

Original papers

A method of green litchi recognition in natural environment based on improved LDA classifier

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ABSTRACT

Green litchi is always difficultly recognized by picking robot under the natural environment because of its similar color feature with background. A method of green litchi recognition based on improved LDA classifier is proposed by this paper. The color features of RGB components of litchi images were firstly analyzed. Then a linear discriminant analysis (LDA) method used for extracting convolutional features for classifying pixels of image was proposed to train the convolution kernel based on 1600 sample pixels. Simultaneously, an idea of 'maximal margin' from SVM to calculate the threshold of LDA classifier was introduced, and the corresponding threshold calculation method was put forward. The AdaBoost method was used in integration of a strong multiple LDA classifier. After classifying pixels, the Hough transform circle detection was used to locate the fruit of litchi by the sphere shape feature. Experiments with the proposed method show that green litchi recognition precision rate is 80.4% and the recall rate is 76.4%. This study provides technical support for the visual identification of green litchi and even other green fruits in natural environment.

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1. Introduction

The tasty and nutritious litchi is an important economic crop. However, litchi harvesting is mainly done by manual work with high cost and low efficiency. Litchi automatic harvest by picking robot becomes a hot research topic. Precise spatial localization to target fruits is the key technique to the picking robot. Present studies (e.g. Guo et al., 2014; Kong et al., 2013; Wang et al., 2016; Xiong et al., 2013; Zou et al., 2012) located red litchi respectively using Otsu, K-means or C-means methods, all of which distinguished each single pixel of fruit from background by threshold segmentation. Nevertheless, their performances are all sensitive to lighting and depend greatly on color difference between fruit and background.

Some litchi varieties turn yellow-green after maturation, such as Feizixiao and Gualv. During this period, the yellow-green litchi is similar to the background, so the traditional segmenting methods based on single pixel have low robustness. Currently, there were some researches towards green-fruit locating in the field of

visual technology for picking robot. Rakun et al. (2011) studied green apple and conducted segmentation by combining H component of HSI color model with textural features based on Wigner-Vile distribution. The 3D object reconstruction and location were then conducted using the segmented 2D image. The accuracy of segmentation was 66% while the matching accuracy of 3D shape was 60%. Linker et al. (2012) studied the location of green apple using KNN algorithm. Color and smoothness characteristic calculated with variance were used to segment the potential area of fruit. Then the radians of area were extracted as shape feature to perform further location. The accuracy of apple detection can reach 95%. Zhao et al. (2016) put forward a method to detect green citrus. At first R and B component of RGB color model along with SATD algorithm were used to make initial segmentation. Then 5 different texture features were input to SVM classifier for further detection, whose accuracy reached 83.4%. Kurtulmus et al. (2011) trained 'eigen fruit' model with PCA method. Combining Gabor texture feature, the accuracy for green citrus detecting reached 75.3%. For green fruit detection, all above researches united multiple features for positioning. Since the color of green fruit is similar to the background, pixels sorting with color feature alone cannot meet the required precision. Texture feature, mentioned among all above methods, can reflect the statistical characteristics of image area

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centered on target pixel. However, most of the mentioned researches used texture feature defined artificially, which cannot fully utilize or reflect the relationship between pixels. Taking green litchi as study object, this research put forward a method of litchi recognition based on improved LDA classifier, with image feature being used to calculate the statistical relationship among pixels and the convolution being extracted as classification feature. So convolution can also provide the statistical information of texture characteristics. In order to improve the classifier's generalization ability, the AdaBoost method was used in integration of LDA and SVM with idea of 'maximal margin' to construct separating hyper-plane of LDA. The Hough transform circle detection was used to locate the fruit of litchi by the sphere shape feature after pixel classification.

2. Materials

Feizixiao litchi is taken as the research object in this study. The litchi images were captured on June 14, 2016 in orchard of Zengcheng, Guangdong, China. The visual system is composed of CCD camera and tripod, shown as Fig. 1. The CCD camera is MV-VDM200SC with field angle of 43.60°.

The resolution of captured image is 1499×1000 pixels. 340 images were captured, among which 290 were captured in the distance of 40–90 cm (hereinafter refer to as the Group A) and 50 were captured in the distance of 200–300 cm (hereinafter refer to as the Group B). Capture distance was mainly selected between 40 and 90 cm, which is the effective distance of picking robot operation. In order to realize effectiveness and robustness of the green litchi recognition algorithm, 50 green litchi images of distance 200–300 cm were captured using the same camera. The maturity of litchis differs quite a bit in the image capture in mid-June, shown as Fig. 2a in capture distance of 40–90 cm. Litchis in the red frame are yellow-green with higher maturity and round in

shape, and in the blue frame are turquoise with lower maturity and oval in shape. Both kinds of litchis with different maturity were detection objects in our experiments.

3. Implementation of algorithm

It is necessary to extract effective features with distinction for detecting litchi fruit. There were 3 kinds of features chosen for analysis in this paper, color feature of pixel, convolution feature of neighborhood of pixel and shape feature of the whole contour of the object. These three features extracted from underlying single pixel, statistical information of the neighborhood and abstract feature of the object respectively, are representative image features in different ranges and levels. Components and results of the feature analysis are shown in Fig. 3. The detail and analysis process will be discussed below.

The algorithm implementation process is shown as Fig. 4. The algorithm implementation includes two major stages. Stage 1 is classifier training stage for extracting convolution features. Stage 2 is recognition stage for image segmentation based on the classifier from stage 1 and detection of single litchi fruit by Hough transform circle detection.

3.1. Color feature analysis

The original image is usually encoded in RGB color model. Other color models can be transformed by RGB model. Analysis of color feature of RGB model image can express the distribution of pixels in the original image. Due to light-sensitive color feature, 5 images of back lighting and 5 images of front lighting were selected randomly (see Fig. 5). Then, in these images, pixels of background area and fruit area with different light condition were extracted to calculate the frequency histograms. Shown as Fig. 6, the green histograms represent the histogram of the background pixels, the

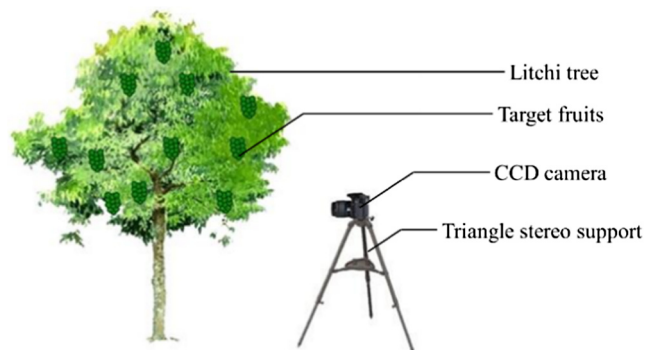


Fig. 1. Schematic of visual system and image acquisition.

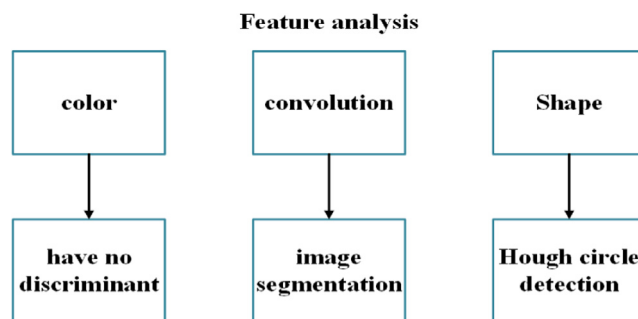


Fig. 3. Components and result of feature analysis.

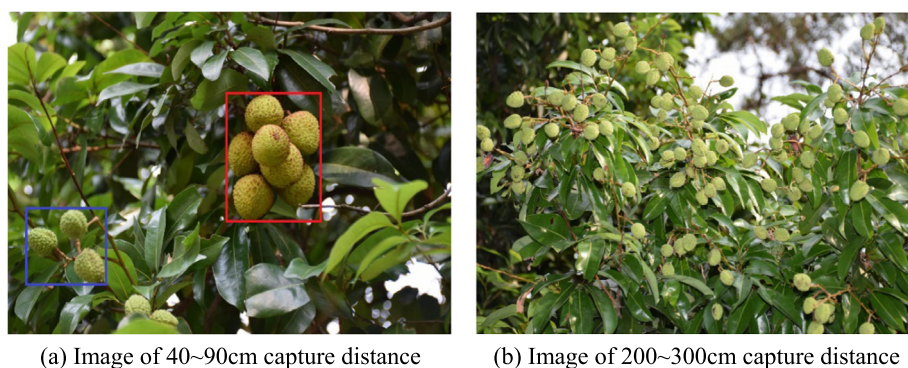


Fig. 2. Image of *Feizixiao* litchi. (a) Image of 40–90 cm capture distance. (b) Image of 200–300 cm capture distance.

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