamma correction is not applied (a). These can be effectively smoothed out using Gamma correction (b).

Conclusion

In this paper, we investigate image mosaic algorithms and its application in integration of grass seed microimages. The SIFT algorithm is employed to extract feature points, define descriptors and obtain initial matches, but some incorrect matches greatly affect the registration accuracy. Therefore, in consideration of the specific characteristics of the grass seed image, the RANSAC algorithm is employed to remove incorrect matches effectively. The refined registration result is obtained through adjusting the registered image on the reference image in the neighborhood of the overlapping region with tiny steps. Image fusion based on the fade-in and fade-out method is used to smooth seams of the stitched image, but the effect is not obvious, so the adaptive Gamma correction method is used to weaken illumination effect on image quality. Finally, we obtain a complete stitched image which contains more information.

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