ISSN: 0128-7680
Pertanika J. Sci. & Technol. **18 (2)**: 243– 253 (2010) © Universiti Putra Malaysia Press

Software Development for Real-Time Weed Colour Analysis

Wan Ishak W. I* **and Khairuddin Abdul Rahman**
Department of Biological and Agricultural Engineering,
Faculty of Engineering, Universiti Putra Malaysia,
43400 UPM, Serdang, Selangor, Malaysia
**E-mail: wiwi@eng.upm.edu.my*

ABSTRACT

The application of computer and machines for agricultural production has been one of the outstanding developments in Malaysian agriculture, especially in overcoming labour shortages in Oil Palm plantations. The on-line automated weedicide sprayer system was developed at Universiti Putra Malaysia to locate the existence and intensity of weeds in real-time environment and to spray the weedicides automatically and precisely. During the start of the spraying operation, the web camera will initially capture the image of weeds. The computer programme will compute the red, green, blue (RGB) values in the form of computer pixel. These values will be used as reference RGB values to be compared with the RGB values of the weeds captured real-time during the spraying operation. The sprayer nozzle will be turned 'on' or 'off', depending on the percentage or intensity of the green colour pixel value of weeds. The sprayer valve will open the nozzle/s when the camera detected the presence of weeds. The purpose is to reduce wastage, reduce labour, reduce cost, and control environment hazard.

Keywords: Weeds, sprayer nozzle, chemical spray, WEB cam, automation, outdoor vision, image processing

INTRODUCTION

Weeds compete with crops for water, light, nutrients and space, and therefore, it reduces crop yields as well as affects the efficient use of machinery. Manual weeding is a laborious operation, thus mechanical or chemical applications are the best options. The most widely used method for weed control is to use agricultural chemicals (herbicides and fertilizer products). In fact, the success of U.S. agriculture is attributable to the effective use of chemicals. Chemical sprayer is the most popular method to eradicate weeds in Malaysia, but this causes hazardous and harmful effects to the environment, crops and human. Weed detection at the time of spraying could be very valuable, particularly to reduce costs involving the uses of chemicals and in reducing environmental contamination. Thus, an on-line automated sprayer was introduced to farmers in Malaysia so as to locate in the real time environment the existence and intensity of weeds and to spray the weedicides automatically and precisely. Many researchers have attempted to detect weeds in crop fields with machine vision system (Choo *et al*., 1990; Tillet, 1991). The purpose of the smart sprayer is to reduce wastage, labour, and cost, control environment hazard and to attract younger generation to have the interest in the agricultural sector.

The advent of computer and camera vision has given a valuable tool for researchers to develop automation systems to increase mechanization technology in the agriculture sector. In particular, vision is the most powerful and complicated sense. It provides us with a remarkable amount of information of our surroundings and enables us to interact intelligently with the environment.

Received: 25 February 2008
Accepted: 6 June 2008
*Corresponding Author

Vision systems are a new field of research in the agricultural sector. Research on machine vision has been applied to agriculture to identify weeds. Many researchers have tried various image processing methods, and worked in different environments; however, most of the work has been done indoors (Abdul Malik Hamid, 1998; Hazlina Hamdan, 2005). Most of the work in outdoor lighting conditions has been associated with robotic fruit harvesting (Kondo and Ting, 1998). In this research, a machine vision technology was developed to identify weeds in the outdoor environment. There is a practical need for a real time machine for weed detection and to reduce the use of and dependency on agricultural chemicals.

In this project, the ATV Polaris 500 ATP vehicle was installed with a commercial boom sprayer. The commercial sprayer was modified with an automation system guided with a web camera to detect the presence of weeds. The commercial sprayer was modified and installed with 2 cameras for 6 nozzles spaced at a distance of 45 cm. The sprayer was installed with the web camera, portable computer, ICPCON I-7042, and SST-2400 radio modem. Module ICPCON I-7042 and radio modem (SST-2400) were selected as data acquisition and control. SST-2400 radio modem is the heart of the PC based control system. They provide digital input/output and other functions. The radio modem that was set as a receiver receives the signals and transfers them to the ICP modules (I-7042) via RS-485 bus. The ICPCON I-7042 and SST-2400 were later replaced with locally made 'parallel port controller board'. The purpose of this study was to develop an automated sprayer using a camera vision for the application of chemicals on an autonomous all terrain vehicles (ATV). The specific objective of this project was to detect the presence of weeds in real-time and to spray chemicals precisely to eradicate weeds.

METHODOLOGY

In this project, the commercial sprayer was modified. The normally close (NC) solenoid valve was mounted at the nozzles for the purpose of switching ON/OFF the nozzles. The nozzles will be turned 'ON' when the camera detects weeds and turned off when the camera does not detect any weed. These switching ON/OFF functions will reduce the amount or volume of chemicals to be sprayed and therefore help to reduce hazards to the environment and production cost. The normally open (NO) solenoid valve was installed at the chemical tank. If there was nothing to be sprayed, the NO solenoid valve would by-pass the chemical liquid back to the tank. This is meant to avoid the high-pressure build-up in the main sprayer line. *Fig. 1* shows the ATV mounted with an automatic sprayer.

Two PC web cameras were installed to the left and right sides of the boom sprayer. The camera on the left will display the image of the weeds to be sprayed by three nozzles labelled as nozzles 1, 2 and 3, whereas the camera on the right is meant for the other 3 nozzles, namely nozzles 4, 5 and 6. Each camera covers 3 segmented displayed images for the 3 specific areas of applications from the 3 nozzles. These cameras control the area of spraying. The respective nozzles will trigger the spray solution when the weeds appear in green at their respective areas. In addition, selective spraying can be carried out whereby only respective nozzle will spray the chemicals in the presence of the weeds. The respective nozzle will be closed when the green colour of the weeds is not detected.

The variation of the daylight of the outdoor environment changes the light intensity, and thus changes the RGB of the agriculture products. Therefore, the values of RGB of the images captured vary according to the time of the day and to the presence of clouds. In order to avoid the variations of light intensity of the outdoor environment, the RGB values colour of the weeds were captured in real time. These values were saved and used as a reference RGB colour. During the spraying operation, the on-line cameras captures and analyzes the image of weeds in real-time and compares with the reference RGB colour of the weeds which is captured on the real-time basis. In short, the



Fig. 1: A web camera and communication devices installed to the automatic sprayer

spray nozzle will be opened or closed based on the presence and intensity of weeds captured on the camera.

Image Processing

In computer, the intensity of the colours is based on bits. A 24-bit colour is required to represent a non-normalized RGB co-ordinated with a decimal value from 0 to 255 (Rafael and Richard, 2002). *Fig. 2* shows the RGB 24 bit colour cube to demonstrate the above. A colour in the RGB colour model can be described by indicating how much of each of the red, green, and blue color is included. A full intensity red in the RGB colour model is (255, 0, and 0). A colour camera output can be decoded into three images to represent the RGB components of the full image. The three components of the colour image can be recombined in the software or hardware to produce intensity, saturation and hue images, which can be more convenient for subsequent processing.

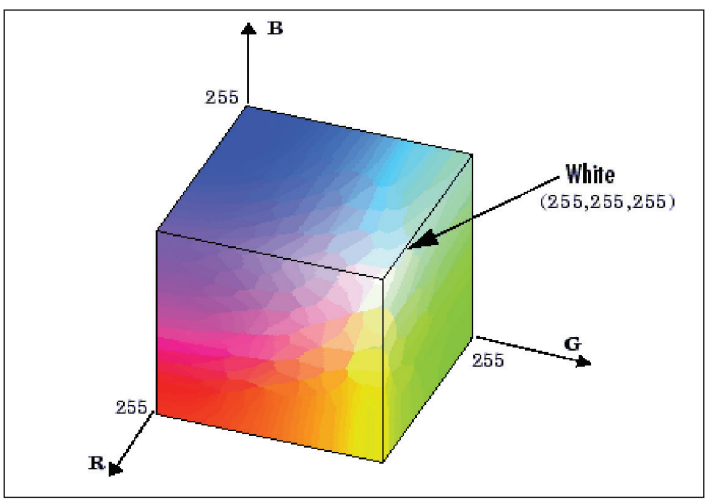


Fig. 2: RGB 24 bit colour cube

This spraying system uses USB webcam to capture the images of weeds. The image is sampled into a rectangular array of pixels. Each pixel has x and y coordinates that correspond to its location within the images. *Fig. 3* shows a sample of the image captured using the USB web camera. The x coordinate is the pixel's horizontal location, whereas the y coordinate is the pixel's vertical location. The pair of coordinates (x, y) is called the intensity or grey level of the images of the point. The grey level images are then calculated by linear combination of an RGB vector of the colour images. The Visual Basic programme (VB) reads the RGB values of each pixel of the total area of the image. The RGB colour pixels range from 0 to 255. The basic API pixel routines obtained from the VB programming language is used to read the RGB value pixel by pixel of the image. The function reads one by one from the first pixel to the end of the pixel coordinate. The algorithm used to read all the pixels of the images is shown in *Fig. 4*. This algorithm shows all the pixel values for each coordinate of the image. Each coordinate will extract the RGB colour pixel which ranges from 0 to 255. When the user clicks on the camera for a specified piece of weed, the programme will then compute the RGB pixel values.

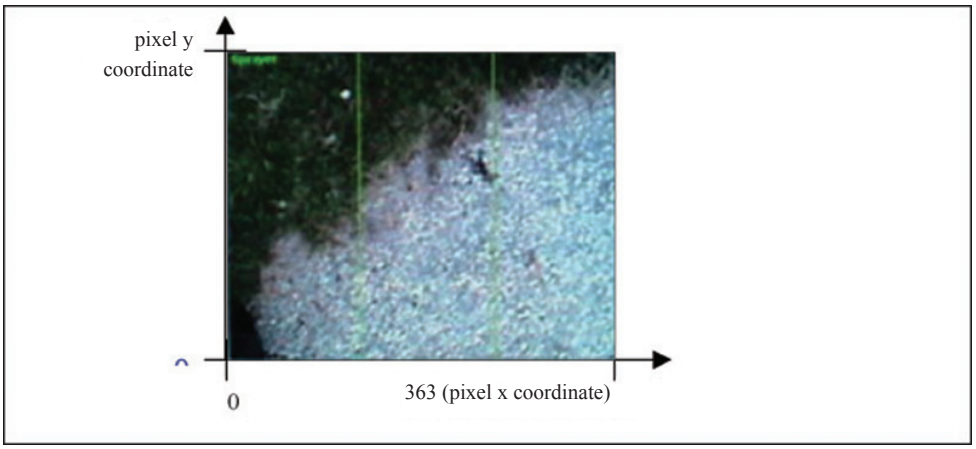


Fig. 3: Sample images captured and analyzed

```
From two-dimension function, f(x,y);
        Read for f(x) = 0 until image width value
                Read for f(y) = 0  until image height value
                        Get pixel value on coordinate pixel, f(x,y);
                End loop
        End loop
```

Fig. 4: Algorithm to extract pixel value from an image

During the start of the spraying operation, the web camera will initially capture the image of weeds and analyze the red, green, blue (RGB) values in terms of computer pixels. Through appropriate real-time image processing algorithm, which is based on colour image as raw data, the information pertaining to weeds locations and their densities is therefore extracted. The image is sampled into a rectangular array of pixels. Each pixel has x, y coordinates that correspond to their locations within the images. The green weed colour is selected as a reference point and set at the range of plus and minus 10 from the RGB selected pixel values. The programme illustrated in *Fig. 5* shows that the range of plus and minus 10 values from the RGB selected pixel value are set. These values are used as the reference to compare with the values of the RGB of weeds captured real-time during the spraying operation. The information of the reference point will be sent to a sprayer controller. When the camera captures the real time image of weeds, the computer will then calculate the percentage of the green pixels available in the frame and compare with the RGB pixel of the reference point. The pump and nozzles will open or close based on the percentage or intensity of the green colour pixel value of the weeds. In the real-time system, the respond time is a critical parameter. Therefore, the overall system must be well visualized and designed for a successful integration.

```
R pixel value range
 = ( R > R pixel value selection -10 ) and ( R < R pixel value selection +10)
G pixel value range
          = ( G > G pixel value selection -10 ) and ( G < G pixel value selection +10)
B pixel value range
          = ( B > B pixel value selection -10 ) and ( B < B pixel value selection +10)
```

Fig. 5: Algorithm for the colour pixel range from the pixel selected

Software Development

In this project, Microsoft Visual Basic 6.0 was used to develop the graphical user interface (GUI) to monitor the parameters controlling the autonomous sprayer operations. *Fig. 6* illustrates the flow chart of the software showing the algorithm for the automated weedicide sprayer spraying system. The algorithm starts with the camera capturing the image, analyses it, calculates the percentage of RGB and instructs the nozzles to open or close for the spraying operations. *Fig. 7* shows the GUI screen of the monitor which is divided into 3 frames as captured by one camera. The three frames were for the 3 units of the spray nozzles. The camera grabs the image and analyzes the red, green, blue (RGB) values in terms of computer pixels. The sprayer nozzle will be turned on or off, depending on the percentage or intensity of the green colour value of weeds.

Each feature in the GUI has its own special code. Some examples given below illustrate the source code for nozzle 1 which is connected to channel no. 9, and nozzle 2 to channel no. 8.

Source code for the nozzle:

```
Private Sub Noz1on_Click ()
DCON_X1.ChannelNo = 9
DCON_X1.DigitalOutCh True
End Sub

Private Sub Noz2on_Click ()
DCON_X1.ChannelNo = 8
DCON_X1.DigitalOutCh True
End Sub

Private Sub Noz1off_Click ()
DCON_X1.ChannelNo = 9
DCON_X1.DigitalOutCh False
End Sub

Private Sub Noz2off_Click ()
DCON_X1.ChannelNo = 8
DCON_X1.DigitalOutCh False
End Sub
```

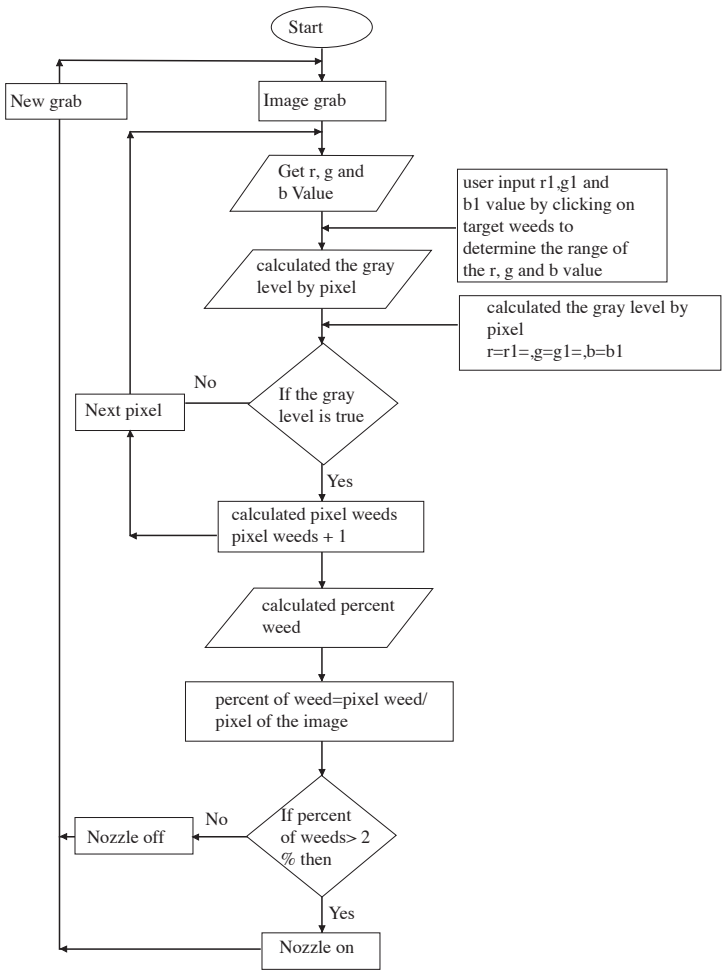


Fig. 6: Flow chart of the software for the automated weedicide sprayer

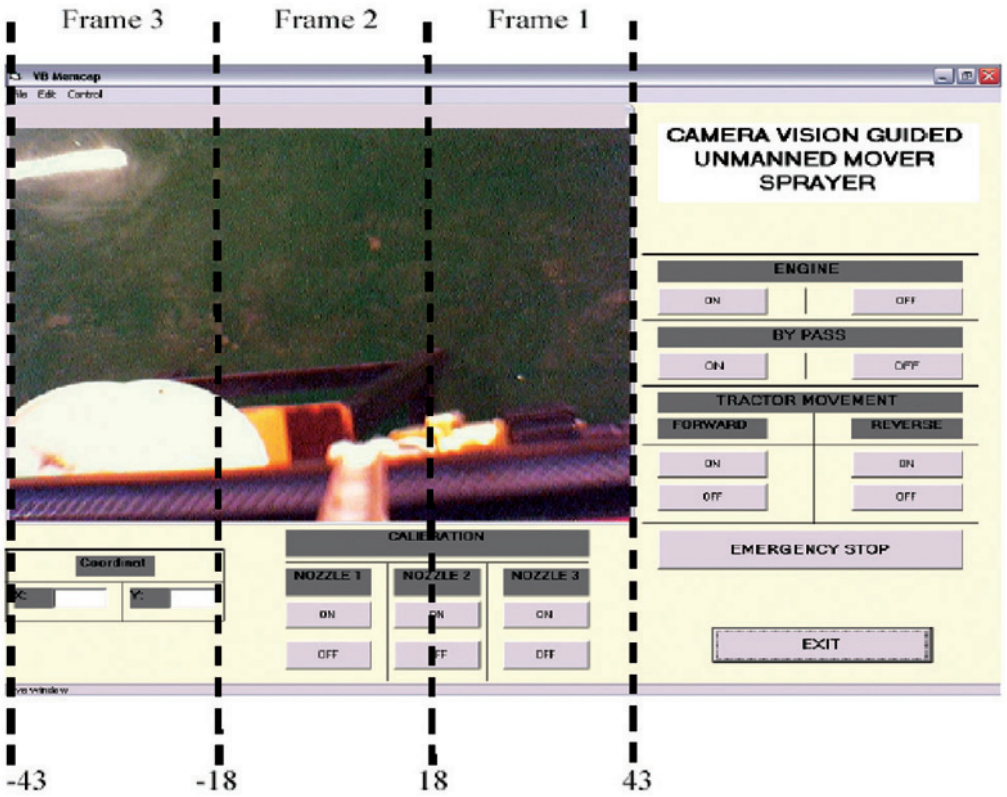


Fig. 7: Boundaries of image frames in GUI

The information presented in Table 1 is useful in determining the task for each output channel of the ICPCON I-87057. The software packages for ICPCON I-7000/8000/87K series module used were I-7000/8000 Utility and NAP 7000X. Table 1 shows the output signals assigned to the ICPCON I-87057. Meanwhile, the source codes were written by referring them to the information given in Table 1. It also helps in the troubleshooting process whenever problems occur.

TABLE 1
Output assigning of the ICPCON I-87057

Module	Channel	Description
I-87057	DO0	Bypass
	DO1	Nozzle1
	DO2	Nozzle2
	DO3	Nozzle3
	DO4	Engine (Ignition)
	DO5	Motor (Forward)
	DO6	Motor (Reverse)

RESULTS AND DISCUSSION

Two web cameras were installed to capture the image of weeds. During the start of the spraying operation, the web camera will initially capture the image of weeds manually and then analyze the red, green, blue (RGB) values in terms of computer pixels. These values will be used as the reference point to be compared with the values of the RGB of weeds captured real-time during the spraying operation. When the camera captures the real time image of weeds, the computer will calculate the percentage of the green pixels available in the frame and compare it with the RGB pixel of the reference point. When the green colour of the weeds matches the reference RGB value stored in the computer, it will trigger the nozzle to spray out chemical solutions to the target area. The green weeds to be sprayed were calculated based on the percentage of their intensity and the percentage of their green pixels.

Table 2 shows the percentage of green grasses which was set to open and close the nozzles and pump of the tank. The sprayer pump and the nozzles will be switched 'ON' at 20 to 100% intensity of weeds and 4 to 100% of pixels of green weeds. The pump and nozzles will be opened or closed based on the percentage or intensity of the green colour pixel value of weeds. In the real-time system, the respond time is a critical parameter. Therefore, the overall system must be well-visualized and designed for a successful integration.

TABLE 2
The status of nozzle based on percentage of rgb and pixel value of weeds

	Sprayer status	
Grass area	0% - 20%	20% - 100%
Pixel percentage of green grass	0.00% - 4.0%	4.0% - 100%
Nozzle status	Off	On
Pump status	On	On
Sprayer status result	Off spraying	On spraying

Spraying system was tested to make sure that the entire components were in a good condition and working perfectly. Calibration was carried out manually for each nozzle using the command button in the Graphical User Interface (GUI). The camera will initially capture the image of weeds and display it on the computer screen. The weeds captured by the camera in each frame were analyzed to activate the respective nozzle, i.e. to either open or close it. The signal from the computer will then be transferred to the PC parallel port which will send the voltage signal to the pump and the nozzle. The GUI screen was divided into 3 frames as captured by one camera. The 3 frames for the 3 units of spray nozzles. The GUI was tested to make sure that it works according to the autonomous sprayer system working process. Each nozzle (nozzle 1, nozzle 2, and nozzle 3) can be operated individually in their respective area of spray. Image which was captured was divided into three frames. The first nozzle can only operate in frame 1, while the second nozzle in frame 2, and the third nozzle in frame 3, respectively. When the user clicks on the region of frame 1, nozzle 1 will be turned ON, while the other nozzles will be turned OFF. The NC solenoid valves mounted on the nozzle will carry out these functions. The Normally Closed (NC) valves were installed on the nozzles for the 'off' un-operated operation. The valve will open the nozzle when the camera detects the presence of weeds. Therefore, the user can select from the image the particular area of weeds to be sprayed. Each application of ON operation will take 2 seconds before

it is turned OFF again. If there is nothing to be sprayed, the NO solenoid valves mounted at the tank is opened to by pass the liquid back to the tank. This is done to avoid the high-pressure build up in the main sprayer line. The GUI was designed to have an emergency stop button if the user needs to immediately stop the autonomous sprayer. *Fig. 8* shows the calculated percentage of the pixel of green weeds for each green weed area captured by the camera. The computer programme was written to activate the pump and the nozzle at a certain percentage of pixel values.

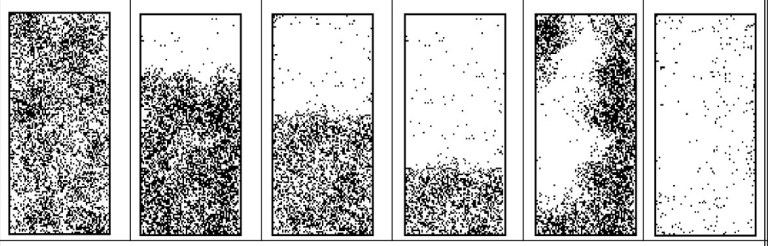
	Percentage of green grass selection					
Area size	X 121	X 121	X 121	X 121	X 121	X 121
Pixel view						
	Percentage of green grass selection					
Grass area	100%	75%	50%	25%	50%	0%
Pixel percentage of green grass	20%	15%	10%	5%	10%	1%
Nozzle status	On	On	On	On	On	Off
Pump status	On	On	On	On	On	On
Sprayer status result	On	On	On	On	On	Off

Fig. 8: The percentages of the green grass selections

Fig. 9 shows a sample of the results gathered from the experiment carried out in this study. It shows the GUI of the weeds captured by the web camera. The image was automatically divided into 3 frames for the operation of the three nozzles which was captured by one camera. Each frame was then analyzed for pixel count. Nozzle 1 was 'off' with the pixel percentage of 13.8, while nozzles 2 and 3 were in the 'on' mode when the percentage of pixel values exceeded 20%.

The concept of the smart sprayer, which includes PC web camera, personal computer, a programmable microcontroller ICPCON and sprayer system, was apparently achieved in this study. This particular project had successfully detected the presence of and intensity of weeds using a camera vision. The normally close (NC) solenoid valve was mounted on the nozzles for the purpose of switching ON/OFF the nozzles. They will be turned 'ON' when the camera detects weeds but turned off when the camera does not detect any weed. These ON/OFF functions help to reduce the amount or volume of chemicals to be sprayed and therefore lower release of hazardous substances into the environment, apart from reducing production cost.

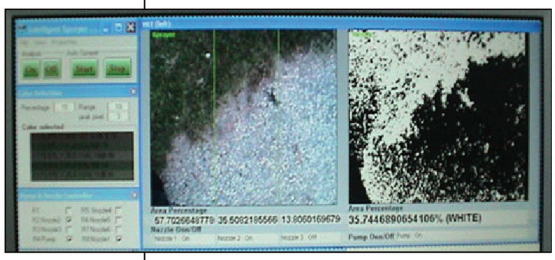
	Image		
Images grab			
			
Image area	High x 363		
Image weight	X = 0 to x = 363 pixels		
	Create partition		
Partition weight	X > 0 and X <= 121	X > 121 and X <= 232	X > 232 and x <= 363
Size x area	X = 121	X = 121	X = 121
Nozzle	1st nozzle	2nd nozzle	3rd nozzle
	RGB pixel value = 131769		
Grass areas	%	%	%
Image grab			
	Pixels counter		
Pixel view			
Pixel count	76031	46778	18184
	Percentage of grass pixels		
Pixel green grass	52%	35.5%	13.8%
	Pump & nozzle status		
Pump	On	On	On
Nozzle	On	On	Off

Fig. 9: Experimental results for the sprayer system

CONCLUSIONS

The automated sprayer system was successfully developed using the combination of the electromechanical system, controllers, and the software. The controllers consist of I/O module (ICPCON I-7042) and also a pair of (SST-2400) for data transmission. The graphical user interface (GUI) software, which was used to control the whole automatic system, was developed by visual basic programming. The software developed using the GUI has features which enable the user to perform the desired task on the computer instead of manually operating the sprayer.

In the real oil palm plantation environment, the variations of the daylight affect the image analysis of the weeds. The variations of the daylight changes the light intensity and thus changing the RGB values of the weeds. Therefore, the RGB value colour of the weeds is captured in real time so as to reduce the variations of light intensity of the outdoor environment. These values are saved and used as a reference colour. During the spraying operation, the online cameras will capture the image of weeds and compare it with the reference colour of the weeds which is captured on the real-time basis. At the moment, the reference RGB colour was taken at a few hours interval or at times when adverse daylight changes. The researcher of this project is looking forward to installing the third web camera to automatically capture the reference image colour of weeds in the real time.

In this research, a machine vision technology was developed to identify weeds in the outdoor environments. Although there have been efforts to control in row weeds, no system has been completed as a real time implement for field use. Thus, there is a practical need for a real time machine for weed detection, as well as to reduce the use of agricultural chemicals. Weed detection at the time of spraying may be very valuable to reduce chemicals costs and prevent environmental contamination. Similarly, much of the machine vision weed detecting research has been done with control lighting rather than variable lighting associated with outdoor field conditions.

REFERENCES

Abdul Malik B. Hamid. (1998). Camera vision to identify and recognize the colours oil palm fruit bunch. Final year Thesis, Universiti Putra Malaysia.

Choi, C.H., Choi, D.C., Erbach and Smith, R.J. (1990). Navigational tractor guidance system, *Transactions of ASAE, 33*(3), 699–706.

Hazlina Hamdan. (2005). Design and development of camera vision guided unmanned mover sprayer. Final year Thesis, Universiti Putra Malaysia.

Kondo, N. and Ting, K.C. (1998). Robotics for bio production systems. ASAE. St. Joseph, Michigan. USA.

Gonzalez, R. C. and Woods, R. E. (2002). *Digital Image Processing.* New Jersey: Prentice Hall.

Tillet, N.D. (1991). Automatic guidance sensors for agricultural field machines: A review. *Journal of Agricultural Engineering Reasearch, 50*(3), 167–187.