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Weed detection using image processing under different illumination for site-specific areas spraying

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ABSTRACT

Large area bold type spraying of chemical herbicide is not only a waste of herbicides and labor, but also leads to environmental pollution and food quality problems. Traditional methods have the problems of high light and sample quality etc requirements. Therefore, accurately identifying weeds and precisely spraying are important strategies for promoting agricultural sustainable development. To avoid the influence of different illumination on images, this paper adopts the color model and then proposes component to gray images; the vertical projection method and the linear scanning method are combined to quickly identify the center line of the crop rows; the classic Weeds Infestation Rate (WIR) is modified to decrease the computational complexity and the improved horizontal scanning method is taken to calculate within cells; finally, Modified Weeds Infestation Rate (MWIR) is used to realize real-time decision through the minimum error ratio of Bayesian decision under normal distribution. The experimental results show that the accuracy of this algorithm is 92.5%, which exceeds the BP algorithm and SVM algorithm.

1. Introduction

China is a developing agriculture country, and agricultural development is closely related to its economic and social development. In the long-term management of agricultural production, weeds are always a strong threat to crops. Weeds hold the features of fast growth rate, larger growth increment, competing water, fertilizer, space with different stages of crops, which are harmful for crops growth (Xu, 2013). In addition, farmland weeding also affects the harvest speed, increases the operating costs and reduces economic benefit (Zhang et al., 2011). In China, farmland weeds are about 1500 kinds, of which there are 38 kinds of swart weeds, 94 kinds of regional weeds and 364 kinds common weeds (Wei et al., 2012). According to the Ministry of Agriculture and Plant Protection Station statistics, the amount of labor used in farmland weeding is up to 20–30 million labor days, farmland weeding accounts for 1/3–1/2 of the total workload of farm employment, and that causes an average of 13.4% of food losses and about 17,500 kiloton per year (Wu, 2010).

At present, China mainly adopts large bold type chemical herbicide spraying which cannot accurately determine the distribution of crops and weeds, therefore, it results in not just low utilization rate of herbicides, but also some serious problems like environmental pollution, chemical pesticide residue, weeds resistance, and ecological and safety of agricultural products. Besides, it goes against the concepts of human health, green environmental protection, and accurate and efficient modern agriculture. In modern precision agriculture research, to accurately identify the distribution of crops and weeds, and to spray on the weeds area only with the aid of vision technology can not only control weeds effectively, guarantee the quality of the crops and yield, but can effectively reduce the effects of chemical herbicide on the ecological environment. Therefore, accurate weeds identification is the obvious developmental trend of "precision agriculture" (Wu, 2010).

In consideration of the overall efficiency and cost, weeds identification mainly adopts computer vision method at home and abroad currently. It includes color-based identification, shape-based identification, texture-based and location-based identification. Li (2014) extracted a variety of distinguishing features of field crops through the ground imaging spectrometer data, and then combined multi-feature for weeds identification through SVM, whose result showed the weeds identification precision was high. What should be mentioned is that the training samples should be consistent, and there are higher requirements for the training samples in this method. Huang et al. (2013) took the three leaf stage, three rows of corn field image as the research objects, through establishment of mapping relation between actual field corn line width and line width images to determine the coverage scope

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based on identification rate and speed, and they got the weeds identification of 89.2%. However, this method is only applicable to equally spaced line width crops as three leaf stage. Yang and Li (2014)) used the BP neural network to identify weeds, and the weeds identification precision was higher. But the accuracy can be affected by the selection of training samples. Manh et al. (2001) detected the end of leaves, and deformed the model to match the blade. However, this method is only limited to the unobstructed blade edge. Gebhardt and Khbauch (2007) used morphological method to achieve images segmentation and obtain weeds leaf images, then they used the color and texture features for weeds identification. Their weeds identification rate was about 90%. But, there are problems like the complex calculation, slow identification speed, and poor real-time capability in this method. Tellaeche et al. (2011) combined basic suitable image processing techniques to extract cells, and used Support Vector Machines to determine if a cell must to be sprayed. But, this method is only applied to green plant characteristics is apparently.

Many traditional chemical herbicides spraying methods are no longer suited to modern agricultural development. "Precision agriculture" will become the future trend of agricultural development, and weeds identification is an important part of it (Zhao et al., 2003). Based on the studies in China and abroad, this paper aims at the effect of field illumination on images segmentation, converting the *RGB* images to *YCrCb* color model, and adopting the *Cg* component that is unrelated to different illumination for images graying; for the histogram of *Cg* component has double peak properties, this study utilizes global threshold method for images binary; to quickly identify the center line of the crop rows, this study combines the vertical projection method with the linear scanning method; to reduce the correlation and computational complexity between each component, the Weeds Infestation Rate (WIR) is improved to the Modified Weeds Infestation Rate (MWIR), and the improved horizontal scanning method is taken for calculating MWIR within the cells; Finally the minimum error ratio of Bayesian decision under normal distribution is used to realized online variable spraying. Flow chart is shown in Fig. 1.

2. Image acquisition and preprocessing

2.1. Image acquisition

In this paper, the 1300 images were taken in the experimental plot in north campus of Northwest A&F University, May to July, 2013; they were taken in different light conditions (sunny, cloudy), periods and plots; they were collected by manual collection. Also, The camera was fixed on the console. The image size is $4208 * 3120$ and format is *JPEG*. Acquired images are shown in Fig. 2.

2.2. The selection of color space

Color is an important characteristic of the plant identification. Because the images in this paper were under different light conditions, which can be easily affected by many environmental factors, therefore, in order to more accurately identify crops and guarantee the accuracy of identification algorithm, appropriate color feature vector selection is critical and a suitable color space is the prerequisite.

Color space, also known as color model, uses the coordinate system or subspace to describe colors (Meng et al., 2014). At present, the most commonly used color space models are *RGB*, *HSI* and *YCrCb*. For *RGB* color space model, all sorts of colors are gotten by *R* (red), *G* (green), *B* (blue) three color channels transformation and mutual superposition. All colors that humans can perceive can be expressed by color space model (Yang and Zhu, 2010), but the three color channels are highly correlated, which are more sensitive to the changes of lightness (Meng et al., 2014). Because the images of this paper were easily affected by lightness, it could result in information uncertainty of images segmentation and reduce the accuracy of images segmentation precision by using the *RGB* color space model for images processing. *HSI* color space model uses *H* (hue), *S* (saturation) and *I* (intensity) to represent. In different light conditions, *H* component is not obvious and can identify objects in different colors, so it is more suitable for processing images that are sensitive to illumination changes. However, the *H* and *S* color components are nonlinear transformation by *R*, *G*, *B* component, which have singular point, so it can affect images segmentation precision and computational complexity (Lin and Hu, 2012). In *YCrCb* color space model, *Y* represent rightness, *Cr* and *Cr* represent red and blue concentration offset component. In this color space model, the luminance and chrominance are separated, which is more suitable for processing images that are sensitive to illumination changes. Because the farmland images are mainly green component, the *YCrCb* color space model lacks the differences of green signal and light brightness, so this paper adopted the *Cg* component to describe the green crops features (Meng et al., 2014). *Cg* component can be obtained by matrix transformations from *RGB* color space model. Thus, conversion algorithm was simpler and calculation was smaller. The conversion formula is as shown in formula (1) Ghazali et al., 2012.

$$\begin{bmatrix} Y \\ Cg \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -81.085 & 112 & -30.915 \\ 112 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}. \quad (1)$$

2.3. Image preprocessing

Gray images contain only luminance information, no color information. In order to extract the plant characteristics and process images accurately, color images must be converted to gray images (Liu et al., 2013). Due to the different light conditions of images acquisition, this paper selected the *YCrCb* color space model with the introduction of *Cg* component gray images. Conversion results are as shown in Fig 7(b), (f), (j).

When being converted to gray images, the gray images can be binary to segment crops and soil background. As shown in Fig. 8 (a), (d), (g), the histogram of the images has double peak properties in which it is better to use global threshold (He et al., 2008).

In the process of images acquisition, some factors such as insufficient light, uneven exposure can result in images noise. Meanwhile, there were still many dummy white pixels such as plant shadows, plant residues after binary processing, which would affect the accuracy of WIR. Therefore, removing the noise pixels was necessary. After experimental comparison (Liu et al., 2013), it was found the effect of median filter was remarkable in pulse interference, salt and pepper noise, and Gaussian template for Gaussian noise effect was obvious. So, this paper mainly adopted median filter, supplemented by Gaussian template.

3. Identification of the center line of crop rows

At present, line detection algorithms mainly include Hough transform and perspective method. Hough transform uses the duality of point-line, that is to say, after transforming the line in the original images space coordinate system into the points in the parameter space, and then accumulating and counting all the possible points that falling on boundary line to finally complete the detection task (Duan et al., 2010). By using the global feature of an image, the robustness of the Hough transformation is strong,