Determination of weed coverage percentage using digital images

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Abstract

The objective of this study was to access the performance to discriminate plant and background of an algorithm for percentage of weed cover determination using techniques of digital image processing. The algorithms were developed using LabView software. To evaluate the algorithm a study was performed in a 0.8-hectare experimental field irrigated by a center pivot system and planted with common bean crop. The field was divided in half and equally cultivated under no-till and conventional agricultural practices. The image acquisition system consisted of two cameras, one color (RGB) and the other near infrared (NIR), which acquired simultaneously two images of the same scene. The results showed that the highest overall accuracy was obtained with the RGB images in both tillage systems. Thus it was possible to deduce that the color camera would be most suitable to calculate the weed coverage percentage in both tillage and no-tillage systems.

Key words: digital image processing, precision agriculture, common bean.

1. Introduction

According to the Food and Agriculture Organization of the United Nations (FAO), weeds are considered the farmer number one enemy. The damage they cause to crops in the world comes to US$ 95 billion per year, with a decrease in production. If farmers want to increase the productivity of their crops, they should improve the weed control (FAO, 2010).

One of the most effective means to combat the weed growth has been the herbicides application. The conventional weed control method applies chemicals where there is no weed by using a uniform rate of herbicide. Doing site-specific weed control can help farmers improve the use of agricultural inputs, improve the crop quality and mitigate the environmental problems.

The use of machine vision systems has been studied for site-specific application of herbicides (Gée et al., 2008). Digital image processing techniques can be used to calculate the weed coverage percentage. This variable is an useful tool to show the dynamic of the weed spatial variability, as well as to assist in site-specific herbicide application.

The objective of this study was to access the performance to discriminate plant and background of an algorithm for percentage of weed cover determination.
2. Material and Methods

This study was conducted in a 0.8 ha experimental field irrigated by a center pivot system with common bean crop. The field was equally divided between half cultivated under no-till and other half under conventional agricultural practices.

2.1 Image Acquisition System

The image acquisition system consisted of two cameras, one monochrome with an infrared longpass filter, and one color. Thus, it was acquired four images representing R, G, B and NIR spectral bands with dimensions of 480 x 640 pixels each, representing 4.9 x 6.5 m of the field. More details about the image system can be found in (Silva Jr et al., 2012).

The system was attached to the center pivot structure and pointed down to focus the crop rows. While the center-pivot structure was running on its circular trajectory, the cameras were manually moved on the center pivot structure to acquire sample images over the entire field.

2.2 Image Processing and Analysis

An image processing algorithm was developed in the NI LabView® environment to output the percentage of weed cover in each image. Firstly, plants in the image were discriminated from the background. Then, the identified plants were classified as crop and weed by detecting the crop row location. Finally, once the crop rows were identified, the other segmented plant pixels were summed to estimate the weed cover in each image.

The crop rows were segmented on the color and NIR images using the iterative method proposed by Yang et al. (2001). Instead of thresholding the color images, the segmentation was done on the normalized excess green images (Meyer et al., 1998):

\[ Evd = \frac{(2 \times G - R - B)(G + R + B)}{\sqrt{(2 \times G - R - B)^2 + (G + R + B)^2}} \]  

After segmentation, opening and closing morphological operations were applied for noise reduction and to obtain a filtered image. Then, the angle of the crop rows in the binary images was determined using the Hough Transform (Duda & Hart, 1972). The crop row angle was used to rotate the image until to set the crop rows vertically. A block of 320 (V) x 480 (H) pixels was cut in the center of the rotated image. Summing each column of the image block, the algorithm identified the position and the width of the crop rows and removed them, leaving only plants identified between the crop rows. Finally, based on the number of pixels representing plants between crop rows, the percentage of weed cover was estimated for each image. The image processing steps are shown in Figure 1.
2.3. Evaluation of Image Processing Algorithms

To evaluate the algorithm, it was randomly sampled 10 NIR images and 10 color images, in each planting system. These images were processed by the algorithm. On each of the processed image, 100 pixels were randomly sampled to estimate the overall accuracy and Kappa index from confusion matrix as described by Hudson and Ramm (1987).

FIGURE 1: Images processing steps for estimating the percentage cover of weeds between crop rows.
3. Results/Conclusions

The algorithm performance was accessed using the confusion matrices (Tables 1-4).

<table>
<thead>
<tr>
<th>TABLE 1: Confusion matrix for color image and conventional tillage field</th>
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<tbody>
<tr>
<td>Estimated Value</td>
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<tr>
<td>Plant</td>
</tr>
<tr>
<td>Plant</td>
</tr>
<tr>
<td>No-Plant</td>
</tr>
<tr>
<td>Erros of Omission (%)</td>
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Kappa = 0.65

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<tr>
<th>TABLE 2: Confusion matrix for NIR image and conventional tillage field</th>
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<tr>
<td>Estimated Value</td>
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<tr>
<td>Plant</td>
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<tr>
<td>Plant</td>
</tr>
<tr>
<td>No-Plant</td>
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<tr>
<td>Erros of Omission (%)</td>
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</tbody>
</table>

Kappa = 0.30

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<th>TABLE 3: Confusion matrix for color image and no-tillage field</th>
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<tr>
<td>Estimated Value</td>
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<tr>
<td>Plant</td>
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<td>Plant</td>
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<tr>
<td>No-Plant</td>
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<tr>
<td>Erros of Omission (%)</td>
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Kappa = 0.71

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<tr>
<th>TABLE 4: Confusion matrix for NIR image and no-tillage field</th>
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<tr>
<td>Estimated Value</td>
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<td>Plant</td>
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<td>Plant</td>
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<tr>
<td>No-Plant</td>
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<td>Erros of Omission (%)</td>
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</tbody>
</table>

Kappa = 0.40

For both systems, tillage and no-tillage fields, the algorithm presented better performance when processing color images. Thus, the discrimination between plant (weed and crop) and background (soil and residue) using the excess green index was greater than NIR images.

Figure 2 is shown an example of the most discrimination power of the color image. The binary image from NIR tended to mix up the residue and soil background with plant, increasing the width of the detected crop row and increasing the weed coverage area.

The Kappa values indicated that all classifications between plant and non-plant for the images processing were better than a random classification (Kappa greater than zero). According to the criteria used by Landis and Koch (1977) for evaluating Kappa values, the algorithm performance using color camera was considered very good. Using NIR images, the algorithm presented a fair, according to those authors.
FIGURE 2: Example of the common error of the algorithm when using NIR image: (A) original color image, (B) binary image from color image and (C) binary image from NIR image.

Finally, it is possible to deduce that the color camera would be most suitable to calculate the weed coverage percentage in both tillage and no-tillage systems.

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5. References


