DEVELOPMENT OF REAL-TIME COLOR ANALYSIS FOR THE ON-LINE AUTOMATED WEEDING OPERATIONS

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ABSTRACT

Weeds compete with the crop for water, light, nutrients and space, and therefore reduce crop yields and also affect the efficient use of machinery. Chemical sprayer is the most popular method to eradicate weeds but has cause hazardous to the environment, crops and workers. A smart sprayer is required to control the usage of chemical weedicides at the optimal level. Thus an on-line automated sprayer is introduced to the Malaysian farmers to locate in the real time environment the existence and intensity of weeds and to spray the weedicides automatically and precisely. The purpose is to reduce wastage, reduce labor, reduce cost, control environment hazard and to attract younger generation to be attracted to agricultural sector.

The application of computer and machines for agricultural production has been one of the outstanding developments in Malaysian agriculture especially in overcoming labor shortages in Oil Palm plantations. The automated sprayer system developed at Universiti Putra Malaysia, uses web camera with combinations of electromechanical system, sensor system, controllers, wireless data communication and software. During the start of the spraying operation, the web camera will initially capture the image of weeds and analyzed the red, green, blue (RGB) value in terms of computer pixel. These values will be used as the reference RGB values to compare with the values of the RGB of weeds captured real-time during the spraying operation. The sprayer nozzle will turn ‘on’ or ‘off’ depending on the percentage or intensity of green color pixel value of weeds. The Normally Closed (NC) valves were installed on the sprayer nozzles for the ‘off’ un-operated operation. The valve will open the nozzle/s when the camera detected the presence of weeds. The Normally Open (NO) valve was mounted at the tank to open or by pass the liquid back to the tank. This was to avoid the high-pressure build up in the main sprayer line.

Key words: Weeds, weed sprayer, automation, outdoor vision, camera vision, color recognition, RGB, computer controller.

INTRODUCTION

Weeds compete with the crop for water, light, nutrients and space, and therefore reduce crop yields and also affect the efficient use of machinery. Manual labors are popularly used to perform tedious weeding activities in the oil palm plantation field. Manual weeding is laborious operations, 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 but has cause hazardous and harmful to the environment, crops and human. Chemical sprayers are popularly applied using knapsack sprayers for small farm and tractor mounted boom sprayer for large scale operations. Malaysia as a tropical country, receive frequent seasonal and occasional rainfall which affect the effectiveness of using chemical spray. Usage of weedicides at optimal level is the utmost important as the wastage will affect chemical pollution, especially when carried by rain water. A smart sprayer is required to control the usage of chemical weedicide at the optimal level. Thus an on-line automated sprayer is introduced to the Malaysian farmers 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 crops fields with machine vision system (Choo,C.H. et al., 1990; and Tillet, N.D., 1991). Weed detection at the time of spraying could be very valuable for reducing chemicals costs and reducing environmental contamination. Little research with a primary objective of real time operation has been done on machine vision weed sensing. Real time computation must produce a correct result within a specified time and is where the correctness of a computation depends not only on the logical correctness but also on the time at which the results are produced. The purpose of the smart sprayer is to reduce wastage, reduce labor, reduce cost, control environment hazard and to attract younger generation to be attracted to agricultural sector.

The advent of computer and camera vision has given a valuable tools for researcher to develop automation systems to increase mechanization technology in agriculture sector. 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. Machine vision is a technology that employs a computer and camera to analyse and interpret images in a manner resembling human vision. With the application of modern technology, machines with a sense of vision are widely used in the industrial sector. In the industrial sector, vision systems are used under working environment. Vision systems are used to detect products, for quality control purposes by their shapes and patterns. Machine vision applications use the optical properties of a material to provide information that can be used to define material and feature characteristics. For agriculture, the optical properties may be related to physical characteristics of the product and the electromagnetic spectral characteristics. Machine vision technologies have been applied to agriculture to identify weeds. Many researchers have tried various image processing methods, working in different environments however most of the work has been done indoors (Abdul Malik Hamid, 1998, and Hazlina Hamdan, 2005). 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 yet been completed as a real time implement for a field use. There is a practical need for a real time machine for weed detection and to reduce the use of agricultural chemicals. Similarly, much of the machine vision weed detecting research has been done with control lighting rather than variable lighting associated with outdoor field conditions. Most of the work in outdoor lighting conditions has been associated with robotic fruit harvesting (Kondo and Ting,1998).

Vision systems are a new field of research in the agricultural sector. Knowledge on how biological vision systems operate is directly concerned with signals from the sensors. In agricultural applications, especially for fruit handling, we cannot detect fruit quality just by its shape or pattern. This is because a fruit may have a different shape and pattern but the same level of quality (Kondo and Ting, 1998). To solve this problem, the vision system should be able to analyse the colour of the object or fruit. 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 software or hardware to produce intensity, saturation and hue images, which can be more convenient for subsequent processing. In computer, the intensity of the colours is based on bits. It is 24-bit colour (&bits red, &bits green and &bits blue), each representing a non-normalized RGB co-ordinate with a decimal value from 0 to 255 (Rafael and Richard, 2002).

The variations of the daylight change the light intensity thus changing the RGB of the agriculture products. The objective of this study is to model the system that can determine the target image at the outdoor environment with changing light intensity. To avoid the variations of light intensity of the outdoor environment, the RGB values color of the weeds are captured real time. These values are saved and used as a reference color. During the spraying operation, the on-line cameras will capture the image of the weeds and compare with the reference color of weeds that was captured on real-time basis. The spray nozzle will open or closed based on the presence and intensity of weeds captured on the camera.

METHODOLOGY

The objective for this project will be on detecting the presence of weeds and also the intensity of weeds by using camera vision. The purpose of this study was to develop an automated sprayer by using camera vision for the application of herbicides spraying on an autonomous all terrain vehicle (ATV).

Sprayer System

In the design stage, the length and size of the galvanized pipes and hoses were first determined. A half inches galvanized pipe was chosen because of the high resistance characteristic to high pressure and also it can hold more weight if other heavy components are attached to it. Figure 1 shows the fabrication of the galvanized pipe, T-joint, NC solenoid valve and the nozzle.

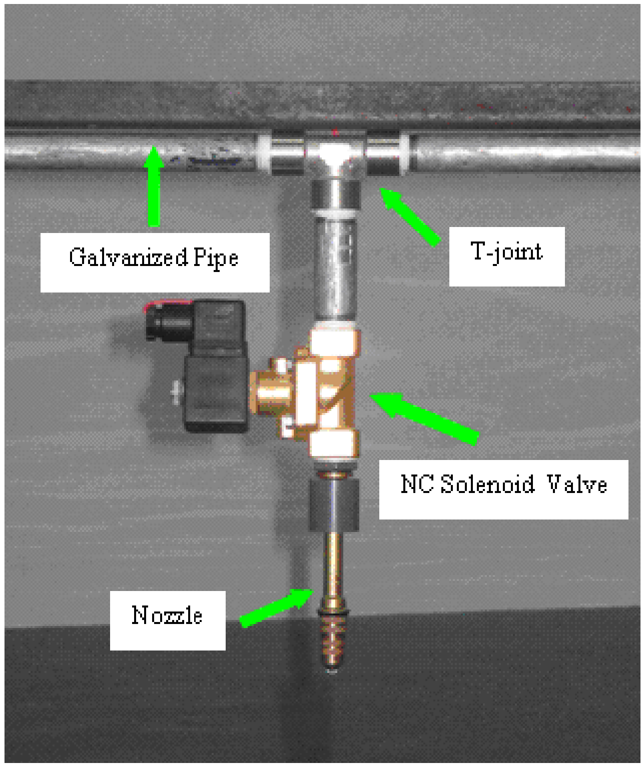

Figure 1: The Fabrication of NC Solenoid Valve and the Nozzle.

A 5.0 mm narrow nozzle was selected. It produces largest droplets while providing adequate coverage at the intended application rate and pressure to minimize drift. Little modification has been made to the nozzle so it can suit the sprayer design. The normally close (NC) solenoid valve was mounted at the nozzles for the purpose of ON/OFF of the nozzles. It will 'ON' when the camera detects the weed and turnoff when the camera detects no weed. This ON/OFF function will reduce the amount volume to be sprayed and therefore help to reduce hazardous to the environment as well as production cost. Figure 2 shows the ATV being mounted with the automatic sprayer. The sprayer was installed with the web camera, portable computer, ICPCON I-7042 and SST-2400 radio modem.

Figure 2: Automatic Sprayer Installed with Web Camera and Communication Devices.

Controller System

The concept of the smart sprayer which includes PC web camera, personal computer, a programmable microcontroller ICPCON and sprayer system is shown in Figure 3. This project concentrates on the concept and development of detecting the presence of weed by using camera vision.

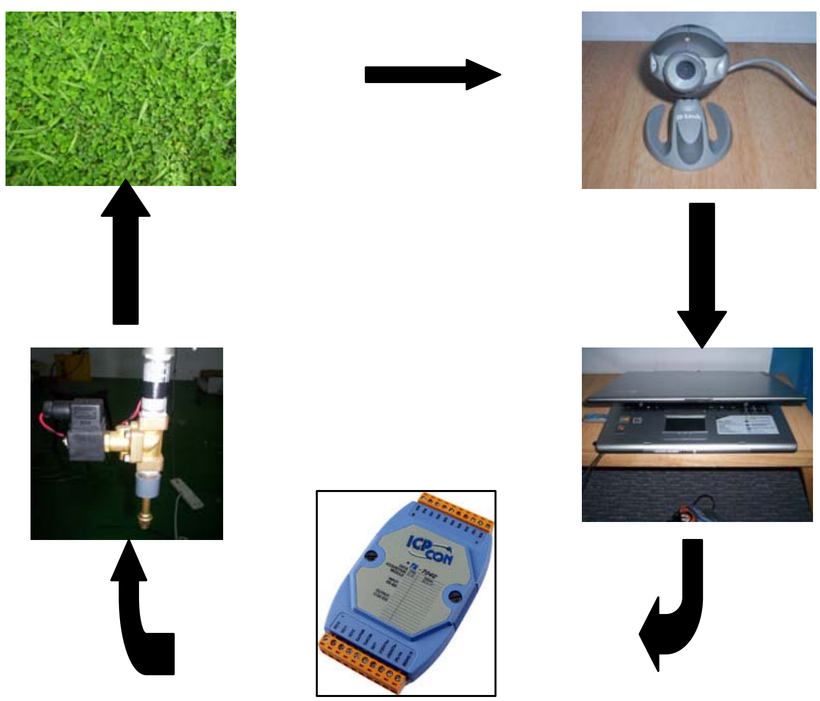

Figure 3: Concept of the Automated Sprayer

Module ICPCON I-7042 and radio modem (SST-2400) were selected as the 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 receiver received the signals and transfers it to the ICP modules (I-7042) via RS-485 bus. The ICPCON I-7042 and SST-2400 was later replaced with locally made ‘parallel port controller board’.

The automated sprayer system uses web camera with combinations of electromechanical system, sensor system, controllers, wireless data communication and software. 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 and analyzed the red, green, blue (RGB) value in terms of computer pixel. Through appropriate real-time image processing algorithm, which is based on color image as raw data, information of weeds locations and their densities were extracted. The image was sampled into a rectangular array of pixels. Each pixel has an x, y coordinates that corresponds to its location within the images. The green weed color was selected as a reference point and was set at the range of plus and minus 10 from the RGB selected pixel values. These values was 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 capture the real time image of weeds, the computer will calculate the percentage of green pixels available in the frame and compare with the RGB pixel of the reference point. The pump and nozzles will open or closed based on the percentage or intensity of green color pixel value of weeds. In real-time system, respond time is a critical parameter. Therefore, overall system must be well visualized and designed, for successful integration.

Image Processing

The RGB color model and the abbreviation "RGB" came from the three primary colors, Red, Green and Blue. The RGB color model itself does not define what is meant by "red", "green" and "blue", and the results of mixing them are not exact unless the exact spectral make-up of the red, green and blue primaries are defined. A color in the RGB color model can be described by indicating how much of each of the red, green and blue color is included. Each can vary between the minimum (no color) and maximum (full intensity). If all the colors are at minimum the result is black. If all the colors at maximum, the result is white. The color values may be written as numbers in the range 0 to 255, simply by multiplying the range 0.0 to 1.0 by 255. This is commonly found in computer science, where programmers have found it convenient to store each color value in one 8-bit byte. This convention has become so widespread that many writers now consider the range 0 to 255 authoritative and do not give a context for their values. Full intensity red in RGB color model is (255,0,0).

This spraying system uses USB webcam to capture the images of the weeds. The image is sampled into a rectangular array of pixels. Each pixel has an x and y coordinates that corresponds to its location within the images. The x coordinate is the pixel’s horizontal location, the y coordinate is the pixel’s vertical location. The pair of coordinate (x,y) is called the intensity or gray level of the images of the point. The gray level images are then calculated by linear combination of an RGB vector of the color images. The Visual Basic program (VB) read the RGB values of each pixels of the total area of the image. The RGB color pixels range from 0 to 255. The basic API pixel routines obtained from the VB programming language was used to read the RGB value pixel by pixel of the image. The function read one by one from first pixel to the end of pixel coordinate. The algorithm to read all pixels of the image is shown in Figure 4. This algorithm will show all pixel values for each coordinate of the image. Each coordinate will extract the RGB color pixel which range from 0 to 255. When the user clicked the camera on a specified piece of weeds, the program will compute the RGB pixel values. The program as in Figure 5, shows that we set the range of plus and minus 10 values from the RGB selected pixel value. Figure 6 shows a sample image captured from USB Web camera for the analysis.

```
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
```

Figure 4: Algorithm to Extract pixel value from image.

```
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)
```

Figure 5: Algorithm for color pixel range from pixel selected

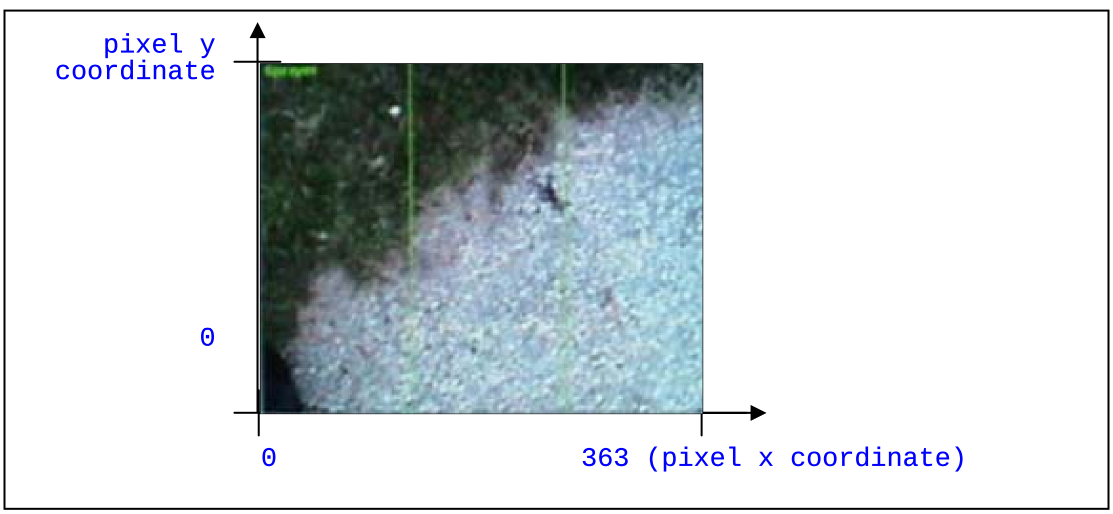

Figure 6: Sample images captured and analyzed.

Software Development

In this project, Microsoft Visual Basic 6.0 was used to develop the graphical user interface (GUI) to monitor the parameters that control the autonomous sprayer operations. A graphical user interface is a method of interacting with a computer through a metaphor of direct manipulation of graphical images and widgets in addition to text (Deitel and Deitel T.R. Nieto ,1999). Figure 7 shows the GUI screen of the monitor being divided into 3 frames captured by one camera. The three frames were for 3 units of spray nozzles. The camera grabbed the image and analyzed the red, green, blue (RGB) value interms of computer pixel. The sprayer nozzle will turn on or off depending on the percentage or intensity of green color value of weeds.

Each feature in the GUI has their own special code. Example below shows the source code for nozzle 1 connected to channel no. 9 and nozzle 2 connected channel no. 8.

Source code for 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
```

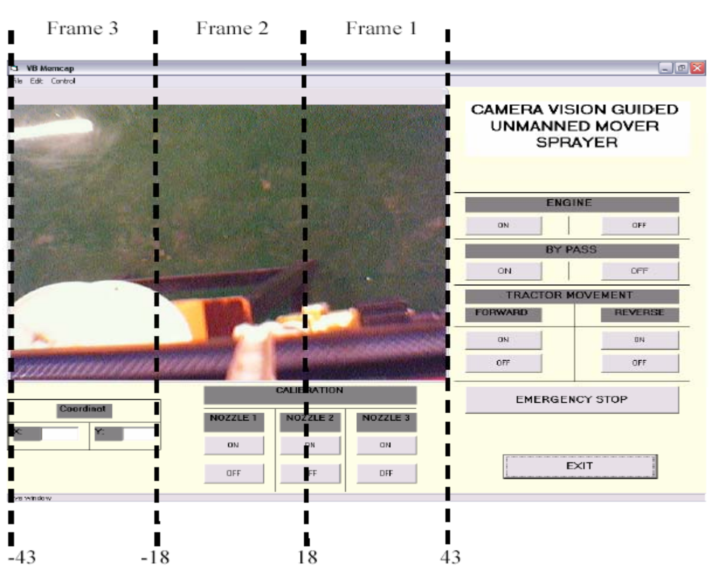

Figure 7: Boun

Information in Table1 is useful in determining the task for each output channels 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 outputs signal assigned for the ICPCON I-87057. The source codes were written by referring to the information in Table 1. It also helps in the troubleshooting process when 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 DISCUSSIONS

The autonomous sprayer system consists of 2 cameras for 6 nozzles spaced at 45 cm apart. The cameras were located on the left and right side of the tractor. These cameras control the area of spraying. The camera will capture the image of the weeds and display on the computer screen. The weeds captured by the camera in each frame were analyzed to activate the respective nozzle either to open or closed. Manually, the user can click on the computer screen. 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. Manual operation was carried out to test the system. The Graphical User Interface (GUI) screen was divided into 3 frames captured by one camera. The 3 frames for the 3 units of spray nozzles. The weeds captured by the camera in each frame were analyzed to activate the respective nozzle either to open or closed. GUI was tested to make sure that it works according to the autonomous sprayer system working process. Spraying system was tested to make sure that the entire components were working in a good condition. Calibration for each nozzle has been made by using the command button in the GUI. Each nozzle (nozzle 1, nozzle 2 and nozzle3) can be operated individually in their respective area of spray. Image that was captured were divided into three frames. The first nozzle can only operate in frame 1, second nozzle in frame 2 and the third nozzle in frame 3 respectively. When the user clicks in the region of frame 1, nozzle 1 will turned ON while the other nozzles will turn OFF. The NC solenoid valves mounted at the nozzle 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 detected the presence of weeds. Therefore, the user can select from the image which area to be sprayed. Each application of ON operation will take 2 seconds before it turned OFF again. If there was nothing to be sprayed, the NO solenoid valves mounted at the tank be open to by pass the liquid back to the tank. This was used 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 needed to immediately stop the autonomous sprayer.

The concept of the smart sprayer which includes PC web camera, personal computer, a programmable microcontroller ICPCON and sprayer system was achieved. The objective for this project was successful in detecting the presence of weeds and also the intensity of weeds by using camera vision. The normally close (NC) solenoid valve was mounted at the nozzles for the purpose of ON/OFF of the nozzles. It will 'ON' when the camera detects the weed and turnoff when the camera detects no weed. This ON/OFF function will reduce the amount volume to be sprayed and therefore help to reduce hazardous to the environment as well as production cost.

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 and analyzed the red, green, blue (RGB) value in terms of computer pixel. The image was sampled into a rectangular array of pixels. Each pixel has an x, y coordinates that corresponds to its location within the images. The green weed color was selected as a reference point and was set at the range of plus and minus 10 from the RGB selected pixel values. These values will be used as the reference to compare with the values of the RGB of weeds captured real-time during the spraying operation. When the camera capture the real time image of weeds, the computer will calculate the percentage of green pixels available in the frame and compare with the RGB pixel of the reference point. When the green color of the weeds matched with the reference RGB value stored in the computer, it will trigger the nozzle to spray out the chemical solution to the target area. The green weeds to be sprayed were calculated based on the percentage of intensity of weeds and percentage of green pixels of the weeds. The sprayer pump and the nozzles will be ON at 21 to 100% intensity of weeds and 4 to 100% of pixels percent of green weeds. The pump and nozzles will open or closed based on the percentage or intensity of green color pixel value of weeds. In real-time system, respond time is a critical parameter. Therefore, overall system must be well visualized and designed, for successful integration.

Table 2 shows the percentage of green grass to activate the nozzle for spraying operation. Figure 8 shows the image grabbed and analysed for the pixel counts. The pump and nozzles will open or closed based on the pixel of the green grass or weeds.

Table 2: Percentage of Green Grass for Sprayer Operation

	Sprayer status	
Grass area	0% - 20%	21% - 100%
Pixel percent of green grass	0.00% - 0.40%	0.41% - 100%
Nozzle status	Off	On
Pump status	Off	On
Sprayer status result	Of Spray	On Spraying

Two pc web camera were installed on the left and right hand side of the boom sprayer. The camera on the left will display the image of the weeds to be sprayed by three nozzles; nozzle 1 ,2, and 3, while the camera on the right for another 3 nozzles; nozzle 4,5 and 6. Each camera will cover 3 segmented displayed images for the 3 specific area of applications from the 3 nozzles. The respective nozzles will trigger the spray solution when the weed with green color appear at their respective area. Selective spraying can be carried out whereby only respective nozzle will spray the chemical in the presence of the weeds. The respective nozzle will be closed when the green colour of weeds failed to be detected.

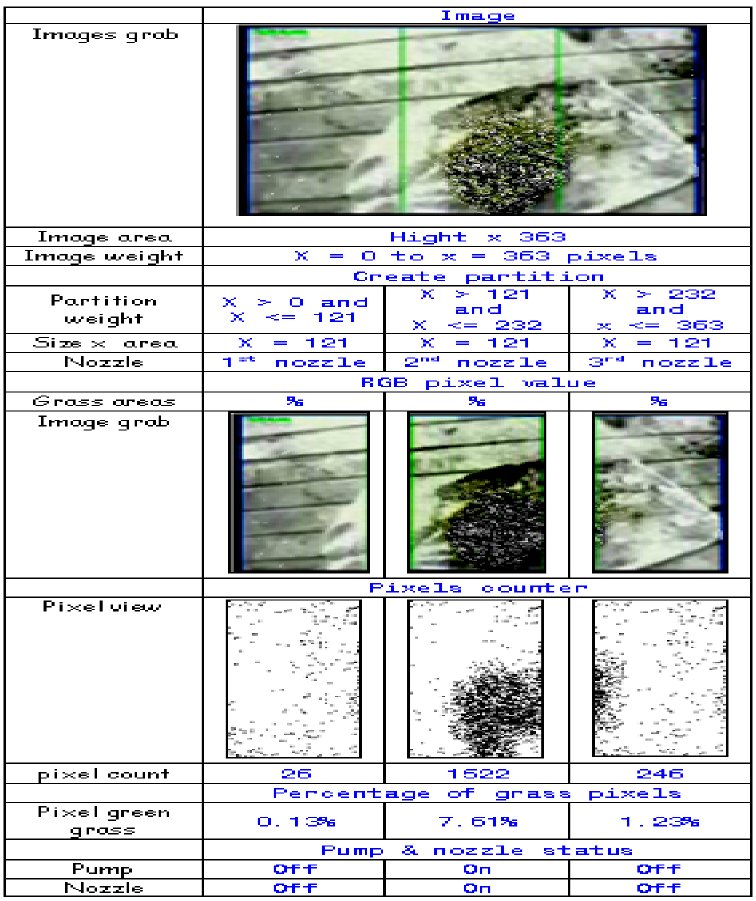

Figure 8: Image Grabbed and Analysed for Pixel Counts.

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 to control the whole automatic system was developed by visual basic programming. The GUI has features, which enable the user to perform the desired task on the computer instead of operating hands on directly on the sprayer

In this project, a commercial sprayer was modified with an automation system guided with the web camera to detect the presence of weed. Detection of weed was based on the reflectance of the green color value from RGB color value. The web camera capture the image of weeds, analyse the color, compare with the real time image in the database and sent the message to the spraying nozzle and the controller of the mover. The spraying nozzle will open or closed based on the presence of the weeds. The speed of mover or speed of spraying will be based on the intensity of the weeds detected.

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 thus changing the RGB values of the weeds. To reduce the variations of light intensity of the outdoor environment, the RGB values color of the weeds are captured real time. These values are saved and used as a reference color. During the spraying operation, the on-line cameras will capture the image of the weeds and compare with the reference color of weeds that was captured on real-time basis. At the moment, the reference RGB color was taken at a few hours interval or at times when adverse daylight changes. The researcher of this project is looking into installing the third web camera, to capture the reference image color of weeds in real time automatically.

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 yet been completed as a real time implement for a field use. There is a practical need for a real time machine for weed detection and to reduce the use of agricultural chemicals. Weed detection at the time of spraying could be very valuable for reducing chemicals costs and reducing 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.

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