RESEARCH AND DEVELOPMENT OF OIL PALM HARVESTER ROBOT AT UNIVERSITI PUTRA MALAYSIA

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ABSTRACT

For several decades, Malaysia was the largest producers of agricultural products especially palm oil and rubber. Presently, Malaysian agricultural sector is at crucial stage. Labor problem is said to be one of the contributing factor for the higher cost of production and deteriorating agro-based industries. Automation and robotics technology must be introduced and developed immediately in the plantation sector especially in solving the harvesting, collection and transportation of the oil palm FFB. This paper describes on the development of oil palm FFB bio-production robot at Universiti Putra Malaysia.The initial project started in 1993 involved in the modification of the grabber for oil palm FFB by changing of the manual control to an automatic control system using the solenoid control valves. With the use of hydraulic cylinders, relief valves, flow control valves, relays, sensors, limit switches and 4/3 way solenoid valves, the grabber was able to function automatically to grab, lift, turn, position and drop the oil palm FFB inside the dumper. In 1997, a portable agricultural robot was designed and fabricated using hydraulic system from the tractor as the power source. This robot was automate using computer control system namely: Hydraulic Simulation Software (Hydraulsim) and Genie Software. Research progressed to the development of end effectors namely the cutter to harvest the oil palm FFB and the use of Programmable Logic Controller (PLC) as the controller to automate the process of harvesting. Camera vision using web cam was later introduced for the Videogrammetry technique and triangulation method to measure the x,y,and z distance of the oil palm FFB on the plant.The robot systems, computer control system, camera vision, unmanned tractor, and online harvesting robot were 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.

Key words: Automation, Harvesting Robot, Oil Palm FFB, Camera Vision, Controller, Autonomous Tractor, End Effector

INTRODUCTION

Agriculture 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. As the largest producer and exporter of palm oil and palm oil products, in general, Malaysia plays an important role in fulfilling the growing global need for oils and fats. The Malaysian oil palm industry continues to contribute significantly to the country’s economic development and foreign exchange earnings. However, the Malaysian oil palm industry needs more emphasis on its research and development to meet the world challenge and to maintain Malaysia as the top world producer of palm oil. The major problem faced by the oil palm plantation is shortage of labor, which will only be solved with the introduction of appropriate machineries.

Developing countries with agriculture as their main economy should follow the examples of countries like USA and Japan in successfully modernizing and mechanizing their agricultural sector. Today only about 5% of the total population of USA are involved in agriculture and inspite of this, the country can produce excess food for export. Developed countries are able to achieve such a high status of agricultural production simply because they employ engineering technology in their agricultural sector. To shape the agricultural and plantation industries in Malaysia, application of engineering and mechanization technologies in agriculture must be implemented

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immediately and continuously.

For several decades, Malaysia was the largest producers of agricultural products especially palm oil and rubber. Lately, Malaysian agricultural sector is at crucial stage. The production of our agricultural commodities and our primary commodities, namely oil palm, rubber and cocoa, is very labour intensive. Labour problem and inadequate technology input are said to be the contributing factors for the deteriorating agro-based industries. Lower production was due to the impact of industrialization, which causes the transfers of resources such as manpower, land and capital out of the agricultural sector into the manufacturing sectors. In spite of these, we must continue to push forward our industrialization programme without denying the importance of agro-based industries. The increasing adoption of modern technologies and production process to increase productivity will free labour, which is very important for both agricultural and manufacturing sectors. It is envisaged that the effect of labour shortage can be reduced by increasing the productivity of existing labour through mechanization. In this light, efforts must be made towards increasing the application of science and technology (S&T) through the use of modern technology to attain a higher agricultural productivity.

To shape the agro-based industry in Malaysia, new technology such as automation and robotics, information technology, nano technology, space technology, and energy technology must be developed and introduced. Robotic systems represent in principle new technical means of complex automatic production processes. A robot is defined as a programmable multi-functional manipulator designed to move material, part or specialized device through variable programmed motion for the performance of a variety of task (Schlussel, 1985). Generally speaking, the traditional or industrial robot is good at handling object whose physical properties are regular and static. The agriculture robot, however, needs to be able to handle growing biological object. The properties of growing plants and animals are dynamic. The complexity of designing and developing agricultural robots are that they have to withstand bad weather, dust and other adverse condition as compared to industrial robot that are housed in the control environment.

The tomato-harvesting robot was started (Kawamura et al., 1984) at Kyoto University, Japan. These technologies have been applied to many agricultural production processes in the world. Harvesting robots for apples, oranges, melons, grapes, cucumbers, cherry tomatoes, strawberries, mushrooms, etc., seedling production robots, and plant management robots were studied in the USA, Europe, and Asia. Kondo et al., (1993) carried out research and development on the basic mechanism of robot to be adapted to the tomato plant. In 1986, the Agricultural Industry Development, SpA of Italy and the University of Florida initiated a research program to develop a real-time, vision-servoing, robotic picking technology suitable for actual production conditions (Harrell et al., 1990).

Robotics technology in agricultural and plantation industry is still new and still under research and development. It should be introduced and developed immediately in the agricultural sector especially in solving the harvesting, collection and transportation of the oil palm FFB. As part of the strategy to enlarge the technology base, the universities are expected to play a more important role in S & T and manpower development. The universities take the lead to enhance education and research capabilities, in order to provide effective support for the acquisition of the new and emerging technologies. Universiti Putra Malaysia (UPM) plays a major role in basic and applied research in all aspects of agricultural for further development of agricultural activities in keeping with the aspirations of the country.

Higher institutions, such as Universiti Putra Malaysia, has been producing quality professional agricultural engineers required for the future growth and development of the agricultural sector. In 1992 the Department of Biological and Agricultural Engineering at UPM introduced an option on agricultural mechanization and automation in the new Agricultural Engineering curriculum. It was introduced to adopt to the new advancement in this technological age to automate the agricultural sector. These agricultural engineers are capable of solving engineering problems peculiar to the agricultural sector. Agricultural engineers are presently being trained at the university to meet the nation's demand for specially trained personnel to serve the agricultural sector.

R & D ON AGRICULTURAL ROBOT

The development of agricultural robot at UPM started in 1992 with the review of Agricultural Engineering Curriculum. Wan Zulkarnain Othman (1993) carried out the first 'Final Year Project' with the title 'Agricultural Robots for Harvesting Oil Palm.' Bouketir Omrane (1999), was the first master's student completed his research with the title 'Camera Vision Interfacing 3DOF Agriculture Robot.' In 1997, a portable agricultural robot was designed and fabricated using portable hydraulic system or hydraulic system from the tractor as the power source. . The project was to automate the picking and loading of oil palm FFB using the ‘grabber’. With the use of hydraulic cylinders, relief valves, flow control valves, relays, sensors, limit switches and 4/3 way solenoid valves, the grabber was able to function automatically with the push of only one start button. Using only one button the grabber will grab, lift, turn, position and drop the oil palm FFB inside the dumper (Figure 1). This robot was automate using computer control system namely: Hydraulic Simulation Software (Hydraulism), Genie Software and Programmable Logic Control (PLC). Consequently in 1997 a pneumatic control robot arm was designed and fabricated to be used to harvest and collect lighter materials such as cocoa pod (Figure 2). The objective of the project was to design a pneumatic circuit using pneumatic simulation software or pneusim and PLC, to integrate with the robot arm.

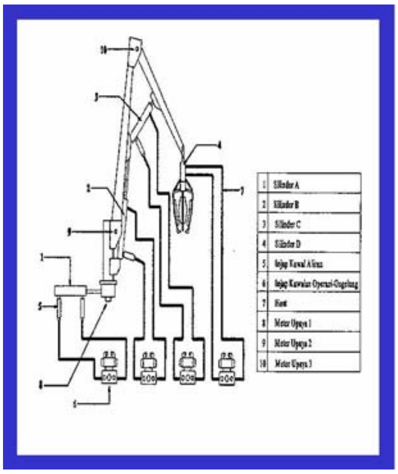

Figure 1: Oil Palm FFB Grabber

Figure 2: Cocoa Pod Harvester Robot

Other final year projects related to harvesting robot include: ‘Robotic and Automation in Agricultural Production’, ‘Computer Controlled System in Picking and Harvesting of Oil Palm’,’ Camera Vision to Recognize and Identify the Quality Oil Palm Fruit Bunch’,’ Design and Fabrication of Cocoa Harvester using Pneumatic Control System’,’ Design and Fabrication of Oil Palm FFB Cutter and Harvester using Hydrausim Control System’,’ Vehicle and Robot Control Using Transducers and Sensors’,’ Design and Fabrication of Hydraulic Driven Cutter to Harvest Oil Palm ffb’,’ Transducers to Locate the Oil Palm Fruit Bunches for Robot Arm’,’ Remote Control System for Manipulation of Robot Arm’,’ Design and Fabrication of remote Control Hydrostatic Transmission for Agrovehicle’,’ Design and Fabrication of Oil Palm Frond Cutter using Hydraulic Powered Strings’,’ Evaluation and Modification of Robot for the Hydraulic Power Saw Chain Cutter End Effector’,’ Obstacle Detection of Unmanned Tractor’,’ Development of Oil Palm FFB Cutter Robot End-Effector’,’ Development of Robot Colour Vision for
Harvesting of Oil Palm FFB’.

HARVESTER ROBOT

The robot system has basic components; the manipulator, the controller, the power source and end-effector. The manipulator does the physical work of the robotic system. The movement of manipulator is controlled by actuators or drive systems. The drive system can use electric, hydraulic or pneumatic power. The controller, generally a microprocessor-based system is to control the robot manipulator’s movement The end effector is a device connected to the wrist flange of the manipulators arm. In agricultural sectors, robots are used to perform transplanting of seedling, pruning, harvesting, sheep shearing, meat processing and picking of agricultural product. The main area of application of robot in agriculture is at the harvesting stage. It is hoped that with the development of agricultural robot, the hard and labour intensive need in picking and harvesting oil palm FFB in the plantation can be easier, simpler and interesting plus most important of all, will reduce the manpower shortage problem

(a) Development of End Effectors

The first major task of a fruit picking and harvesting robot is to design and fabricate the suitable end effectors. Each particular agricultural products has a peculiar way of harvesting method, thus requires specialized end effector (fingers, cutters or pickers). The manual harvesting methods will be the best example to be made in a designing a mechanical harvester.

Various end-effectors or robot fingers were designed and fabricated. End effector with grippers was designed specifically to pick the oil palm FFB on the ground and carried it to the trailer. The gripper was designed similar to the human hand and fingers, using double acting hydraulic cylinder to open and close the gripper (Bouketir Omrane, 1999). The end effector was developed to operate as fast as possible without damaging the fruits. Another development is the designed of the two-finger gripper with a cutting tool specifically to grip and cut the oil palm frond and FFB from the tree. The cutting tool was mounted at the end of the gripper (Rahimi, 1998). Various blades attached to the end effector of the robot were also tested and evaluated. The size and the eye of the blade have to give the cutter the ability to cut the fruit bunch. In 1999, a project was carried out to design and fabricate an oil palm frond cutter using string cutter driven by hydraulic motor (Noor Azmi, 1999). The structure of the string cutter was a double plate on 'V' shape. The string was attached on pulleys along the mainframe, run by high-speed hydraulic motor (Figure 3). During the same year, the hydraulic driven circular blade attached to the end of the effector was designed, fabricated and tested. The cutter was able to cut the oil palm fronds and FFB during harvesting. Another project was carried out in 1999 to design and fabricate the claw cutting concept for oil palm harvester. Cutting operation was accomplished by the blades of equal size moving in the opposite directions as the scissors (Mariyati, 1999). Hydraulic system was used as a power source-driven at low speed by a high torque motor to rotate the cam to actuate the claw cutter. Various harvesting end effectors were designed, fabricated and tested and are available at UPM.

Figure 3: String Cutter Oil Palm FFB Harvester

(b) Development of Computer Control System

In 1996, a computer control system for the agricultural robot was introduced with an application of 'Genie Software' to automate the movement of the cranes or robot arms (Wan Ishak and Zohadie, 1999). Basically, the operator inserts the co-ordinate of the oil palm bunch position into the computer and the 'Genie Software' as the control element will process the input data and give instruction to the robot arm to pick the oil palm FFB. The final results showed the concept of computer control system in loading FFB to replace manual loading was successfully developed with the Genie software

Another computer control system using Hydraulism (Hydraulic Simulation Software) to automate the control of the agricultural robot was designed and tested. The hydraulism require the user to design the hydraulic circuit similar to the arrangement of the actuators of the agricultural robot. These circuits are important to determine the sequence of the robot arm movement and to actuate the solenoid valve to move the actuators namely cylinders and motors. In order to automate the robot, Hydraulism software was interfaced with the robot arm using I/O interface and relay cards. The I/O interface card will receive the input signal from the computer and transmit it to the relay card whereby the relay interface card then sent the signal to the solenoid valve of the robot to move the

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robot arm. These softwares have the advantage over the 'Genie' control system which required no installation of the limit switches and electrical wiring along the robot arm.

In 1997 and 1998, projects on the design and fabrication of agricultural robot using PLC as controller was carried out. During the operation, an output was developed from the PLC to solenoid valve. This electrical signal control the ON and OFF switch of the solenoid valve. The solenoid valve directs the flow of fluid into and out of the actuators. A feedback device allows the PLC to identify the position of the stroke of the cylinder and motor rotation. Positional correction was made by the PLC and fed to the solenoid valve.
In 1999, another project was carried out to study on the various type of transducers suitable for the agricultural robot and to integrate the signal from the transducer to the robotic arm through the use of PLC. In this project, SYSMAC, a ladder programming software was used that catered to Omron's C-series PLCs. The CPM1A was connected to the PC via an RS-232C cable. One end of RS-232 was connected to the PC serial port, while the other end of the cable, was connected to the RS-232C adapter attached to the CPM1A.

In 1999, another control system was developed for the robot arm to harvest and collect the cocoa pod. Two photo sensors were required in order to scan the presence of the cocoa pod in the robot's work envelope. When the photo sensor 1 senses the presence of the cocoa pod then the movement of the robotic arm stops. Simultaneously the fingers will extend. Sensor 2 will detect the cocoa pod and allows the finger or gripper to pick and harvest the cocoa pod. The cocoa pod were detected by the transducer consisting of light beam transmitter with LED and a receiver composed of a photodiode or phototransistor. A feedback control system will automate the function such as grip the fruit, rotates the fruit at 90°, gripper cylinder to pull the fruit and later return to home position. When there is no fruit for the first scanning, the robot will shift to another position scanning work volume envelope.

(c) Development of vision system

The goal of robot vision research is to enable the robot to simulate human visual perception of understanding and analyzing real time image sequences. A vision device is usually mounted on the robot in order to guide the end-effector to the desired position and orientation through the computer vision or image processing. The variations of lighting intensity from time to time and place to place, causing difficulty in developing a complete vision system in terms of automatic recognition of the object's colour.

The first project on camera vision was carried out in early 1997. This project was on the camera vision to identify and recognize the colours of oil palm FFB. The Sony CCD single chip camera was used to grab images of interest. 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 objectives of the project were to differentiate and analyze the colours between the oil palm FFB, to identify the maturity of the fruits and to develop a computer program to process data related to colour of the fruit. Experiments were carried out 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. This signal can be used to turn 'ON' a switch to activate machine or robot arm.

The colour vision system was enhanced by developing the simulation of the kinematical manipulator on calculated workspace. When CCD camera detects the red object of target, the system will calculate the image plane by pixel units. It then transfers to the manipulator Cartesian plane which translate in centimeter units. The system was tested in a laboratory environment in which the illumination intensity was fixed and the system was found to work only when distance from target to manipulator (z –axis) was fixed.

The use of camera has failed to obtain sufficient information about fruit, mainly in unconstraint environment, where many factors affect the scene such as weather conditions, colour of leaves and their position according the fruit and light contrast. A Master's student, Hudzari (2000) developed the 'robot eye' system for agriculture robot to predict actual distance of the target object. The 'robot eye' used WebCam digital cameras for 3D coordinate measurement that displayed the real environment in the user interface that was created using Visual Basic Version 6. Videogrammetry technique and triangulation method were used to measure distance of the target object. By 'clicking' on the image displayed on the user interface (UI), the 3-dimensional (3D) distance of the target from robot arm will be generated and sends a signal to the robot to grip the selected target.

(d) Development of autonomous robot traveling device

The unmanned tractor control system is PC-Based control system. The system consisted of Acer Inspiron Laptop, a pair of radio Modem, ICP Modules (Digital and Analog modules) sensors, and Visual Basic as control software. SST-2400 Radio Modem is the "heart" of the PC-Based control system. It handles the signal transfer from the computer to the tractor. The Radio Modem communicates with the computer by using the RS-232 serial port. The Radio Modem that is set as receiver received the signal and transfers it to the ICP Modules via RS-485 bus. The radio modem need to be configured before it can be used.

In this research a Kubota L3010 hydrostatic drive tractor was modified to automate the 'on' 'off' of the engine, forward and backward gear system, the brake system and the steering system. The Kubota L3010 was equipped with sensors (Ultrasonic, range, magnetic, limit switch, encoder and potentiometer) and the controller to acquire the data of the surrounding information from the sensors. The range sensor was placed parallel to the front tires to sense the obstacle, which is parallel to the tires. The ultrasonic sensor was placed at different angle, and has a different range sensing. The sensors will generate a set of a Boolean logic. Each set of the Boolean logics represents the information about the distance and angle of the obstacle. The controller will use the information contained in the Boolean logics to make a decision to avoid the obstacle.

In this project a Graphical User Interface (GUI) was developed by using Visual Basic Program. From the developed GUI the user can control and monitor the data from the tractor remotely by using the Laptop computer. The GUI has two layers namely Control panel layer and Monitoring and Simulation layer. The Control panel layer is used to start and off the tractor engine, control the gear engagement, control the accelerator, control the brake system and also display the obstacles condition. While the Monitoring and Simulation layer help the user to direct the tractor to the selected position as displayed in the pre determine map. The map was scaled to the area of 15 cm X 15 cm, which represent 150m X 150m of the field area. In the Monitoring and Simulation layer, the user can select to direct the tractor by entering the grid coordinates manually. User can also monitor the rate of speed, tire turning angle and the traveling distance.

(e) Development of on-line harvesting robot

The latest development in the R&D of oil palm harvester robot is the conceptual on-line harvesting operation. Robotic and wireless technology in agricultural industry, especially in Malaysia is still new and still under research and development. Monitoring and control of mobile harvesting robot through wireless LAN are the pioneer concept and development for the new future to resolve part of the modernize agriculture industry.

This research present a wireless LAN interface designed to remotely operate mobile harvesting robots in agriculture field through the web. The operator directs the robot arm to the oil palm FFB on the plant through the Internet Super Highway with the help of wireless network devices and CCD communication camera. The interfaces have been tested extensively using a hydrostatic with harvesting robot with the help of the CMOS web Camera. The operator in the office able to guide and control the mobile harvesting robot in the plantation through the wireless LAN from a distance. Once the mobile harvesting robot are in the range of reachable to the targeted fruit, the operator can command the mobile harvesting robot to cut the targeted fruit automatically.

In this research a modified 4WD Kubota L-3010 tractor was used as an autonomous mover (research platform). The ICP CON I/O Module was installed to the mobile harvesting robot as the input/output-controlling device. It handles the signal transfer from the computer to the mobile harvesting robot. The function of I-7042 output module is to control the solenoid valves to move the robot arm. The I-7053 digital input module was used to handle the input signal from the potentiometer to give the position of the robot arm. The I-7520 module was used to convert the computer RS232 standard signal to RS485 bus to be used by the I/O modules. The TCP/IP GUI interface allows operator to send the robot to a position in the field, and receive real time video to monitor the mobile harvesting robot work space

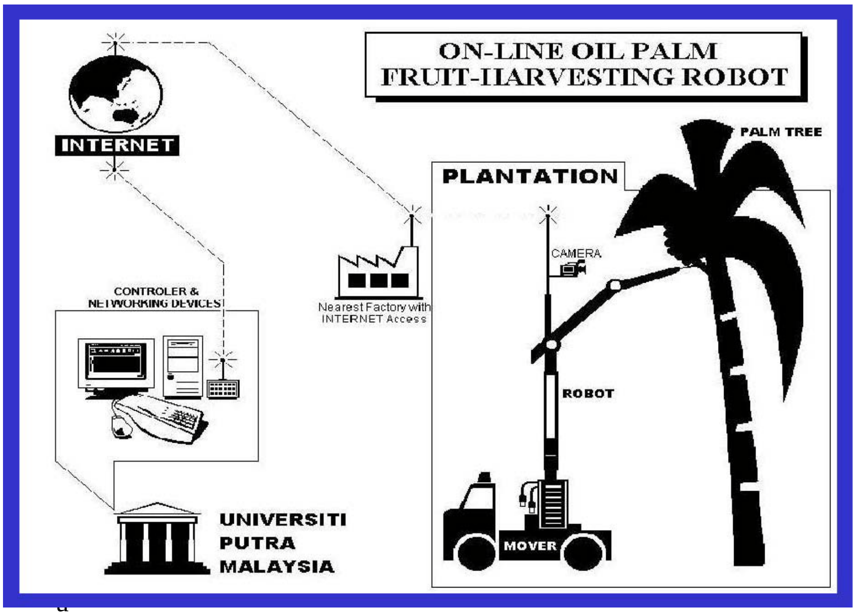

Figure 4: Conceptual Diagram On-Line Oil Palm FFB Harvesting Robot

CONCLUSION

It is envisaged that increasing productivity of existing labour through mechanization can increase agricultural productivity. Farm mechanization has been considered as the critical factor in industrialization process. It has released agricultural workers to industries, thus contributing to the nation' industrialized expansion. By introducing new engineering technology such as automation and robotic technology more manpower can be reduced, lighten burden, increase productivity as well as making agricultural jobs more interesting.

Our own efforts at UPM emphasize the development of agricultural sector. Faculty of Engineering, UPM through the Department of Biological and Agricultural Engineering has set up an Agricultural Mechanization and Automation laboratory to offer research and academic program on mechanization, automation and robotics in agriculture. Automation and robotic technology in agricultural industry, especially in Malaysia is still new and still under research and development. It is hoped with the introduction of automation and robotics in the agro-based industry, the hard and labour intensive agricultural operations can be easier, interesting and most important of all will solve manpower problems.

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