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Microcontroller based roller contact type herbicide applicator for weed control under row crops

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ABSTRACT

A microcontroller based manually operated three row roller contact type herbicide applicator was designed and developed for control of the weed population in field crops. A control system was developed to apply the quantity of the herbicide based on quantified weed information. The unit consists of a camera for capturing the images of weeds, MATLAB software for image acquisition and processing in a laptop, a serial port communication for communicating between laptop and controller, a microcontroller for controlling the application of herbicide through a relay, and a dc solenoid valve for variable rate application of herbicide on the applicating roller. The captured image was analyzed by the image processing toolbox in the MATLAB software, to extract weed information in the image, which is then transferred to a microcontroller using serial port interface. The microcontroller activates the solenoid valve using a relay according to algorithm for decision of the herbicide amount. Field test results of the machine indicate an average of 50% saving in the amount of herbicide, with weeding efficiency of 90%.

1. Introduction

Weeds are plants, grown in unwanted areas, which impair the quality of farm produce and reduce the crop yields. Conventional farming system, apply high amount of herbicide. In order to reduce the herbicide application in agricultural fields, protect the environment and ensure water saving, precision application of herbicide is required. As herbicides became available, they gradually replaced cultivation as a method to control undesirable vegetation (Sprague, 1986). The conventional practice of applying herbicides uniformly across a whole field seems undesirable from both economic and environmental view points (Christensen et al., 1996). The most common type of herbicide application in India is direct spraying with the help of commercially available manual or power operated sprayers. However, the major problem in direct spraying is drift of chemical on non targeted areas. Contact transmission of the herbicide is an exact method of depositing the chemical at the target plants and is a possible solution to the above problem. Wyse and Habstritt (1977) developed a contact type herbicide applicator roller-wiper absorbing pad of carpet. Messersmith and Lym (1985) tested the roller-wiper technique for use in leafy spurge control. Cohen and Shaked (1982) developed a carpet recirculating glyphosate applicator for row crops using a carpet recirculatory applicator. Gaultney et al. (1984) evaluated the feasibility of roller wiper herbicide application for woody plant control. They used carpet covered roller mounted on front of a crawler tractor rotated at different speeds for study. Mayeux and Crane (1984) developed a carpet roller for range lands which was mounted on parallel linkage in front of a small farm tractor. Welker (1985) developed a surface-roller wiper to apply herbicides to broadleaf weeds in turf. They compared roller wiper and sprayer applications for drift hazards. No evidence of herbicide drift was found when 2, 4-D was applied with a roller wiper.

Tewari and Mittra (1982) developed and patented a manually pushed herbicide applicator (IITWAM-82) for row crops. He reported that the performance of sponge roller in Arhar crop was excellent and uniformity of application achieved was 100 per cent. The herbicide solution required was 100–120 l/ha. Welker (1985) developed a hand roller herbicide wiper for lawns and gardens. He reported that excellent control of broad leaf weeds was achieved using 2, 4-D, Paraquat and with no evidence of herbicide drift.

Researchers such as Brown et al. (1994) and Cho et al. (2002) had used CCD camera for image acquisition, but this type of camera is very costly. Therefore, this research concern to create an easily available web cam based image acquisition system. Leemans and Destain (2006), and Muangkasem et al. (2010) used digital camera

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to capture an image and then further image processing was done on those captured images. The image processing is done on the basis of comparison of intensities of red (R), green (G) and blue (B) components of each pixel of an image. The green area of each image and the ratio of the green area to the whole image area (i.e. the greenness ratio) were determined, as an estimate of the weed coverage (Yang et al., 2003).

Most of the weeds are present in between inter row crop. Therefore, in this research only inter row weeds are considered. Several herbicide applications are done by researcher for inter row weeds. Paice et al. (1996) developed an experimental sprayer for investigating the effects of spatially variable herbicide dose. Their treatment was based on the treatment map prepared previously by weed mapping. Tian et al. (2000) developed and tested a machine-vision-system-guided precision sprayer. They integrated a real time machine vision sensing system with an automatic herbicide sprayer. However, the system was not sui for smaller weed patches.

This paper presents the development of a microcontroller based technology for site specific herbicide application with automatic weed detection technique, using machine vision and image processing for precise amount of herbicide application.

2. Methodology

2.1. General concept of herbicide applicator

The control system consists of digital cameras, laptop computer, Microcontroller, Relay, DC solenoid valve, and proximity switch. Camera captures ground cover underneath the camera and sends to laptop, where the application software process the captured image on the basis of comparison of intensities of R, G and B components of each pixel (the smallest single component of a digital image) of image. The image is analyzed at each pixel for weed detection. When G color intensity is greater than R as well as B color intensity the pixel is assumed to be green pixel, whereas, G color intensity is less than R as well as B color intensity that pixel is assumed to be background. The captured image having 640×480 pixels and the size of each pixel is 0.98 mm^2 at a height of 588 mm above the ground surface to capture the targeted area only in between crop row. The percentage of weeds present in between crop rows was calculated in terms of green index (Eq. (1)). Later on microcontroller activates the relay of each solenoid valve depending on the amount of herbicide required (Eq. (2)) on the application roller which rolls on the weeds smears chemical onto it. A proximity switch was installed with a ground wheel to sense the distance travelled by the rollers. As the rollers cover a distance of 600 mm, the proximity switch sends the signal to the camera through microcontroller to capture new image and the cycle will be repeated again. The Frame Grabe Interval property in MATLAB specifies how often the video input object acquires a frame from the video stream. The system acquires an image frame after every 600 mm distance and the extra frames acquired in that period are deleted. The weeds are killed in 48–72 h of time. The flow chart of the herbicide application control system is depicted in Fig. 1.

The weed density in between row crops is refers as Green Index (GI).

$$GI = \frac{\text{Total no. of green pixels in image frame}}{\text{Total no. of pixels in the same image frame}} \quad (1)$$

The green index is characterized into four levels i.e. (i) Very low (0–5%), (ii) Low (5–30%), (iii) Medium (30–70%) and (iv) High (70–100%).

The herbicide amount is calculated from following equation,

$$\text{Herbicide Amount} = R_A \times A \times \text{Green Index} \quad (2)$$

where R_A is the Rate of application of the herbicide per hectare and A is the Area covered by the image in ha.

2.2. Microcontroller processor design

A serial port (RS232) communication was used to transfer data (control signal for microcontroller) from laptop to microcontroller, Atmel AT89C2051. The signal was processed by the microcontroller for opening or closing the solenoid valve. Programming of microcontroller was done in assembly language. The 12 V DC normally closed solenoid valve was used and the circuit diagram is shown in Fig. 2.

2.3. Program for image acquisition and herbicide application

A Graphical User Interface (GUI) was developed with MATLAB software which allows the user to interact with electronic devices. Input parameters in GUI are application rate (AR), roller width (RW), operational speed (OS), and the output parameters are distance between camera and roller, camera height. Three push buttons OK, START, STOP are included in GUI. It also includes green index box as well as original and binary image box for each of camera mounted on machine. GUI programming in MATLAB has the following main parts, and a view of GUI is shown in Fig. 3.

a. Code block for calculation of distance between camera and roller, and height of camera.
b. Code block for configuring serial port properties and video input object properties.
c. Starting of video input.
d. Image acquisition, processing and green index calculation.
e. Algorithm for spraying decision.

During image processing, the red, green, and blue components of RGB image are extracted. Fundamental theory to discriminate weed from soil background was that the acquired image was separated into individual R, G and B components and for each pixel R, G and B values were compared, if green component intensity was greater than R as well as B component intensity, the pixel is identified as a green pixel i.e. a part of weed. When the green pixels are identified the original image is converted to binary image

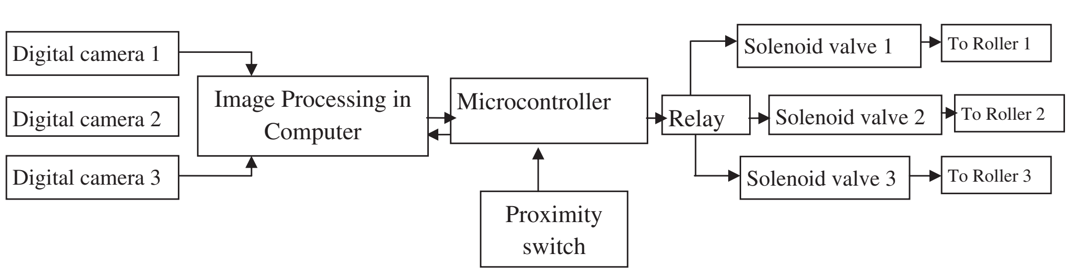

Fig. 1. Flow chart for herbicide application system.