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Research Article

Calculation Method Based on Flower Petal Area and Other Plant Leaf Spot Area

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Abstract

In order to calculate the area of irregular shapes such as plant leaves and diseased spots or flower petals, this paper presents a new method to calculate them by using flood fill algorithm, HSV color space, improved k-means algorithm and morphological operation. First, 501 butterfly petal images and pathological leaf images of Bauhinia and phyllotaxus were collected, and then flood was used Fill algorithm selects the disease-free area and records the selected pixel value. HSV color space conversion is applied to the image to facilitate the segmentation of leaves. Then, the improved k-means algorithm is used to extract the binary image of leaves and record the pixel value of the outer contour with morphological closed operation. Finally, the proportion and truth of the disease spots of plant leaves are obtained by calculating the pixel value and the real value of the rectangle in the sampling area Real area. Compared with the results of artificial labeling, the average accuracy of petal area and lesion area of Phalaenopsis was 96.3% and 96.61%, respectively. It can be seen that the program can calculate the area of irregular shape of plant surface accurately. In conclusion, this method can replace the artificial grid method to calculate the information of plant leaf area and disease proportion, and effectively reduce the work intensity of experimental personnel.

Keywords

Image Processing, Plant Leaf Area, Contour Extraction, Lesion Area Calculation, Edge Detection

1. Introduction

Plant leaves are the medium for photosynthesis and transpiration. Leaf area is the key index to study plant growth and breeding cultivation, and also has a great impact on the yield of crops currently planted. The emergence of plant diseases and insect pests is an important reason for the slow development of plants and the decline of yield. Therefore, how to measure the area of plant leaf spots quickly and accurately is of great significance for the determination and research of the degree of plant diseases. The area of flower petals is an important index to evaluate its observation value. However, the shape of leaves, petals and diseased spots of plants are irregular.

In traditional methods, leaf area meter is usually used for measurement. Leaf area meter can accurately measure the area of the blade, but the instrument is expensive, square method, mass method and regression analysis method are cumbersome and time-consuming [1]. In recent years, image processing technology has been applied in the field of plant leaf area measurement, which is not only cheap but also convenient and efficient. Because image processing tech-

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nology is in the primary stage in the field of plant leaf measurement, but it has a good prospect in the field of agriculture [2-4]. The thresholding algorithm of plant leaf segmentation usually uses the thresholding method or Otus method to perform binary image segmentation [5]. Independent background separation can be effectively separated by changing the color space model, among which RGB, HSV, CIELAB and YCbCr color models are usually studied [6]. Through the extraction of color and texture features, combined with the normalized difference index (NDI) for spectral analysis of samples, a method of plant canopy separation based on artificial neural network is explored [7]. However, the above methods have some disadvantages. For example, threshold segmentation needs to set different thresholds for different images, and it is expensive to use hyperspectral measurement equipment. The segmentation effect of RGB based color model has a high requirement on the shooting environment, and the pixel value will change significantly with the use of different imaging sensors. This model becomes unreliable for the change of lighting color or shadow conditions [8]. Based on the above points, HSV, YCbCr, CIELAB and other color space-based models are used for segmentation. Such a model is closer to human perception [9]. Using k-means or Otsu algorithm for image binarization to reduce program steps and improve efficiency.

After analyzing the advantages of the above image segmentation algorithm and referring to a large number of image segmentation algorithm knowledge, this paper proposes a method to calculate the disease area of plant leaves by using flood fill, K-means, HSV color space and morphological operation [10-13]. First, use flood Fill algorithm divides the lesion and calculates the pixel value of F, then uses HSV chroma space to distinguish the background and leaf, uses K-means clustering algorithm to binarize the image [14-16], then carries out morphological close operation to reduce small interference, finally recognizes the contour of the plant leaf and calculates the pixel value of occupation, and carries out the actual area value of the reference point manually marked The image information, such as the actual area of plant leaves and flower petals, the area of disease spots and the proportion of disease spots, is obtained by calculation, so as to provide a useful reference for relevant researchers.

2. Materials and Methods

2.1. Image Acquisition

In this paper, 16 megapixel front camera is used for image acquisition. The image size is set to 800 × 800 pixels. The most clear image is selected as sample data three times for each shooting repetition. When collecting the pathological areas of the leaves of Bauhinia and Bauhinia, when there is no light interference, each single leaf is photographed and collected, and when it is photographed 40 cm above the leaf, 146 samples of Bauhinia and 71 samples of Bauhinia are collected. When collecting the petals of Phalaenopsis, 6 petals of Phalaenopsis were placed 40 cm below the petals, and 150 sample images of Phalaenopsis were collected. In order to verify the accuracy of the test method, Photoshop was used to manually segment the collected lesions. The binary mask image with the background of 0 and 255 was used as the reference for the calculation of the lesion area in this experiment. The outer contour of the petals was manually marked by the petals of Phalaenopsis, and the binary mask image was made as the reference for the calculation of the petal area in this experiment.

2.2. Segmentation of Plant Leaf Lesions

In the process of plant leaf disease segmentation, the flood fill algorithm is used to segment the disease spots. The flood fill algorithm is mainly applicable to the image with large gray value difference between the filled area and the non filled area, and then accesses each point in the given area until the area with large gray value difference is accessed. The HSV color space is used to segment the background which is not related to the plant leaves.

2.3. Improved k-means Clustering Algorithm for Image Contour Extraction

Before calculating the area of plant leaves or flower petals, the irrelevant background needs to B e segmented, but the leaves or flower petals cannot be completely separated through the RGB image through the color channel (Figure 1-a, b, c), and when the RGB is converted into the HSV color space for segmentation, the saturation channel (Figure 1-d, e, f) can be seen from Figure 1 below to perfectly separate the irrelevant background.

The binary method is usually used to segment the plant leaves, while the traditional binary image usually needs to set the threshold, which increases the workload of operators. K-means and Otus are usually used in order to make binarization reasonable. Figure 2 shows that Otus loses a lot when processing the blade edge, which reduces the accuracy of the calculation by comparing the original figure (Figure 2 (a)) with the k-means algorithm effect (Figure 2 (b)) and Otus effect (Figure 2 (c)). So we use k-means algorithm to binarize the blade image.

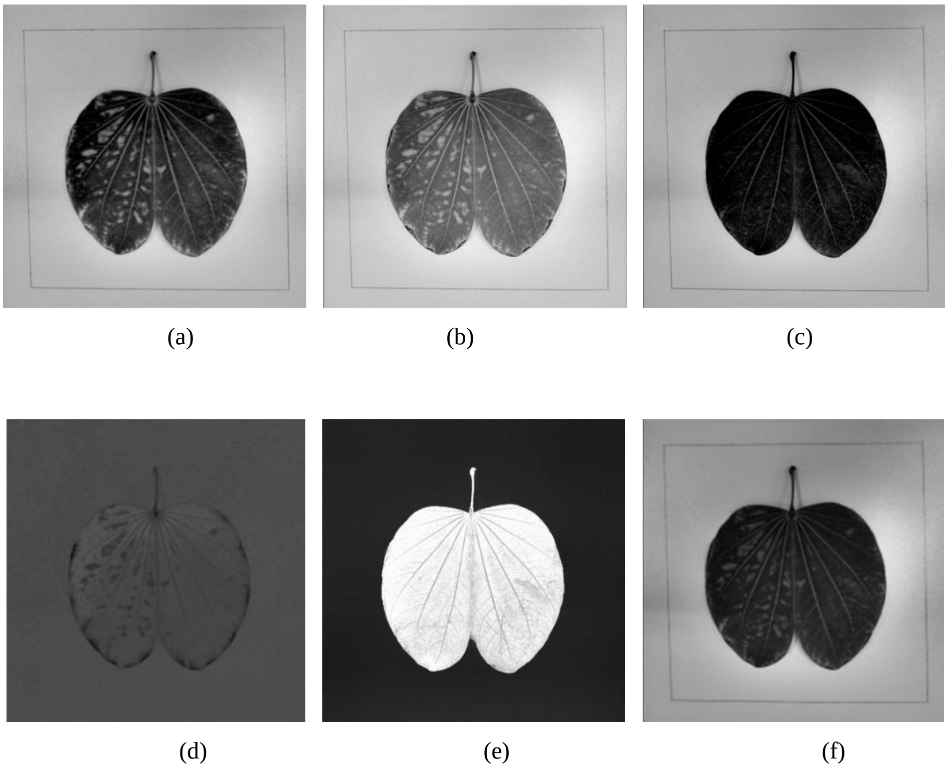

Figure 1. *RGB and HSV color space segmentation effect: (a) Effect of red channel on image segmentation; (b) Effect of green channel on image segmentation; (c) Effect of bule channel on image segmentation; (d) Effect of hue channel on image segmentation; (e) Effect of saturation channel on image segmentation; (f) Effect of lightness channel on image segmentation.*

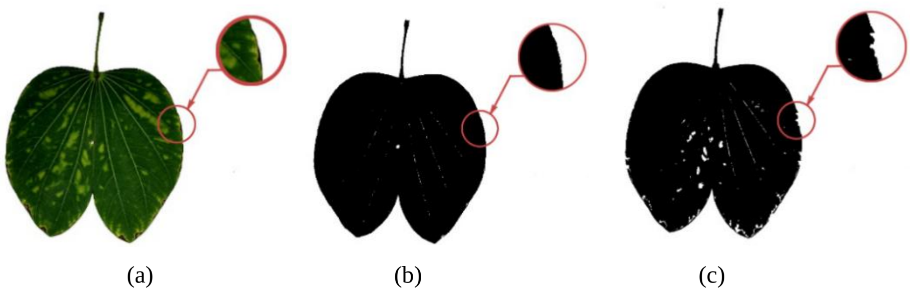

Figure 2. *Effect of K-Means and Otsu Algorithm on target object segmentation: (a) The original image of the target object; (b) K-means clustering algorithm segmentation effect map; (c) Otsu algorithm segmentation effect map.*

The K-Means clustering algorithm, derived from a vector quantization method in signal processing, is now popular as a cluster analysis method in the field of data mining. The purpose of K-Means Clustering: when dividing n points into k clusters, each points belongs to corresponding clustering of the nearest mean. It sets as the clustering criterion.

Known that $(x_1,x_2,...,x_n)$ is an observation set, where each observation is a d-dimensional vector, and K-Means clustering divides the n observations into k sets ($k \le n$), Make the sum of squares within the group of the smallest. Its goal is to find clusters S_i that satisfied the following formula, given in Eqs. (1)-(3).

$$arg_s \min \sum_{i=1}^{k} \sum_{x \in S_i} \|X - \mu_i\|^2 \quad (1)$$

Where μ_i is the mean of all points in S_i .

The improved clustering algorithm adds a function to automatically exclude interference contours generated by K-Means clustering if the contour size of the binary image is less than a certain threshold.

$$\mathrm{dst}(x, y) = \begin{cases} maxVal & src(x, y) > thresh \\ 0 & otherwise \end{cases} \quad (2)$$

After using the improved K-Means clustering algorithm to obtain images, due to the influence of lesions and other factors, leaf blade leaves holes, which affect the quasi-linearity of the subsequent area calculation, and Morphological Closure can exclude small holes in the image. The mathematical formula is as follows:

$$A \cdot B = (A \oplus B) \ominus B \quad (3)$$

$\oplus$ and Θ indicate corrosion and expansion respectively. In this paper, OpenCV's built-in find Contour function is used to draw the contour of the binary image. In order to ensure the accuracy of the experimental data, it is only necessary to record pixel value of the outer contour of the image leaf or the petal, and performed weighted superposition with the original image to verify the correctness.

2.4. Petal area and leaf area calculation

Known the real area of the image marker point rectangle, the actual leaf area can be known by calculating the pixel value of the marker point rectangle in the image, the pixel value of the phalaenopsis petal and the pixel value of the lesion. The true area of plant leaves in Eps.(4):

$$S_l = S_r \times \frac{P_l}{P_r} \quad (4)$$

S_l represents the true area of the petals of Phalaenopsis and other plants, S_r represents the real area of the rectangle, P_l represents the pixel value of the flower petals and lesions, and P_r represents the pixel value of the rectangle. According to this formula, the real area of flower petals, plant leaves and leaf lesions can be calculated using a computer.

2.5. Calculation of Petal Area and Leaf Lesion Area

Through the algorithm, the flower petals and plant leaf lesions are accurately segmented with complete contours of lesions. The contours of the flower petals and plant leaves are also accurately segmented. In order to objectively evaluate the algorithm effect, the measurement area of the flower petals and plant leaves, the area of lesion measurement, the proportion of lesions and the parameters of artificial markers are compared to obtain the correct rate of measurement, and the formula for correct rate is as follow (5):

$$\text{Correct rate} = \frac{\mathit{Correct\ split\ rate}}{\mathit{Actual\ split\ area}} \times 100\% \quad (5)$$

At the same time, in order to meet the difference between the measured value and the true value, the mean square error index is introduced to evaluate the accuracy of the program. The mean square error formula is (6):

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{m}(y_i - \hat{y}_i)^2 \quad (6)$$

Where, y_i is the measured value of the program, and $\hat{y}_i$ is the real value measured.

3. Materials and Methods

3.1. Flood Fill Algorithm and HSV Chromaticity Space Segmentation Effect

For the image of plant leaf lesions, the Flood Fill Algorithm is used to effectively segment the image lesions and record the pixel values occupied by the lesions. The Flood Fill Algorithm can well handle the segmentation of lesions (Figure 3). HSV Chromaticity Space is used to exclude unrelated backgrounds when the flower petals from the unrelated background of other plant leaves, and the HSV Chromaticity Space can effectively separate the plant leaves and background (Figure 4).

Figure 3. *Plant leaf lesion identification.*

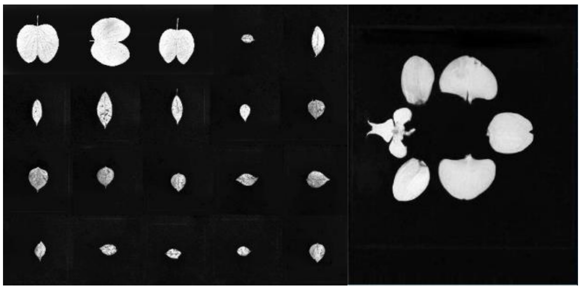

Figure 4. *HSV color space segmentation effect diagram.*

3.2. Improved Contour Extraction Effects

The improved K-Means clustering algorithm can effectively eliminate the interference contour caused by background and other factors. The picture is almost noise-free, and the outer contours of the plant leaves are completely preserved (Figure 5). The experimental results show that the Morphological Closure Operation can solve the problem of hollow holes in binary images well and preserve the shape of the blades well. The results also show that OpenCV can complete the task of segmenting the outer contour of the binary image well and easily (Figure 6).

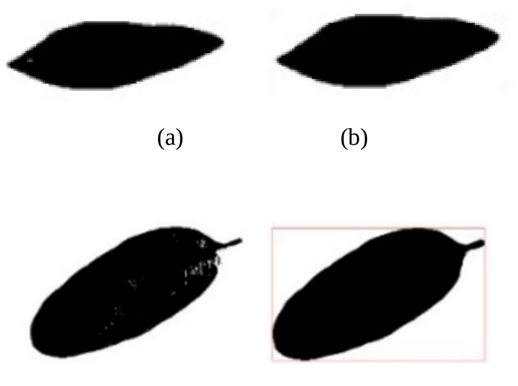

Figure 5. *The effect of improved K-Means clustering algorithm: (a) K-Means algorithm; (b) Improved K-Means algorithm; (c) Original image; (d) Morphological closure.*

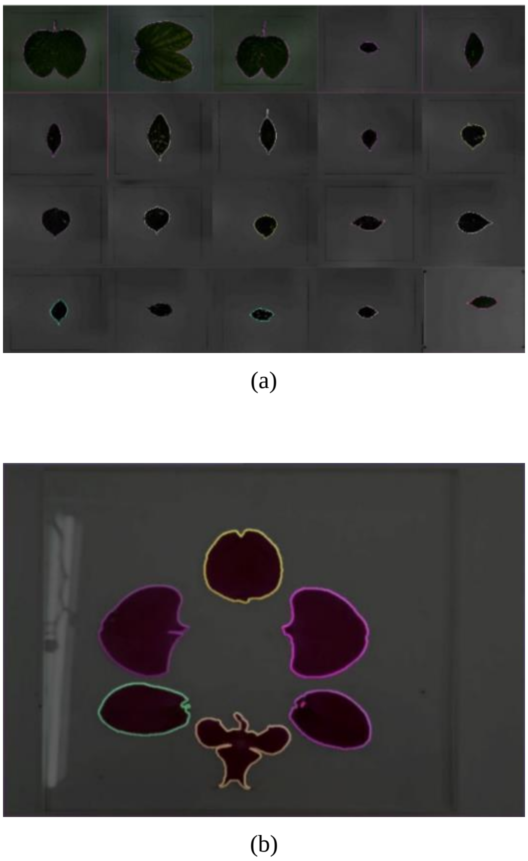

Figure 6. *Plant leaf (flower petal) outline recognition diagram: (a) Plant leaf outline; (b) Phalaenopsis outline.*

3.3. Segmentation Accuracy Rates of Flower Petals and Plant Leaf Lesions

As shown in table 1, it is the program segmentation data of Bauhinia, phyllotaxy and Phalaenopsis leaf area. It can be seen that the improved k-means clustering algorithm improves the accuracy of image segmentation significantly, among which the accuracy of Bauhinia segmentation is 96.41%, the accuracy of yezihua segmentation is 96.9, and the accuracy of Phalaenopsis segmentation is 95.59%. Figure 7 showed comparison between the K-means clustering algorithm of Phalaenopsis sample data and the improved algorithm in this paper shows that in 150 Phalaenopsis samples, the improved k-means clustering algorithm in this paper improves the segmentation accuracy significantly. Table 2 shows the segmentation data of the disease spots of Bauhinia and Bauhinia, in which the accuracy rate of the segmentation of the disease spots of Bauhinia is 97.02%, and the accuracy rate of the segmentation of the disease spots of Bauhinia is 96.2%. Figure 8 showed the comparison effect of the accuracy rate of the segmentation of the disease spots of the leaves and the occupancy rate of the disease spots in 146 samples of Bauhinia. The results show that the average correct rate of the program is 96.3% for leaf area, 96.61% for lesion area and 95.97% for lesion proportion. The algorithm can meet the practical application requirements.

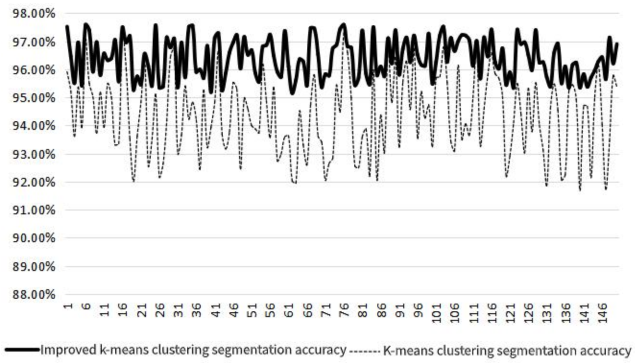

Figure 7. *Algorithm comparison.*

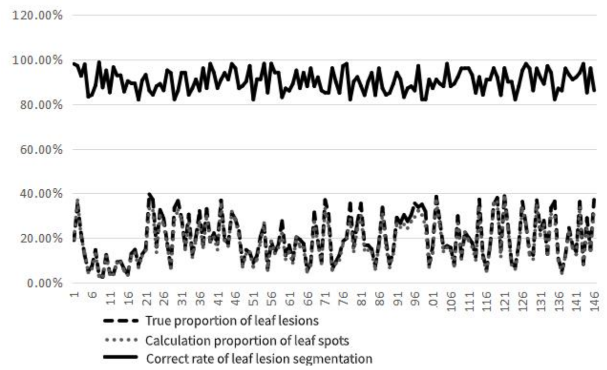

Figure 8. *Calculation and comparison of plant leaf lesion segmentation.*

Table 1. *Segmentation calculation of leaf and petal area of plants.*

Name	Number of samples	K-means clustering segmentation accuracy/%	Improved k-means clustering segmentation accuracy/%	Standard deviation/%	Error/%
Bauhinia blakeana	146	94.40	96.41	3.59	0.71
Bougainvillea	71	92.87	96.90	3.10	1.05
Phalaenopsis	150	92.89	95.59	4.41	1.89

Table 2. *Calculation of plant leaf lesion segmentation.*

Name	Number of samples	Leaf lesion segmentation			Calculation of the proportion of leaf spots		
		Accuracy rate/%	Standard deviation/%	Error/%	Accuracy rate/%	Standard deviation/%	Error/%
Bauhinia blakeana	146	96.20	0.60	3.80	95.54	0.59	3.57
Bougainvillea	71	97.02	2.04	2.98	96.41	1.97	2.19

4. Results

Caldas et al., by adding a known area reference, used to get the real area represented by each pixel, and the measurement results are very close to the measurement results of the leaf area meter [17]. C. Igathinathan et al. Developed a software system to measure the width, height and area of leaves. This method realized the complete segmentation of leaves by transforming RGB color model into HSV color model [18]. Hassan et al. Proposed a non-destructive measurement method of leaf area based on computer vision. Through experiments, it is proved that K-means clustering algorithm is due to Otsu method [19]. Chen Taotao et al. Corrected the image through spatial transformation, reduced the camera perspective distortion and effectively improved the accuracy of measurement [20]. Chen Ding Cai et al. Improved the measurement method of leaf spot, selected the circular reference in the selection of the reference, used the flood fill algorithm to select and calculate the diseased area of the leaf, and obtained the leaf area and the diseased area product through the corrected image. The measurement accuracy has been significantly improved [21].

After calculating the leaf area, lesion area and proportion by using the formula, the segmentation accuracy of the program is verified by using the manually marked data [22]. The results show that the segmentation method of this experiment can effectively complete the task and achieve high accuracy. In conclusion, the segmentation method of this experiment can effectively calculate the area of flower petals and the area of disease spots of plant leaves.

5. Conclusions

This paper introduces an algorithm for calculating the area of plant leaf diseases and image segmentation technology, which can be used to calculate the area of plant leaves and flowers. Using the method of this paper, the experiment of calculating the area of petals of Phalaenopsis and the area of diseased spots of leaves of flowers and Bauhinia is concluded as follows:

(1) Through the combination of a variety of algorithms, the best measurement results are obtained. In the calculation of flower petals and plant leaves, the results show that the average correct rate of the disease area is 96.61%.

(2) The average accuracy of measuring leaf area and flower petals is 96.3%

In conclusion, this method can replace the artificial grid method to calculate the information of plant leaf area and disease proportion, and effectively reduce the work intensity of experimental personnel.

Abbreviations

MSE Mean Square Error

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Conflicts of Interest

The authors declare no conflicts of interest.

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