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AGRICULTURAL MECHATRONIC RESEARCH AT UNIVERSITI PUTRA MALAYSIA

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ABSTRACT

The application of computer, mechatronics and machines for agricultural production has been one of the outstanding developments in Malaysian agriculture. This paper and presentation will describe on the recent research at Universiti Putra Malaysia (UPM) on the uses of camera vision system towards machines and equipments for the agricultural operations. Color vision is the most important indicator for the farmer to determine fresh fruit bunches (FFB) oil palm fruit maturity in manual harvesting process. The variations of the daylight caused changing the light intensity thus becomes the main issue that effect on automatic recognition process. In this study, the relationships of oil extraction rate (OER), fruit ripeness and fruit colour were determined. The objective of this project is to develop the software to enable the planters to determine the time of harvesting the matured fruits. The software was then downloaded to the handphone as a portable camera and portable computer for real-time determination of fruit maturity.

Research on 'Camera Vision to Determine the Oil Palm Yield' describes on the use of Hemispherical Photography Camera to determine the Leaf Area Index (LAI) as the main factor in growth modeling of the crops. Canopy structure is an important variable for any physiology experiment as well as for studies related to radiation, photosynthesis, energy exchange, gas exchanges, nutrition analysis, fertilizer treatment, pest management and soil fertility analysis. Leaf area index is a main component of canopy structure. Based on the measurements of the geometry of sky visibility and sky obstruction, hemispherical photographs can be used to calculate solar radiation regimes and plant canopy characteristics such as Leaf Area Index (LAI). The equation of LAI was used to predict yield of crop.

The research on 'On-line automated weedicide sprayer system' describes on how to locate in the real time environment the existence and intensity of weeds and to spray the weedicides automatically and precisely. The sprayer nozzle will turn 'on' or 'off' depending on the percentage or intensity of green color pixel value of weeds. The sprayer valve will open the nozzle/s when the camera detected the presence of weeds. The above concept can be applied to other agricultural operations such as grading of agricultural products in terms of color.

INRODUCTION

Malaysia has set the vision of attaining the status of a fully industrialized country by the year 2020. This goal is not entirely out of reach, given Malaysia's abundant natural resources and strong economic performance. Plantation industry in Malaysia is still one of the biggest enterprise and the most important sector in Malaysia's economy. In the last 35 years, Malaysia has emerged as the number one producer of palm oil. Currently, Malaysia accounts for about 55% of world palm oil production and about 62% of world exports. The Malaysian oil palm industry continues to contribute significantly to the country's economic development and foreign exchange earnings. Malaysian oil palm industry needs more emphasis on its research and development to meet the world challenge and to maintain Malaysia as the top

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world producer of palm oil. Efforts are being made towards increasing the application of science and technology (S&T) and research and development (R&D) in the oil palm industry. The universities are expected to play more important role in S&T and R&D. The Faculty of Engineering, established formerly as Faculty of Agricultural Engineering since 1975, gave due emphasis to the solution of engineering problems in the agricultural sector. Agricultural mechanization research was given the top priority in the development of agriculture sector. Given the existence of broad based multi-disciplinary skills, Universiti Putra Malaysia are in position to contribute significantly to upgrade agricultural mechanization to robotics and automation in agriculture. Agricultural mechatronic research came into being in early 1990's during the program Bachelor of Agricultural Engineering curriculum review whereby options on 'Agricultural Robotics and Automation' was introduced. The first Final Year Project on 'Agricultural Robot for Harvesting Oil Palm' by Wan Zulkarnain Othman was completed in 1993. In August 2004, the author delivered the inaugural lecture on 'Agricultural Robot: A New Technology Development for Agro-Based Industry.

To shape the agrobase (agricultural and plantation) industries in Malaysia, application of engineering and mechanization technologies in agriculture must be introduced immediately. Mechanization and the application of engineering technologies constitute major aspects to agricultural modernization. The introduction of high technology in mechanization and automation of agricultural production must be intensified. The robot systems, computer control system, camera vision, unmanned tractor, online harvesting robot and gantry system must be studied, designed and tested. With the use of the computer control software, interface hardware, valves and actuators, the prototype robot able to move the manipulators to harvest and collect agricultural products. Machine vision for the agricultural robot able to identify the object to be picked and harvested. Tractor equipped with sensors and controllers enable the tractor to operate automatically. Wireless networking device with communication camera and communication software enable the operator to control the unmanned mobile harvesting robot through internet. Robots must also develop for the gantry system. Engineering control system must be studied and introduced in green houses to improve on the plant growth. Mechatronics will be the best to describe the use of mechanical and electronic components for agricultural machines for the above research.

Development of Vision System

In determining the colour properties, the experiment was initially conducted under controlled environment, that is, in the laboratory. The first project on camera vision was carried out in early1979 by Wan Ishak at Lousiana State University, USA [1]. Camera vision was used for automatic colour sorting of peppers by measuring the amount of light reflected from the fruits of different colour levels at particular wavelengths or combinations of wavelengths. Wan Ishak [1] found out that the pepper designated as "green color" showed a reflectance range of 500 to 560 nm wavelengths and "red colour" at reflectance range of 620 to 720 wavelengths. Peppers showed an increase in reflectance responses at wavelengths of 660 nm as they matured, indicating a decrease in chlorophyll absorption. The next project carried out by the author in 1997 was on the camera vision to identify and recognize the colours of oil palm FFB. Figure 1 shows colour intensity of oil palm fruit bunch using RGB camera. The objectives of the project were to differentiate and analyze the colours between the oil palm FFB, to differentiate between the colours of oil palm FFB with other objects available in the oil palm plantation, to identify the maturity of the fruits and to develop a computer program to process data related to colour of the fruit. Wan Ishak et al., [2] conducted experiments in the laboratory environment, where the light intensity was controlled. The result showed that the ripe category could be differentiated from other category of specimens depending on the RGB (Red, Green and Blue) intensity, range and average. The above project achieved to produce electrical signal through the parallel port of the computer, when the camera detected the 'ripe' category of oil palm FFB. The experiment carried out showed that when the camera detected the 'ripe' bunch that matched with the reference red colour intensity in the computer, the LED was turned 'ON'. This signal can be used to turn 'ON' a switch to activate machine or robot arm.

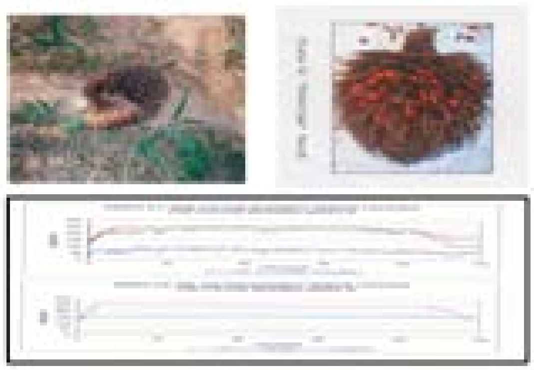

Fig. 1: Colour Intensity Graph of Oil Palm FFB using RGB Camera.

The goal of robot vision research is to enable the robot to simulate human visual perception of understanding and analyzing real time image sequences. Wan Ishak and Zohadie [3] integrate the knowledge of the vision system to the robot arm. A vision device was mounted on the robot in order to guide the end-effector to the desired position and orientation through the computer vision or image processing. Research on machine vision and image processing was carried out so that the robot arm can identify the object without the help of human brain and eyes. The Sony CCD single chip camera was used to grab images of interest. An Intel Pentium 166 MHz processor with a memory of at least 16 Mbytes RAMS was used for processing the data from this image. When the camera viewed the object, the Mill Intellicam grabbed the image and saved in the CPU. Matrox Inspector was then used to analyze the intensity of RGB color of the Image. The data was then compiled in the C++ program to determine the composition of colour of the fruits. The colours of fruits were analyzed based on its maturity. Figure 2 shows the experiment carried on camera vision that was attached to the robot arm.

Fig. 2: Experiment on Camera Vision to Detect and Harvest Crop

Development of Real-Time Automated Weedicide Sprayer

In this project, the ATV Polaris 500 ATP vehicle was installed with a commercial boom sprayer. Wan Ishak and Khairuddin [4] modified a commercial sprayer with an automation system guided with the web camera to detect the presence of weed. The commercial sprayer was modified and installed with 2 cameras for 6 nozzles spaced at 45 cm apart. 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 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 purpose of this study was to develop an automated sprayer by using camera vision for detecting the presence of weeds in real-time and spray the chemicals precisely to eradicate weeds. Weed detection at the time of spraying could be very valuable for reducing chemicals costs and reducing environmental contamination.

In this project, the commercial sprayer was modified. 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. The normally open (NO) solenoid valve was installed at the chemical tank. If there was nothing to be sprayed, the NO solenoid valve will by pass the chemical liquid back to the tank. This was to avoid the high-pressure build up in the main sprayer line. Figure 3 shows the ATV being mounted with the automatic sprayer.

Fig. 3: Automatic Sprayer Installed with Web Camera and Communication Devices.

Two pc web cameras 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 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 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 color of weeds failed to be detected. The closing and opening of valves were controlled by the electromechanical system that receives the instruction from the camera vision. Experiments carried out shows that the nozzle is closed when the percentage of weeds detected is less than 2%. It is half open at 3% to 50% and fully open at more than 51%. The application rate of spraying can be determined from the result of the spraying operation.

Hand Phone to Predict Oil Palm Maturity

Colour is considered a fundamental physical property of agriculture products and foods. Color is a common indicator used to recognize ripeness of the agricultural products and thus determine the best time to harvest the products. It is the most important indicator for the farmer to determine the fresh fruit bunches (FFB) oil palm fruit maturity in harvesting process. Optimum ripeness of oil palm fresh fruit bunches (FFB) is very crucial to the oil palm purchasing centers and palm oil mills. Presently the oil palm FFB are graded manually using visual human judgment of fruit bunch grader. The definition of matured colour oil palm FFB differs between planters and sellers due to the fact that human eyes perceive colours differently. The right stage of ripeness is critical to ensure optimum quality and quantity of oil production. The critical issue in harvesting the oil palm FFB is to harvest at the right stage of ripeness for ensuring that the maximum quantity and quality of palm oil is present for extraction of oil at the palm oil mills. If the oil palm FFB is harvested too early, the bunch will be too young and may not reach optimum oil content when processed while if it is harvested at overripe stage, the oil will contain high acid which will decrease the oil quality. The time of harvest for the matured oil palm FFB is determined by the colour of the fruits by the naked eyes. The skin color of the fruit bunch will change from black to reddish and orange during ripening process. The change in the mesocarp color is due to the accumulation of the carotene pigments, which also corresponds to the oil content of the mesocarp when analyzed. Thus an experiment was carried out to determine the relationship between the colour and the quality of oil in the fruits [5].

Nikon coolpix 4500 digital camera (Nikon, Japan) was used to capture the fruit image and store it digitally. It was equipped with a lens type Nikon 3x Tele Converter TC-E3ED. Minolta MPOB colorimeter CR 10 (Minolta, Japan) was used to determine the ripeness of oil palm fruit based on mesocarp surface color. This colorimeter equipment was used to validate the ripeness of the oil palm fruits after determining the mesocarp oil content using Soxhlet extraction process. The samples of fruits from different maturity stages were harvested from 5, 16 and 20 years old oil palm trees. The samples were weighed and chopped. The samples were dried at 70°C for a day to remove the water in the fruits. The dry nuts and mesocarp were weighed and blended before packed into filter papers (Whatman Cat No. 1001 150). The oil was extracted in Soxhlet extractor using chemical solvent, namely hexane. The remnant fibre and thimble were dried under 70°C for a day to remove the remaining hexane. The samples were weighed. All reading was inserted to automatic embedded calculation for oil to dry mesocarp ratio.

The hue pixel values of different fruits maturity were captured and analysed based on outdoor light condition of environment. The relationship of mesocarp oil content with optical properties for fruit color of hue was illustrated using trendline analysis of polynomial second order method. The results showed that the hue value of FFB image was highly significant in determining the oil content of oil palm fruit:

$$y = -0.0116x^2 + 5.2376x - 514.88; \quad R^2 = 0.884$$

where y = mesocarp oil content, x = hue value, R^2 = coefficient of determination. The value of $R^2 = 0.884$ showed highly correlation between hue value and the oil content of FFB. The oil content of fruits increased with increasing hue value of fruit skin image. The mesocarp oil content will be maximum at an average of 75% which is similar to earlier findings. Figure 4 shows the graph of the relationship between the mesocarp oil content and their respective hue digital values.

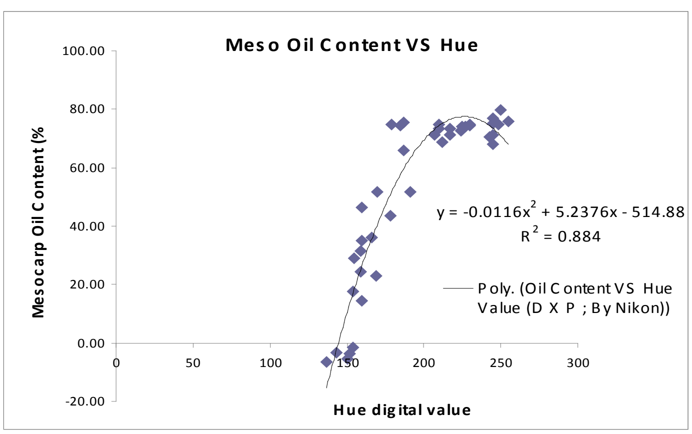

Fig. 4:The relationship of optical properties for fruit color versus mesocarp oil content.

Figure 5 illustrates the graph to determine the number days of harvesting the oil palm FFB. The graph was developed through the experiments as described above. The suitable days for harvesting were calculated based on the above equation of $y = -0.0116x^2 + 5.2376x - 514.88$. Let say the hue value from the camera is 200, so the oil content found using the above equation is: $y = -0.0116(200^2) + 5.2376(200) - 514.88 = 68.64$. The mesocarp oil content for hue of fruit color at 200 is 68.64%. From the above graph of Figure 5, the matured fruit was found to have hue of 224 with 74.22% oil content which indicated the day for harvest. The unripe fruit with measured hue of 158 has an oil content of 24.44% and indicates a 63 days before the fruit began ripening.

Nikon digital camera and Keyence Vision System were used for the experiment to determine the hue property of the oil palm FFB. The soxhlet extractor machine was used to analyse oil mesocarp content. The relationship of the mesocarp oil content and Hue optical properties for FFB surface were determined and validated using MPOB Minolta ripeness meter. The program was then downloaded to the Handheld PDA as shown in Figure 6. The mentioned software with its unified interface will allow the user to take a picture from the FFB using the built-in camera of the PDA. The picture is analyze inside the PDA using a Hue based image processing algorithm, Geotag it with the current location data received through the Built-in GPS, save it in a database for further analyses and finally showing the results on the screen which consisted of the Oil Content Percentage and Days left to harvest.

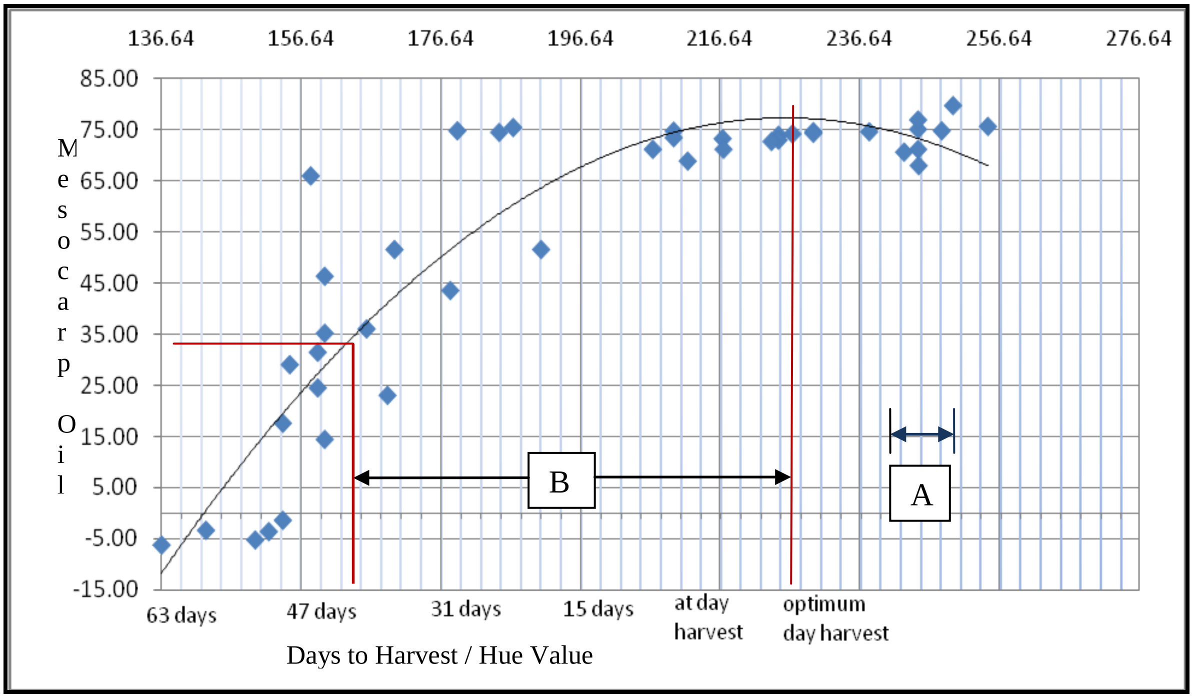

Fig. 5:The graph to determine the day of harvesting the FFB.

Fig. 6: Samsung Omnia II Handphone with Windows Mobile

CONCLUSION

Malaysian Agriculture is operating under competitive global environment and is losing grounds due to increasing costs of production, serious shortage of skilled agricultural workers and inadequate technology input. Technology input will reduce the dependence of labour and thus increase the utilization of labour and thus increase the utilization of natural resources. Mechanization has always played a supporting role in agricultural and plantation development. Agriculture and Food mechanization must emphasize on new technology with the application of automation and mechatronics. As a conclusion, mechatronic and other discipline of engineering must be studied and apply for the benefit to improve on the automation system in the agricultural sector. It is said that vision is so important that it can account for more than 90% of the total information obtained from all the senses put together. The goal of camera vision research is to simulate human visual perception of understanding and analyzing real time image sequences. Thus initial research was successful for the vision system to determine the maturity of crops, sorting of crops by color and precise spraying of chemicals to eliminate weeds.

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