Cuticle segmentation based on visual saliency

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Abstract: The cuticle of plant is an important tissue to keep water and resist the invasion of ultraviolet radiation and so on, it is also one of the most important indexes of plant drought resistance. In this paper, we introduce a method combined salient region detection and threshold segmentation for cuticle segmentation. The method used in the article has the following steps: Firstly, we transformed the slice image from the original RGB space into CIELAB space. Then according to the principle of visual significance, visually salient slice image regions were detected using color and luminance features. Finally, we obtained the segmentation results by threshold segmentation algorithm. We tested this method by 30 slice images of Cleistogenes Songorica. We got the average value of FPR (False Positive Rate), FNR (False Negative Rate) and GSA (Global Segmentation Accuracy) were 0.75%, 7.19% and 98.43%. The method in this paper is more suitable for cuticle segmentation of Cleistogenes Songorica leaf slices and can also provide a reference for other plant leaf slice images.

1. Introduction

The cuticle of plant is an important tissue to keep water and resist the invasion of ultraviolet radiation. It plays an important protective role in plant growth, development and adaptation to stress [1]. The thickness, morphology and chemical composition of the cuticle are closely related to the growth and development of plants and their ability to respond and adapt to the environment. Sun Xiaohong et al [2] studied the morphological and anatomical characteristics of 3 Species of Kobresia. The results showed that the cuticle thickness could be used as an important basis for taxonomy. Kou Meng et al [3] studied ten monocotyledons in the hilly-gullied loess plateau region and shows that there were significant differences in the thickness of the upper cuticle and plants adapt to the environment of drought stress and strong illumination by increasing the thickness of the upper cuticle. Guo Jingyu et al [4] studied the environmental different characteristic of anatomical structure of caragana korshinskii leaflet and pointed out that the thickness of cuticle was related to the mechanical support of plant leaves, and the thicker cuticle can avoid the immediate wilting of plants under drought conditions. TAN Yinyin et al [5] screened of leaf cold-resistant structural indexes and cold resistance evaluation of 5 Michelia species. The results showed that the cold-resistance indexes selected by cluster analysis at different cooling stages were different, the cuticle thickness was the representative indicator at natural cooling stage. Xu Yunlei et al[6] analyzed the leaf anatomical structure differences among different living plants in the...
same community in the Dry-Hot Valley of Jinshajiang, the result shows that the coefficient of variation of upper epidermal cell thickness, leaf thickness and cuticle thickness were all greater than 50%, which may belong to ecological adaptation traits. To sum up, the further study of cuticle is of great significance to reveal plant cold resistance, drought resistance, lodging resistance and plant breeding. At present, the cuticle thickness measured samples with the mode of the manual interactive using microscope almost, the samples were made by means of segregation, paraffin section and so on. This method is time-consuming and laborious, and has large human error, and also is not suitable for batch measurement. In this paper, we took the *Cleistogenes Songorica* leaf as research object, obtained segmentation and extraction of cuticle, which established foundation for the measurement of cuticle thickness.

2. Materials and methods

2.1. Image acquisition
The *Cleistogenes Songorica* leaf samples were collected from the Ordos Etok Banner in July and August 2016 and cut these in to small segments, then put into FAA (Formalin-acetic acid-alcohol) standard fixative to obtain permanent slides by paraffin. We took slice images for analysis using a bio-optical microscope to connect with a computer. The computer that analyzed the image was configured as Intel (R) Core (TM) i5CPU M480@2.67GHz, 6GB memory, Windows7 operating system, Matlab2015a was used for image processing software.

2.2. Segmentation algorithm
On the basis of the characteristics of slice image, the method used in the article has the following steps: Firstly, we transformed the slice image from the original RGB space into CIELAB space. Then according to the principle of visual significance, visually salient slice image regions were detected using color and luminance features. Finally, we obtained the segmentation results by threshold segmentation algorithm.

2.2.1 Color space transformation.
The Red-Green-Blue color space is a probably the simplest and most natural color space, many display devices such as computers, digital cameras, and scanners use this color space, which is also the basic form of image storage, but there is a linear correlation between the three channels in space, so, it is difficult to accurately calculate the difference of color and brightness when applying this model to analyze the significance. We transformed the slice image from the original RGB space into CIELAB space. The conversion formula is given by:

\[
\begin{bmatrix}
X \\
Y \\
Z
\end{bmatrix} = \frac{1}{0.17697} \begin{bmatrix}
0.49 & 0.31 & 0.20 \\
0.17697 & 0.81240 & 0.01063 \\
0.00 & 0.01 & 0.99
\end{bmatrix} \begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]

\[L = 116 \left\{ \frac{Y}{Y_n} \right\} - 16\] (2)

\[a = 500 \left\{ f(\frac{X}{X_n}) - f(\frac{Y}{Y_n}) \right\} \] (3)

\[b = 200 \left\{ f(\frac{Y}{Y_n}) - f(\frac{Z}{Z_n}) \right\} \] (4)

Where \( X_n, Y_n \) and \( Z_n \) are reference white value, \( X / X_n, Y / Y_n \) and \( Z / Z_n \) are linear normalized values.

2.2.2 Saliency detection.
FT algorithm is one of the most classical saliency detection algorithms with low complexity. The saliency feature used in this algorithm is CIELAB color feature, which accords with the cuticle characteristics of significant color and brightness in slice image. In this paper, FT algorithm was used.
to detect the saliency of slice image. In method FT, designed several narrow band-pass DoG filters, which given by:

$$F_N = \sum_{n=0}^{N-1} G(x, y, \rho^{n+1} \sigma_1) - G(x, y, \rho^n \sigma_2) = G(x, y, \sigma \rho^N) - G(x, y, \sigma)$$  \hspace{1cm} (5)$$

where $\rho = \sigma_1 \div \sigma_2 = 1.6, \sigma_1$ and $\sigma_2$ are the standard deviations of the Gaussian.

FT method of finding the saliency map for the slice image formulated as:

$$sm(x, y) = \|I_\mu - I_{\sigma_0}(x, y)\|$$  \hspace{1cm} (6)$$

where $I_\mu$ is the mean image feature vector, $I_{\sigma_0}(x, y)$ is the corresponding image pixel vector value in the Gaussian blurred version (using a $5 \times 5$ separable binomial kernel) of the original image.

2.2.3 Threshold segmentation.
We had obtained the significant image of the anatomical structure of the *Cleistogenes Songorica* leaf by FT saliency detection algorithm, in significant image the pixels value of the cuticle was obviously large. So, we can extract the cuticle by single threshold method. Let significant image be $f(x, y)$ of width $w$ and height $h$ pixels, then the average significant value be:

$$T = \frac{1}{w \times h} \sum_{x=0}^{w-1} \sum_{y=0}^{h-1} sm(x, y)$$  \hspace{1cm} (7)$$

The segmented result $g(x, y)$ formulated as:

$$g(x, y) = \begin{cases} 1 & f(x, y) \geq aT \\ 0 & f(x, y) < aT \end{cases}$$  \hspace{1cm} (8)$$

Where $a$ set as 7.

2.2.4 Segmentation evaluation.
To evaluate the segmentation effect, three indexes were selected: False positive rate (FPR), False negative rate (FNR) [8] and Global segmentation accuracy (GSA). The Golden standard image were obtained by Photoshop software. The smaller the FPR value and FNR value and the greater the GSA value, the better the segmentation accuracy.

3. Test and results analysis
Figure 1 shows the segmentation result. It can be seen that the cuticle can be segmented accurately by this method. This method can eliminate the interference of vascular bundle. To analyze the segmentation quality, we tested 30 slice images which were randomly selected from the *Cleistogenes Songorica* leaf anatomical structure images. The segmentation results were evaluated by the FPR, FNR and GSA, this three values shown as in Table 1. The average false positive rate was 0.75%, the average false negative rate was 7.19%, and the global segmentation accuracy was 98.43%. This shows that we can achieve the segmentation of the cuticle accurately by this method.
4. Conclusions
On the basis of fully analyzing the features of cuticle images, this paper uses FT saliency algorithm and threshold segmentation to realize the accurate segmentation of cuticle. The average false positive rate false detection rate of 30 test images was 0.75%, the average false negative rate was 7.19%, and the global segmentation accuracy was 98.43%.

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