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A Software Development for Real Time Spray Control System in Herbicide Application

Ömer Barış ÖZLÜOYMAK[1*], Ali BOLAT[2], Ali BAYAT[1], Emin GÜZEL[1]

[1] Çukurova University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, Adana/Turkey

[2] Republic of Turkey, Ministry of Food Agriculture and Livestock, Eastern Mediterranean Agricultural Research Institute, Adana/Turkey

*Corresponding Author: ozluoymak@cu.edu.tr

Abstract

Advances in different technologies, such as high-resolution vision systems, innovative sensors and embedded computing systems, are finding direct application in agriculture. In precision farming, image analysis techniques can aid farmers in herbicide applications, and thus lower the risk of soil and water pollution by reducing the amount of chemicals applied. Optical sensors and computer vision, which can be used in automated weed detection and control spray systems, are being used in recent years extensively. A real-time auto tracking and determination system for weed detection and spray on/off were designed, built and set up in the laboratory at the Department of Agricultural Machinery and Technologies Engineering of Çukurova University. In this study; to get the target images, a web camera, mounted at a height of 50 cm above the target object was used. During the start of the weed tracking operation, the web camera captured images of the artificial weeds. Developed software, which could be reprogrammed and adjusted according to the user preference, was created by using LabVIEW. Weed coverage was determined from each image by using a "greenness method" in which the red, green, and blue intensities of each pixel were compared. The sprayer nozzle was turned 'on' or 'off' by using a data acquisition card and a relay card, depending on the green color pixels of weeds. The sprayer valve opened the nozzle when the camera detected the presence of weeds. Image processing performance of this system, in where nozzle and camera were mounted at a stationary position while weeds were on a movable belt, was tested at the different speeds of conveyor belt consisted of an inverter drive system and 3 phase 4 pole electric motor. The laboratory performance evolution revealed that the system could detect the weeds successfully and could be used to decrease the herbicide quantity.

Keywords: Image processing, LabVIEW, Machine vision, Weed detection

INTRODUCTION

Weed control is a significant issue in agricultural crop production (Slaughter et al., 2008; Loni et al., 2014). Nowadays, there is a clear tendency of reducing the use of chemicals in agriculture. Numerous technologies have been developed trying to obtain safer agricultural products and lower environmental impacts.

The concept of precision agriculture provides a valuable framework to achieve this goal (Blasco et al., 2002; Tellaechea et al., 2008; Wan Ishak & Abdul Rahman, 2010; Sabanci & Aydin, 2017).

Especially, research on weed-sensing technologies, sensor fusion and selective crop management with herbicides or others control treatments have progressed significantly (Gonzalez-de-Soto et al., 2016). In addition to the technical realization of weed detection and site specific spraying, the economic benefit of precision weed management is important (Timmermann et al., 2003).

Detection and localization of weeds in the field, is one of the most challenging tasks for automatic weeding. Machine vision is a smart method that can be used to detect and track weeds. Tangwongkit et al. (2006) applied basic mechatronic and machine vision principles to develop a variable rate herbicide applicator to optimize the herbicide application rate corresponding to the amount of weeds by using Borland C^{++} builder program. Sabanci & Aydin (2017) stated that the weeds on sugar beet fields were detected using image processing techniques and a model for variable level spraying liquid application was actualized. The spraying liquid was applied only to the detected plants instead of the whole field with the PLC controlled system. Yang et al. (2003) reported that a digital camera was used to take a series of grid-based images covering the soil between rows of corn in a field. Weed coverage was determined from each image using a “greenness method” in which the red, green, and blue intensities of each pixel were compared. Weed coverage and weed patchiness were estimated based on the percent of greenness area in the images. This information was used to create a weed map. Using weed coverage and weed patchiness as inputs, a fuzzy logic model was developed for use in determining site-specific herbicide application rates. MATLAB was used to develop the fuzzy logic algorithm. Sabancı & Aydın (2014) stated that the weeds between rows in sugar beet fields were determined by using image processing techniques and a model of variable level herbicide application was applied on them with precision spraying robot developed by MATLAB. Shirzadifar et al. (2013) reported that a real-time, site-specific, machine-vision based, inter-row patch herbicide application system was developed and evaluated. The image frames were processed by LabVIEW and MATLAB. The developed algorithm, based on weed coverage ratio and segmentation method for separating soil from plants, was chosen to be 2G-R-B. Wan Ishak & Abdul Rahman (2010) stated that a machine vision technology was developed to identify weeds in the outdoor environments. The automated sprayer system was developed using the combination of the electromechanical system, controllers, and the software. The graphical user interface (GUI) software, which was used to control the whole automatic system, was developed by Visual Basic programming. Tian (2002) reported that the smart sprayer, a local-vision-sensor-based precision chemical application system, was developed and tested. This research integrated a real-time machine vision sensing system and individual nozzle controlling device with a commercial map-driven-ready herbicide sprayer to create an intelligent sensing and spraying system. Jafari et al. (2006a) stated that the relation between three main components (red, green & blue) of the images, which constitute the true color of different plants have been extracted from image data using discriminant analysis.

300 digital images of sugar beet plants and seven types of common sugar beet weeds at different normal lighting conditions were used to provide enough information to feed the discriminant analysis procedure. Discriminant functions and their success rate in weed detection and segmentation of different plant species have been evaluated. MATLAB was used for algorithm development. The objectives of this study were to develop a real-time site-specific spraying system, based on machine vision technology by using LabVIEW and to evaluate the developed system under laboratory conditions.

MATERIAL and METHOD

Material

The weed management system was consisted of a camera, an image acquisition and processing system, a data acquisition device (National Instruments, NI USB-6009), a relay card, a solenoid valve, a spray nozzle and other necessary hardware. The site-specific herbicide application system was only developed for a single row. The image of artificial weed frames were captured by a webcam (Logitech C270) and sent to a laptop computer (Acer, Aspire, 4830TG) through a USB port. The imaging system equipment and working values are given in Table 1. LabVIEW was used as image processing and automation program.

Table 1. Equipment and working values of the imaging system

amera	ensor	xel size	ısor size	l length	Iaximum esolution	orking stance	d of view
ogitech Webcam	CMOS	2.8 µm (square)	3.58 mm x 2.02 mm	4 mm	280 x 720 t the full frames	500 mm	60°

Image processing performance of this system, in where nozzle and camera were mounted at a stationary position while weeds were on a conveyor belt, was tested at the different speeds of conveyor belt consisted of an inverter drive system and 3 phase 4 pole electric motor. The site-specific spraying system as a prototype developed in this study was shown in Figure 1.

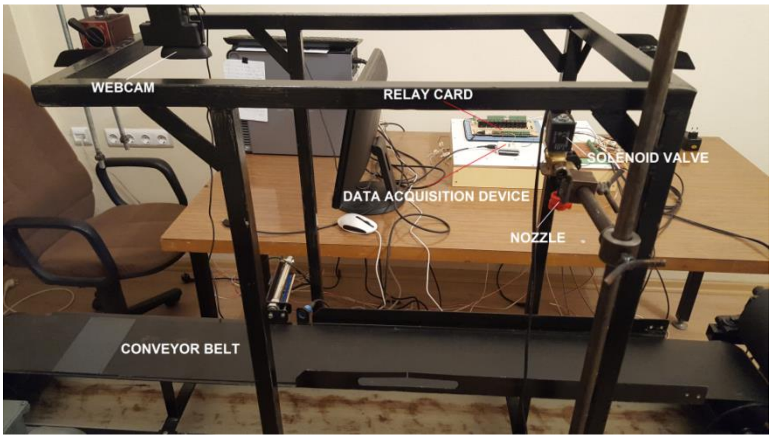

Figure 1. Prototype of real time spray control system developed in this study

Method

Each pixel of the image has three color components, which are red (R), blue (B) and green (G). Since the image pixels corresponding to plant leaves have a greater G component as compared to R and B, the segmentation method for separating soil from plants was chosen to be "2G-R-B (greenness method)" (Jafari et al., 2006b; Shirzadifar et al., 2013).

The segmentation method for separating conveyor belt background from artificial weeds was chosen to be "2G-R-B" because artificial weed image pixels have a greater G component than R and B components (Figure 2).

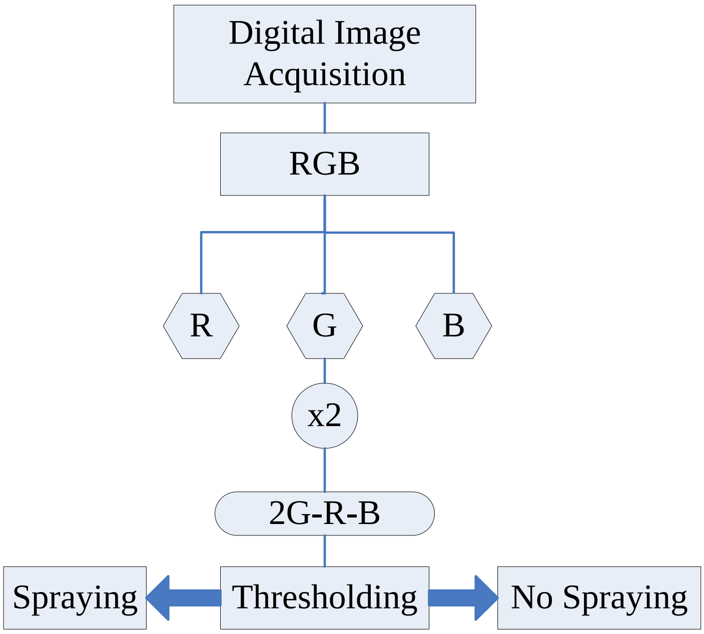

Figure 2. Flowchart of the image processing software

Artificial weed, which its pixels are larger than a preset threshold value, was tracked by the system. While it was moving on the conveyor belt, its x and y coordinate information were taken instantaneously. Spraying process was carried out by activating the solenoid valve while the artificial weed passing under the predefined coordinates in the system. The spraying continued according to the predefined coordinate values. The camera was mounted at a height of 50 cm above the artificial weed to get the images for experiments for which LabVIEW was used.

Evaluation of the Image Processing Algorithm

In this developed system, the artificial weed samples were separated into two categories as 'detected' and 'undetected' to evaluate the performance of the greenness method. It is very important that the system can distinguish the artificial weed and conveyor belt surface from each other. Correct determining and tracking has shown the performance of the image processing algorithm.

Laboratory Tests

The system was designed, built and set up in the chemical application laboratory at the Agricultural Machinery and Technologies Engineering Department of Çukurova University. It was tested to evaluate spraying accuracy of the sprayer at eleven conveyor speeds of 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75 and 3 km/h by using LabVIEW software program. The weed samples were being placed one by one manually on the conveyor belt. For each trial, a total of 100 artificial weed samples were used when making experiments.

Real-time auto tracking and spraying of artificial weed samples in the laboratory was shown in Figure 3. Only tap water was used as spraying liquid.

Figure 3. Real-time auto tracking and spraying of artificial weed sample in the laboratory

The system performance accuracy was calculated according to the conveyor belt speed for each test as shown in Equation 1. Each test was carried out three times to confirm the reliability of the system.

$$System\ Performance\ Accuracy\ (\%) = \frac{A}{B} \times 100 \quad (1)$$

In where, A is the artificial weed samples sprayed by the sprayer nozzle and B is the total number of artificial weed samples.

RESULTS and DISCUSSION

According to the results, artificial weed detection and tracking accuracy was determined by the greenness method. The effect of travel speed of the artificial weeds on conveyor belt was significant on system performance accuracy (Figure 4). The magnitude of spraying delay significantly increased by increasing travel speed. Several factors such as camera quality, solenoid valve response time, system pressure fluctuations resulting from sudden opening and closing of spray nozzles are considered to be responsible for the application delays observed in these tests. Reductions in the sprayed area could be attributed to the larger spraying delays at higher travel speeds. As shown in Figure 4, while identification and tracking efficiency of the system is %100 up to 2.75 km/h, maximum effective operating speed of the system has determined up to 1.5 km/h.

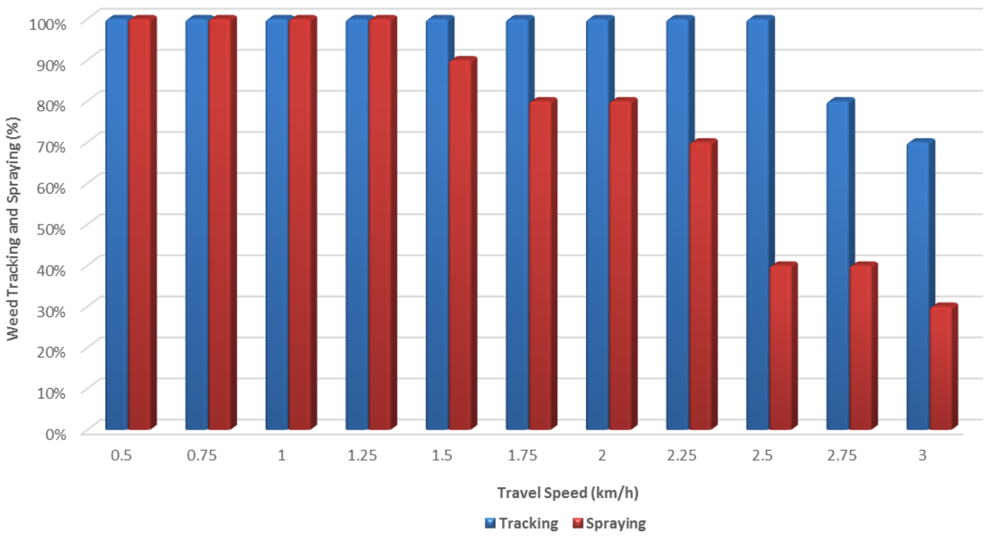

Figure 4. Test results of artificial weed tracking and spraying accuracy at various travel speeds

CONCLUSION

A real time, machine-vision based, site-specific, inter-row spraying system prototype was developed and evaluated in herbicide application. LabVIEW software was used by developing image processing and automation algorithms for this system. The accuracy of the tracking and spraying performance increased at lower travel speeds. High tracking, detection and timing accuracies are the most important advantages of this system. The laboratory performance evolution showed that the proposed system could successfully detect the weeds and could be used to decrease the herbicide quantity. It is obvious that it will provide economics in the use of herbicides when compared to conventional spraying method in the eradication of weeds. Such a system will be both environmentally friendly and cost effective. This study will be a model for researchers, who aim to work on similar topics, and it will have a positive effect on system design in similar areas.

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