# Machine vision system used for real-time detection inter-row weeds

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**Abstract**: A machine vision system to detect inter-row weeds was developed and tested in the lab. The hardware system was mainly made up of a soil-bin device with controllable velocity carriage, 3 CCD cameras used to capture the images and a PC. The software system was developed to transform color images to binary images by the color feature of plants and background, and to distinguish crops and inter-row weeds by the location feature of crop within the field. It indicated that the mean of executed time of capturing and processing a color image (710×512 pixels) was 426 ms, and the correct classification rate of the system was 86%.

**Key words**: machine vision; image processing; real-time detection; inter-row weeds
**CLC number**: TP391.41; S365; S377 **Document code**: A **Article ID**: 1002-6819(2003)05-0114-04

## 1 Introduction

At present, uniform spraying is widely used to herbicide application in China. The approach is based on the assumption that weeds are distributed evenly in fields. However, the distribution of weeds is often "patchy", rather than "even"[12]. Therefore, herbicides should be only applied in the weed-infested areas to save herbicides and diminish herbicidal loadings to the environment. In site-specific crop and weed management, spot spraying is used instead of uniform spraying[2]. To realize spot spraying, the first step is to detect weeds. Now, weed detection using machine vision is the main means.

The plant features of shape[3,5,9,14], texture[8,11], spectra[12] or color[1,4] were utilized in the machine vision systems to detect weed for the determination of the precise location, density or species of weeds within the field. But most of research was done in static state. Only a few systems were achieved in real-time. Lee et al. developed a real-time intelligent robotic weed control system for selective herbicide application to in-row weeds using machine vision. The system could take 0.34s to process one image, representing a 11.43 cm×10.16 cm region of seedline containing 10 plant objects, and travel at a continuous rate of 1.20 km/h. Two features, ELG (Elongation) and CMP (compactness), were found to provide the optimal Bayesian classifier for the images. The correct classification rate of tomatoes and weeds achieved 73.1% and 68.8%, respectively[6,7]. Ge Fan et al. developed a real-time color-based weed detection system in laboratory. The system could process images at a rate of up to 10 frames/s, which corresponded to a vehicle ground speed of 4 m/h. The highest accuracy classification rates of weeds were only 39.4%[4].

The location feature is also one of plant feature, but it is rarely used to segment weeds and crop. At present, there were someone reported that it had merits in application to use plant location to determine the scope of spraying herbicides at seedling[10]. Therefore, the location feature of plant was studied in this system.

The location feature of plant in fields indicates that the crops usually are sown by rows, and the weeds lie in the inter-row and (or) in-row crops. Therefore, the main procedure of weed detection was to determine the location of crop rows firstly, to detect inter-row weeds secondly, and to classify in-row weeds lastly. At the preliminary stage, the main objectives of this study were:

1) To develop image processing algorithms used color and location features to detect inter-row weeds.

2) To test the software and hardware system based on machine vision under laboratory conditions.

Received date: 2003-09-05
Foundation item: National "863" Foundation of Development and Plan of High-New Technology (2001AA245012)
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## 2 Methods

### 2 1 Hardware system development

Figure 1 was an image of the laboratory setup for experiment which consisted of an indoor soil-bin device simulating the movement of a spraying vehicle in field, containers in which crop (wheat) and weeds (Schur et al) were grown, 3 CCD cameras mounted on the soil-bin carriage, an electrical box controlling the speed and a PC-based data acquisition system.

The soil-bin device had an effective length of 6 m. The carriage of the soil-bin traveled at an adjustable ground speed ranging from 1 to 4 km/h. The cameras used were color CCD cameras (Panasonic WV-CP460) with a resolution of 753 × 582 pixels and a shutter speed of 1/500 s They were vertically mounted at the height of 55cm above the soil surface The C-mount lens with a focal length of 16 mm and an iris control of f/1. 4～f/16 were used The actual field of view was 57 cm ×39 cm, digitized into 700×512 pixels The S-video outputs of the cameras were routed to a color frame grabber (Daheng DH-CG300) resided in a P4 PC with 256 MHz CPU and 256M RAM. The frame grabber had a resolution of 768×576 pixels When the BWD software system was triggered, the images were grabbed and written to Windows bitmap files The light source used in the experiment was two 600W Tungsten Halogen lamps The wheat seedlings were planted in 20 cm row spacing and the cameras were positioned over the center of the area between two rows

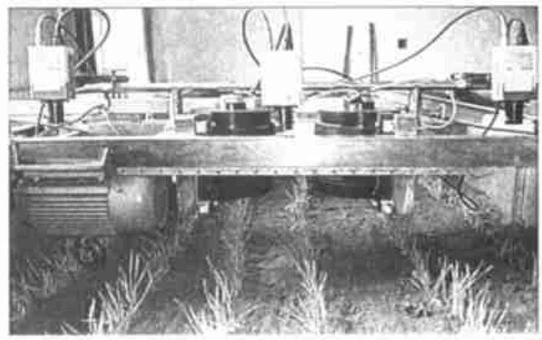

Fig. 1 Lab set up for experiment on real-time inter-row weed detection

### 2 2 Software system development

According to the location feature of plant at seedling and the color feature of plant (green) and soil, the software system of the "Inter-row Weeds Detection System" was developed in Microsoft Visual C++ 6. 0 (enterprise version). The main steps were:

1) It was obviously seen from the Fig. 2a that plants (crop and weeds) were green and background mainly was soil, withered plant residue and gray rocks Therefore, the color feature was used to segment plant and background[13]. According to the statistical analysis result of the RGB triplet of plants and background in the captured color images, a novel color index (G - R, G - B) was explored to directly transform 24-bit RGB source image to binary-image The result of transformation was showed in Fig. 2b.

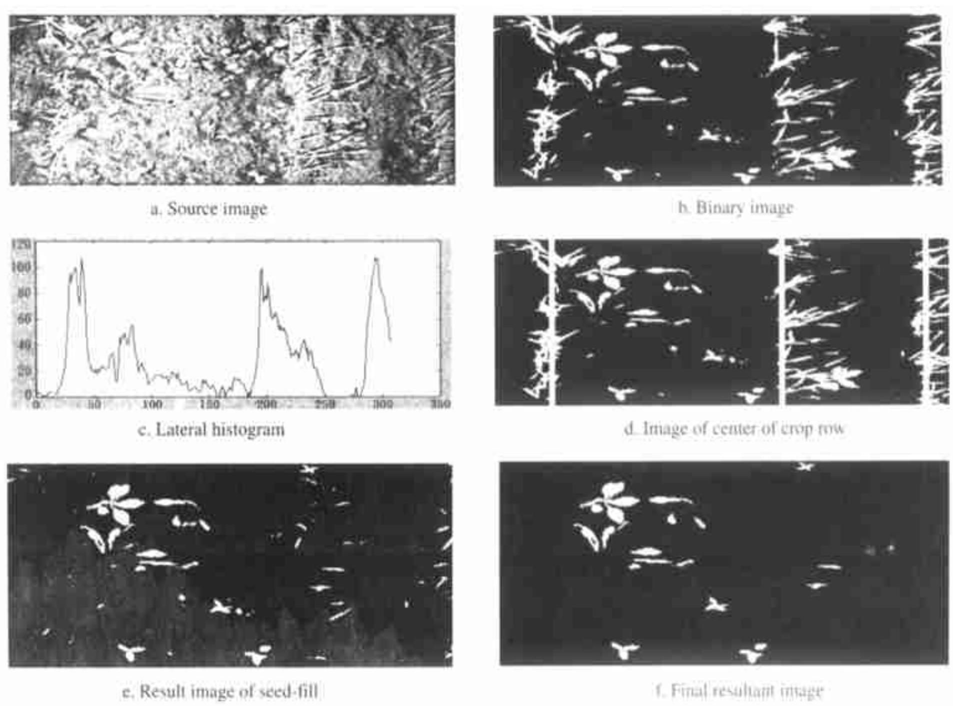


Fig. 2 Images of objecives at different processings

2) According to the location feature, the lateral histogram in which plant pixels were summed per columns (in the row crop direction) to determine the location of crop rows was drawn. It was seen from Fig. 2c that the center of crop row was corresponding to the peak. As Fig. 2d showed, the center of crop row was lined out with white line in the center of crop row.

3) Most crop pixels lied in the crop row. Namely, these pixels connected with the center of crop row numerously were crop pixels, and a few of them were weed pixels because of the overlapping of crop and weed leaves. Therefore, the seed-fill algorithm was used to remove the crop pixels connected with the center of crop row. The result of filling was showed in Fig. 2e.

4) Seen from the Fig. 2e, inter-row weed pixels and a few crop pixels unconnected with the center of crop row were reserved. To reach more precise, the shape feature of weed and crop leaf was used to remove the remained crop pixels. Above all, the particle-erasure algorithm was used to remove the noise (the area of region was less than 5 pixels). Afterwards, the region-label algorithm was utilized to label the remained plant zeroes (most weed pixels and a few crop pixels). At last, the shape analysis algorithm was used to compute the ELG (Elongation) shape feature to remove the left crop pixels. The final between-weed detected result was shown in Fig. 2f.

### 2.3 Test the performance of system

To test the performance of the developed system, 100 frames images were taken and processed in one day while the carriage of the laboratory set-up was moving with a forward travel speed of 2.4 km/h. The performance indices of the detection system were evaluated using the correct classification rate (CCR) and misclassification rate (MCR) which were defined as follows[4]:

$$CCR = \frac{N_{wt}}{N_w}, \quad MCR = \frac{N_{wd} - N_{wt}}{N_s - N_w}$$

Where, $N_{wt}$ and $N_{wd}$ are the number of truly classified and totally detected weed pixels in the finally resultant image, respectively. $N_w$ and $N_s$ are the total number of detectable weed pixels and all pixels in the source image, respectively.

## 3 Results and discussion

The result of experiment showed that the mean of executed time of capturing and processing a color image (710×512 pixels) was 426 ms, and the means of the CCR and MCR of system were 86% and 12%, respectively.

Compared with the intelligent system developed by Lee et al.[6,7], this system was superior in the size of field of view. In the way of the accuracy classification rate, this system was better than the color-based system studied by Ge Fan et al[4]. However, only inter-row weeds were detected in this system.

It was discovered that the CCR and MCR were affected by the degree of the overlapping of crop and inter-row weed leaves and the performance of segmentation from plant to background. Moreover, new algorithms should be developed to detect in-row weeds, which will expand the run time of software system. Therefore, faster algorithms are needed to satisfy with the real-time request. After that, considering the infield factors such as sunlight, weed, carriage's speed, further experiment should be done to test the adaptability of the detection system.

## 4 Conclusions

1) A machine vision system for real-time weed detection was accomplished and elementarily tested in the laboratory set up.

2) Using color and location features, inter-row weeds were successfully classified from a color field image.

3) The CCR and MCR of the system were 86% and 12%, respectively.

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# 实时识别行间杂草的机器视觉系统

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**摘 要**: 在实验室环境条件下, 开发和测试了识别行间杂草的机器视觉系统。硬件系统主要由速度可控的土壤箱设备、三台实时采集图像的摄像机和计算机组成; 软件系统根据植物和背景的颜色特征二值化图像, 再根据田间作物的位置特征识别作物和行间杂草。实验表明, 采集并处理一幅大小为 710×512 像素的彩色图像的平均时间为 426ms, 系统的正确识别率达到了 86%。

**关键词**: 机器视觉; 图像处理; 实时识别; 行间杂草