Designing algorithm for detection of crop rows by using machine vision for use in variable rate systems

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ABSTRACT: Conducting agricultural machines within the farm rows for tillage operations, especially the planting operation (thinning, weeding and spraying), and harvest, in addition to high sensitivity and need to high precision, has a lot of fatigue for the driver. Methods of automated guided machines in the field are, A) directing according to crop rows or previous operations, such as plowed rows, planted rows, and harvested rows; B) directing based on Global Positioning System (GPS). This study aims to provide a new approach for detecting the crop rows based on the Hough transform on the grey scale on the images by using machine vision technology. Images analyzed in this study were taken using a digital CCD camera (Sony Cyber Shot w200) from sugar beet fields in Naghadeh city in the period the plant has 4 to 6 leaves in order to thinning and weeding. In order to remove the soil background and detect the plants, different color spaces and transformations were analyzed by the MATLAB R2011b software. The results of image analysis in different spaces indicated that RGB color space and conversion (combination) of (2R-G + B) is the best choice to remove the crop from the soil background. The main source for making error in the algorithm for detection of crop rows is the weed in the pictures. Results showed that the designed algorithm is able to detect the rows of sugar beets in their growth stages. The average error in detection of crop rows in real conditions was 24 mm and the average processing time was 0.12 seconds per image.

Keywords: Machine vision, Hough transform, Sugar beet, precise agriculture, and Automatic guidance.

INTRODUCTION

Precise agriculture is one of the major achievements of modern technology in order to manage the natural crop production. Precise Agriculture in the National Research Council of America (1998) is defined as a management strategy by using data from various sources and technologies associated with the production decisions. One of the ways to reduce chemicals use is applying precise techniques in farming operations, so that, the use of chemicals is made the least, and their effect is made insignificant. The use of automated guided machines not only reduces the user's fatigue, but also increases the efficiency and safety of operations. In the farms, the main usage is controlling the weeds and thinning. In the Netherlands, one hectare of sugar beet on average requires to 73 hours of hand weeding [Van der Weide et al. 2008]. One way to improve robotic in agriculture is to use vision sensors. Another application for detection of rows is in planting operation. Robotics can play a significant role in this regard. Image classification is a critical task in use of machine vision techniques in precise agriculture. The algorithm which is to be written based on the attributes such as color or intensity, because of the considerable overlap between the three color classes in every dimension of color spaces that are usually present, is rarely accurate enough. The traditional application of herbicides is based on the assumption that weeds are distributed uniformly in the field. Most of researches are conducted in order to develop practical techniques for weed detection and control of herbicide spraying. With regard to contamination of the surface of the farm by debris from the weeds and their seeds, weeding is inevitable. Akmato et al (2002) used an automated vision machine in order to detect the crop row for automated guidance, and moves a moving cultivator which is equipped with hydraulic suspension system for fighting weeds between the rows. In the second case, due to the complexity and the very different conditions in the field, researchers have always been simplified in this regard. Examples are research in laboratory conditions with controlled light, using the
same soil texture, or to take photos so that only a single plant or weed is in the picture. Tang and Tian (2002) have used machine vision to determine the distance between corns. The average error of less than 10 mm occurred at the least correction. Sugart and Olsen (2003) used machines to detect crop rows. The environment for photograph capture is a moving frame with the speed of 0.5 meters per second and taking three pictures per second. Their experiments showed that they can detect the position for planting rows with approximately 6 ± to 12 ± mm error, which depends on the product development around the central line. Using machine vision, Lee et al (1999) designed a robot for weed control in tomatoes, in which the processing time for each image is 0.34 second. They used two halogen lamps together with the angle of 30 degrees. They used aerosol spray solenoid system in the machine. The overall results showed that 24 percent of the tomatoes were incorrectly identified, and 52.4 percent of the weeds were not spraying. Weed control robots are comprised of two machine vision systems. The first system is in the gray scale and has the ability to detect the crop rows in order to guide the robot along the rows of crop. And the second system is based on a color scale, and has ability to distinguish between weeds from the main crop. These robots only have the ability to control weeds between rows, and are not able to control weeds within the rows.

This study is conducted in order to develop a machine vision system based on: A) isolating the vegetation from the background of crop, B) isolating and detecting the crop row. Acting at real time is a goal for this system, so that it can be used as a real-time, without interruption to the variable speed. This study presents a new method to detect crop rows based on Hough transform, to guide the machine between rows of crops with the appropriate speed and precision [Romeo et al, 2012] and [Slaughter et al, 2008].

MATERIALS AND METHODS

One of the major industrial products is the sugar beet, that provides a part of the food needs of people directly and indirectly. Sugar beet is distinguished in four crops, such as sugar beets, red beet, forage beet and leaf beet. Sugar beet is planting in rows, and the growing problem of planting it is weed control between rows, within the rows, and their thinning. Planting line spacing is 50 to 60 centimeters, and the space between plants in a row is 16 to 20 cm. These spaces must be adjusted to obtain the number of 100,000 plants per hectare. Remove the weeds between the rows is simpler than within the rows, since between the rows it is only necessary to identify the row, but within the rows, in addition to identifying the row, we should be able to distinguish the plant from the weeds.

Imaging and image acquisition: This research uses a database of images at three farm with planting Sugar beet with pneumatic planter by bush density of 100000 to 200000 in hectare, from late April to early June in spring 2011 in city of Naghadeh. These images are taken by CCD digital camera Sony Cyber-Shot W200 with 1538 * 2048 pixel resolution, and in Jpeg compression format, and vivid color (as data of) 24-bit in natural and uncontrolled conditions in terms of light and shadow, in different hours of day, and in different weather conditions. In order to do that, we used a frame for placing the camera in 1 and 2 m height, and in vertical 40 and zero degree angles in the farm [Bakker et al 2008].

Preprocessing

At this point, the preparatory works are performed in order to improve and enhance the quality of images to obtain the desired result. At this stage, the appropriate features are extracted from the images for classification and determining the number and location of the crop (Figure 2).

Image processing

In this stage of product characteristics for classification and determining the number and locations of the images are extracted. In this research, in order to image processing, MATLAB R2011b software [Gonzalez and Woods. 1992] Image Processing Toolbox under Seven operating system (Windows 7), and computer with hardware specs of (Processor: Intel ® Core (TM) 2 Duo CPU E7400@2.8 GHz, Installed memory: 2.00 GB RAM, System type: 32-bit Operating System ) is used. 400 pcs of digital images are used in different natural lighting conditions. Natural lighting is significantly varied by weather conditions, observation direction, time of day, and geographical position. Thus, the use of natural light is quite different from artificial lighting conditions, because in terms of quality, it can not be standardized and sustained. In addition to the quality of light, the physical limitations of the hardware used to capture the image caused noise by both systematic and random pictorial data. The main role of image processing is making change in image data, and creating a new image. So that in the new image, the desired part of the picture are improved in terms of quality or its noise impacts are reduced or completely eliminated. Detecting the crop rows by using machine vision has some problems, which makes it different with other applications of this technology, such as separating and classifying the agricultural products. Moreover, different parts of the plant have also different colors. In field conditions, light intensity is uncontrolled, and shading of plant on each other, and machinery and other obstacles on the plants, and change in the angle of radiation change the light intensity. The written and developed algorithm detects the
rows automatically, and eliminates the weeds between the rows (Fig. 2). The algorithm detects the matching scan of the position for the edge of the product. Using the profiles plotted in Figure (1), the green component of the plant can be used to separate the background. Valley of the histograms (Fig. 1 d) can be used as the threshold values used to separate the plants from the background. Thus, in separation the equation (1) can be used in a way that it would be indifferent to changes in light intensity.

\[ \text{Indicator} = 2G - R - B \quad (1) \]

Using this relationship, and choosing the zero threshold, the plant can be separated from the background soil [Søgaard and Olsen, 2003].

Figure 1. Example of the profile components of the main pictures. A) Profile of the Sugar beet. B) Profile of a type of weed. C) profile of the soil background. D) Histogram of the green component.

Figure 2. shows the preprocessing steps. To remove the noise in binary images, Opening, Closing & Reconstruct functions were used. After pre-processing stage, Hough transform was applied for the image noise removal.

Figure 2. pre-processing operation on the image: a) original image for Sugar beet farm. B) The image of the red component. C) green component G. Image d) Blue component image B. e) surplus vegetables image or picture of the linear combination. f) Ottsu thresholding and removing the soil background. G) The final image after morphological processing by instructions strel (‘disk’, r), imerode (pic, s), imreconstruct (erode, pic) for noise removal.

RESULTS AND DISCUSSION

After preprocessing and removing soil backgrounds, the final images are processable, and the results are the Hough transform. The results of the Hough transform are in the form of figure (3). In Figure (3 d) cultivation row is marked with white lines. In order to evaluate the algorithm for crop rows, we use the centration method. In this method, after removing the soil background, we label all plants. Once a labeling, we assign one center to each plant, and then mark the distance to the center, and the Hough transform is calculated (Figure 4).
After processing 400 image by the designed algorithm, and assessing the rows detected by measuring the distance from the center row of plants on the row to the line drawn by the Hough transform, the error was 24 mm, and the mean time for processing each image was 0.12 s. Comparing the results with results from other researchers models, a perfect match can be found [Søgaard, and Olsen. 2003], [Lee, W. S et al. 1999].

REFERENCES