Stamen movement detection of Commelina purpurea based on feature matching

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Abstract. The stamen movement is very important to reproduction of plant. This paper presents a feature-matching-based method to detect stamen movement of Commelina Purpurea using image processing. The regions of stamen were firstly extracted by image segmentation using thresholding. Then, the area discrimination factor of each stamen region was calculated to judge whether these stamens were adhered or not, if such adhesion did exist, the adhered stamens were segmented by watershed algorithm. After that, feature detection and matching were carried out between two adjacent frames in the image sequence in order. Then, the slope and distance statistics between the matching feature points are made to further optimize the matching results and figure out the matching relation of different stamens in the two frames. Finally, through the matching result of different stamens in consecutive frame images, the moving trajectory of the stamens was obtained. The empirical results show that, this method can accurately segment the adhered stamens and acquire stamen trajectory of Commelina Purpurea.

1. Introduction
As a matter of fact, a variety of active movements occur in the pistils and stamens of plants, which is significantly important to pollination[1]. Stamen movement can directly affect sexual reproduction by changing the spatial location of anthers or the frequency and accuracy of pollinators’ contact with pollen, and adjust the timing and process of pollinating[2]. Those stamens in different spatial positions formed by stamen movement improve the potential for attracting and adapting to various floral visitors, which could possibly affect the types and behaviors of floral visitors, thereby adapting to multiple types of pollinators[3].

The stamen movements of many plants have been observed and studied by some researchers at home and abroad, such as Rutas graveolens[3], Cornus canadensis [4], Chimonanthus praecox [5], and Parnassia wightiana[6]. However, the above-mentioned stamen movements are directly observed by visual, or recorded based on observing of dynamic images.

Nowadays, the technology of moving target tracking is under rapid development, which contains classic tracking algorithms like feature matching[7], algorithms based on kernelized correlation filter such as KCF[8], and deep learning based algorithms like ECO[9]. These algorithms have been widely used in the movement detection of pedestrians, vehicles or animals. However, the application of movement detection in vegetation movement, especially stamen movement is rarely seen. As a matter of fact, these techniques can be used for automatic detection of stamen movement to obtain more
convenient and accurate data, so as to provide more basis for correct understanding of the adaptive significance of stamen movement. In this paper, the feature matching method was applied to acquire the stamen moving trajectory of Commelina Purpurea.

2. Process
The original images in the image sequence were converted into HSV component images firstly, and the regions of stamens were extracted by image segmentation using thresholding of the V component image. Then the stamen pixel area was used to judge if the stamens were adhered or not. If the adhesion did exist, the watershed algorithm was applied for doing segmentation to these adhered stamens. After that, feature points were detected and matched between two adjacent frames of the stamen image sequence in order. Then the matching relation of various stamens in the two frames was obtained. Finally, according to the result of matching and the centroid coordinate of stamens, the moving trajectory of each stamen could be acquired. The process to acquire stamen moving trajectory of Commelina Purpurea is as shown in Figure 1:

![Diagram of stamen trajectory acquisition process]

3. Stamen detection
For the detection of stamens, the original images were firstly converted into HSV vector space and taken out H, S, and V component images. Then, the gray histogram of the V component image was calculated. Since the maximum peak of the histogram was adjacent to the darkest side, and according to the segmentation algorithm of trigonometry[10], a right triangle could be formed by the maximum
peak and the maximum gray value. Then, getting the gray value of the position in the histogram which is with largest distance to the hypotenuse of this right triangle. Please refer to Figure 2 for principle of trigonometry.

![Figure 2. The segmentation principle of trigonometry algorithm.](image)

Then, the threshold value was used to segment the V component image to get the binary image, and the connected component was extracted. The largest connected component is actually the petal region in Commelina Purpurea image. Then the H component image of petal region was subtracted from the binary image of petal region to obtain a gray image. Finally, the gray image was segmented using thresholding to obtain a binary image that only contains stamens. The detection process of stamen target is shown in Figure 3.

![Figure 3. Detection of stamen in Commelina Purpurea image. (a) Original image. (b) V component image. (c) Histogram of (b). (d) Result of segmentation. (e) H component image of petal region. (f) Result of Subtract (d) and (e). (g) Binary image of stamen.](image)

4. Split adhered stamens
Since adhesion may exists in stamens, the adhered stamens should be detected and split to obtain single stamen. The connected component in the binary image of stamen was firstly obtained. Since the stamen and pistil are both included and in significantly different color, the stamens could be separated. The stamens are of similar size and same number in one flower, so, the parameter of pixel area in each connected component could be used to judge whether there are adhered stamens. In this case, m stamens were taken out to separately calculate the pixel area (1<=i<=m) of the m stamens, and further to calculate the average area of each single stamen:
Then according to the largest area factor $F_{\text{max}} = S_{\text{max}} / 2S_{\text{avg}}$ and the minimum area factor $F_{\text{min}} = S_{\text{min}} / 2S_{\text{avg}}$ of a single stamen, the area discrimination factor can be obtained:

$$\varepsilon = |F_{\text{max}} + F_{\text{max}} - 1|.$$ 

So, the condition for judging whether there is adhesion in a connected component is: when the area discrimination factor of a connected component $F_i > F_{\text{max}} + \varepsilon$, there are adhered stamens; when $F_{\text{min}} - \varepsilon < F_i < F_{\text{max}} + \varepsilon$, there is a single stamen.

Due to the difference in color saturation between the central and peripheral parts of stamen, the adhered stamens can be split accordingly. The central region of stamen could be extracted out from the S component image of the adhered stamen by thresholding segmentation algorithm. After that, the adhered stamen could be segmented by watershed algorithm[11]. However, this method cannot be used to split the topmost stamens in Figure 4(c). Therefore, other methods need to be used to split them. Because of the edge can be extracted from the adhesion boundary of the two stamens. So that the edge detection becomes necessary in order to achieve segmentation of these stamens. The edge of the adjoin stamens in Figure 4(e) was used to split the central region of the S component as shown in Figure 4(g), finally the adhered stamen could be segmented by watershed algorithm.

5. Acquire stamen moving trajectory

5.1. Feature points detection and matching

The SURF(Speeded Up Robust Features)[12] was applied to detect the feature points of the stamen image. It is actually an improved version of SIFT(Scale Invariant Feature Transform) and a prudent algorithm for local feature points detection and describing. In order to achieve scale invariance in feature detection and matching, the SURF algorithm takes use of the Hessian matrix[13] to determine candidate points, and performs non-maximum suppression to reduce complexity of computation. Besides, combining with concept of integral image[14], which greatly improves running speed of the algorithm. As shown in figure 5, the SURF algorithm is used to detect feature points in two adjacent frames of stamen images.
As for the feature points matching in two frames of image, the Euclidean distance between the spatial vectors was taken as the similarity measurement, and the nearest neighbor distance ratio method[15] was used for matching. Taking a feature point from the reference frame and figuring out two feature points in the current frame which are nearest and next nearest to its feature descriptor. If the distance ratio between the nearest and the next nearest feature points is less than the threshold value \( r \) (in this experiment, the value of \( r \) is set to 0.6), the nearest feature point should be deemed as the matching point. However, this method may have mis-matching phenomenon which can affect the precision of parameter estimation. In order to reduce mis-matching points, bidirectional matching strategy were applied. Only when Point-P in reference frame is the matching point of Point-P’ in current frame, and Point-P’ in current frame is also the matching point of Point-P in reference frame, can the Point-P and Point-P’ be deemed as a pair of matching points. Figure 6 shows the matching result of features points in two frames of stamen image.

5.2. Stamen matching

The matching result of above feature points still contains some mis-matching points, which are unfavorable for stamen matching. Therefore, the matching results need to be optimized further. The slope value between matched feature points was calculated and made in statistics. If the difference of two certain slope values is less than \( j \) (in this experiment, the value of \( j \) is set to 0.02), it would be believed that the two slopes belong to a same range. Then, the quantity of feature points of matching within every specific slope range was thereby counted, and the matching results which number is the first \( n \) were finally reserved. By doing so, the mis-matched feature points could be eliminated to the largest extent. Figure 7 shows the matching result of feature points after optimization.

For stamens matching, a target stamen of matching result was firstly selected to count the distance between the matched feature points. If the difference between any two distances is less than \( d \) (in this experiment, the value of \( d \) is set to 50 pixels), it would be believed that the two distances belong to a same range. Then, the matching can be completed by finding the stamen corresponding to the feature
points in the range with the most in number of distances. Please refer to Figure 8 for the result of stamens matching.

![Figure 8. The result of stamens matching.](image)

For acquiring the trajectories of stamens movement, starting from the first frame of the stamen image sequence, stamens in two adjacent frames of image were matched in order. Then according to the matching result, the corresponding relations between stamens of each frame of image were determined. Finally, the trajectory was drawn according to the centroid coordinate of each stamen.

6. Experiment result
In this paper, the movement trajectories of three groups of Commelina Purpurea stamens in different states were acquired. The images of the three groups of stamens were all taken by camera in a fixed position. In the process of experiment, the stamen regions in these images were firstly extracted. And then the stamen pixel area was used to determine whether the stamen is adhered, and the adhered stamen was segmented by using segmentation algorithm. After that, feature point detection and matching were carried out between two adjacent frames in stamen image sequence to determine the matching result of all stamens. And finally, the stamen moving trajectories were acquired according to the changes of centroid coordinates of all stamens. Figure 9 (a1) ~ Figure 9 (a3) are the first frame of three image sequences respectively, the corresponding stamen images after segmenting are as shown in Figure 9 (b1) ~ Figure 9 (b3). Figure 9 (c1) ~ Figure 9 (c3) are the trajectory images of stamen movement.

![Images](image)
Figure 9. Trajectory of stamen movement, the black point is the start position and the white point is the end position. (a1)–(a3) The first frame of three image sequences. (b1)–(b3) Stamen images after segmenting. (c1)–(c3) The trajectory images of stamen movement in three image sequences.

7. Conclusion
The stamen movement trajectory of Commelina Purpurea was acquired based on feature matching in this paper. Firstly, the stamen regions were extracted from the image, according to the pixel area of stamen to determine if adhesion existed in stamens or not. And then, the segmentation algorithm was applied to split the adhered stamens. After that, feature point detection and matching were carried out on every two adjacent frames in stamen image sequence to determine the matching results of all stamens. And finally, the stamen moving trajectories were acquired according to the changes of centroid coordinates of all stamens. Obtaining the trajectory of stamen movement by feature matching may provide more basis for better understanding the adaptive significance and evolutionary ecology of stamen movement.

References
[1] Ren, M. (2010) Stamen movements in hermaphroditic flowers: diversity and adaptive significance. Journal of Plant Ecology (Chinese Version), 34: 867-875.
[2] Armbruster, W. S., Corbet, S. A., Vey, A. J., Liu, S. J., Huang, S. Q. (2014) In the right place at the right time: Parnassia resolves the herkogamy dilemma by accurate repositioning of stamens and stigmas. Annals of Botany, 113: 97-103.
[3] Ren, M. (2009) Intrafloral stamen differentiations and their adaptive significances. Journal of Plant Ecology (Chinese Version), 33: 222-236.
[4] Whitaker, D. L., Webster, L. A., Edwards, J. (2007) The biomechanics of Cornus canadensis stamens are ideal for catapulting pollen vertically. Functional Ecology, 21: 219-225.
[5] Azuma, H., Toyota, M., Asakawa, Y. (2005) Floral scent chemistry and stamen movement of Chimonanthus praecox (L.) Link (Calycanthaceae). Acta Phytotaxonomica et Geobotanica, 56: 197-201.
[6] Xiao, C. L., Deng, H., Xiang, G. J., Luguba, K. E., Guo, Y. H., Yang, C. F. (2017) Sequential stamen maturation and movement in a protandrous herb: mechanisms increasing pollination efficiency and reducing sexual interference. AoB Plants, 9: 1-11.
[7] Shi, J. (1994) Good features to track. In: 1994 Proceedings of IEEE conference on computer vision and pattern recognition. Washington. pp. 593-600.
[8] Henriques, J. F., Caseiro, R., Martins, P., Batista, J. (2014) High-speed tracking with kernelized correlation filters. IEEE transactions on pattern analysis and machine intelligence, 37: 583-596.
[9] Yun, S., Choi, J., Yoo, Y., Yun, K., Young Choi, J. (2017) Action-decision networks for visual tracking with deep reinforcement learning. In: Proceedings of the IEEE conference on computer vision and pattern recognition. Hawaii. pp. 2711-2720.
[10] Zack, G. W., Rogers, W. E., Latt, S. A. (1977) Automatic measurement of sister chromatid exchange frequency. Journal of Histochemistry & Cytochemistry, 25: 741-753.
[11] Najman, L., Schmitt, M. (1996) Geodesic saliency of watershed contours and hierarchical segmentation. IEEE Transactions on pattern analysis and machine intelligence, 18: 1163-1173.

[12] Bay, H., Ess, A., Tuytelaars, T., Van Gool, L. (2008) Speeded-up robust features (SURF). Computer vision and image understanding, 110: 346-359.

[13] Lakemond, R., Fookes, C., Sridharan, S. (2009) Affine adaptation of local image features using the hessian matrix. In: 2009 Sixth IEEE International Conference on Advanced Video and Signal Based Surveillance. Genova. pp. 496-501.

[14] Viola, P., Jones, M. (2001) Rapid object detection using a boosted cascade of simple features. In: Proceedings of the 2001 IEEE computer society conference on computer vision and pattern recognition. Hawaii. pp. I-I.

[15] Lowe, D. G. (2004) Distinctive image features from scale-invariant keypoints. International journal of computer vision, 60: 91-110.