UNIVERSITI PUTRA MALAYSIA

# MONITORING AND CONTROLLING OF MOBILE HARVESTING ROBOT THROUGH WIRELESS LAN

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By

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**April 2004**

**Chairman : Professor Ir. Wan Ishak Wan Ismail, Ph.D.**

**Faculty : Engineering**

This research project presents a modification of a mobile harvesting robot for communication of human operator with the machine through wireless LAN networking. The adopted harvesting strategy relies on an operator to guide the vehicle through viewing real time video of the workspace to locate the fruit, while the robotic system plans the cutting sequence and makes the approximation for detaching of the fruit. This new strategy will reduce the overall cutting cycle by avoiding the time taken for detection and location of the fruit.

A software program was developed using Visual Basic for the operator to monitor and control the mobile harvesting movement remotely. Java Applet has been integrated into this software to continuously transmit the images from the CMOS web camera to the human operator in real time.

The operator communicates with the robot server through a pair of radio Ethernet devices. The location of fruit and position of the mobile robotic can be easily

retrieved and sent over the wireless TCP/IP protocol. This research has defined the X-axis as the horizontal axis of the target, Y-axis as the distance of target from the mobile harvester and the Z-axis as the vertical axis of the target. All the X, Y and Z – axis coordinates of the targeted fruit can be determined by the triangulation computation method using the video base positioning technique.

To move the mobile harvesting robot to the X, Y and Z coordinates of the target, modification has been done including the attachment of few sensors to the mobile harvesting robot. The input signal to the robot controller commands it to move and stop the robot at the X, Y and Z coordinates precisely.

Abstrak tesis yang di kemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**SISTEM KOMUNIKASI LAN TANPA WAYAR BAGI ROBOT PENUAI**

Oleh

**LIM YU JIAN**

**April 2004**

**Pengerusi : Professor Ir. Wan Ishak Wan Ismail, Ph.D.**

**Fakulti : Kejuruteraan**

Kajiaan ini mempersembahkan pengubahsuain robot penuai untuk sistem komunikasi antara operator dan mesin melalui jaringan LAN tanpa wayar. Strategi penuaian cara ini membolehkan operator memandu robot penuai ke kawasan tuaian dengan panduan siaran video secara langsung bagi mengesan buah. Justeru robot penuai berhenti, operator dapat memastikan buah untuk dituai, manakala robot penuai akan mengira jarak dan lokasi buah pilihan bagi penuain secara automatik. Strategi ini dapat mengurangkan masa penuaian bagi robot untuk mengenalpasti buah pilihan untuk dituai.

Satu pengaturcaraan perisian dibangunkan dengan menggunakan perisian "Visual Basic" bagi tujuan operator mengawal dan meneliti pergerakan robot penuai secara kawalan jarak jauh. "Java Applet" di intergrasikan kedalam perisian ini bagi menghasilkan video secara langsung dari kamera "Web"

Operator berkomunikasi dengan server robot melalui sepasang alatan radio Ethernet. Maklumat mengenai kedudukan buah dan posisi robot penuai dapat di hantar dan diterima melalui protokal TCP/IP tanpa wayar. Dalam penyelidikan ini kami telah mengenal pasti paksi X sebagai jarak mendatar buah dari robot penuai, paksi Y sebagai jarak buah dari robot penuai dan paksi Z sebagai jarak menegak buah dari robot penuai. Kesemua kordinat paksi X,Y dan Z bagi buah dapat di tentukan dengan menggunakan cara "Triangulation Computation" yang mengunakan teknik posisi video.

Bagi menggerakan robot penuai ke kordinasi X,Y dan Z buah, pengubahsuai dan penyambungkan penderia kepada robot penuai telah dilaksanakan. Sistem penderia dapat memberi maklumat kepada perisian kawalan robot yang menggerak dan memberhentikan robot pada kordinat X,Y dan Z secara tepat.

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# CHAPTER 1

# INTRODUCTION

There has been substantial increase in agricultural production in Asia and Pacific over the last two decades. This increase has been primarily due to the improvements in various farming techniques with increased results and reliable support services. Farm-level infrastructures such as irrigation, drainage, farm roads and computer technology have also contributed to this success. The level of infrastructure support has improved over the years as adoption of more sophisticated cropping systems increased. Modern agricultural practices are possible by the provision and improvement of this basic agricultural infrastructure. The use of high yielding variety seeds, increased fertilizer application rates and increased farm automation, also contributed to the increase in agricultural production.

The agricultural sector in Malaysia continues to play a major role in contributing towards national development. In addition to contributing to GDP, employment and export earnings, the sector provides raw materials to domestic agro-based industries as well as food for the population. At the same time, this sector is continuing its move towards conserving the ecology and environment as well as ensuring sustainable development. With rapid economic transformation towards industrialization, the sector's share of GDP increased from –2.8 per cent in 1998 to 0.6 per cent in 2000 and then declined from 2.5 per cent in 2001 to 1.0 per cent in 2002, as shown in Table 1.1.

**Table 1.1 - Malaysian gross domestic product by industry, 1998 - 2002**

**GROSS DOMESTIC PRODUCT**

| | 1998 | | 1999 | | 2000 | | 2001 | | 2002 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RM million | % growth | RM million | % growth | RM million | % growth | RM million | % growth | RM million | % growth |
| **Supply (at constant 1987 prices)** | | | | | | | | | | |
| Agriculture, forestry & fishing | 17,512 | -2.8 | 17,575 | 0.4 | 17,687 | 0.6 | 18,129 | 2.5 | 18,315 | 1.0 |
| Mining and quarrying | 14,357 | 0.4 | 13,977 | -2.6 | 14,416 | 3.1 | 14,444 | 0.2 | 14,883 | 3.0 |
| Manufacturing | 50,900 | -13.4 | 57,761 | 13.5 | 69,867 | 31.0 | 66,271 | -5.1 | 69,052 | 4.2 |
| Construction | 7,241 | -24.0 | 6,926 | -4.4 | 6,996 | 1.0 | 7,159 | 2.3 | 7,332 | 2.4 |
| Services | 101,753 | -0.4 | 106,654 | 4.8 | 111,747 | 4.8 | 117,218 | 4.9 | 121,656 | 3.8 |
| Electricity, gas & water | 6,745 | 11.1 | 7,334 | 8.7 | 7,886 | 7.5 | 8,330 | 6.6 | 8,868 | 6.5 |
| Transport, Storage & communications | 14,720 | -0.3 | 15,557 | 6.7 | 16,694 | 7.3 | 17,567 | 5.2 | 18,435 | 5.0 |
| Wholesale & retail trade hotel & restaurant | 28,489 | -3.4 | 29,240 | 2.6 | 30,949 | 5.8 | 31,956 | 3.3 | 32,935 | 3.1 |
| Finance, real estate & businese services | 23,563 | -1.9 | 24,895 | 5.6 | 26,161 | 5.1 | 38,066 | 7.3 | 29,052 | 3.6 |
| Government services | 13,180 | 1.1 | 14,195 | 7.7 | 14,395 | 1.4 | 15,178 | 5.4 | 15,785 | 4.0 |
| Other services | 15,036 | 1.9 | 15,433 | 2.6 | 15,662 | 1.5 | 16,121 | 2.9 | 16,544 | 2.6 |
| Less : Imputed bank service charges | 13,956 | 1.4 | 14,896 | 6.7 | 16,090 | 8.0 | 17,727 | 10.2 | 18,573 | 4.8 |
| Plus : Import duties | 4,430 | -42.4 | 5,319 | 20.1 | 4,742 | -10.9 | 4,693 | -1.0 | 4,789 | 2.0 |
| GDP at purchasers' value | 182,237 | -7.4 | 193,317 | 6.1 | 209,365 | 8.3 | 210,188 | 0.4 | 217,453 | 3.5 |
| **Demand (at constant 1987 prices)** | | | | | | | | | | |
| Private consumption | 82,031 | -10.2 | 84,719 | 3.3 | 95,086 | 12.2 | 97,779 | 2.8 | 142,668 | 5.0 |
| Private investment | 31,973 | -55.2 | 24,995 | -21.8 | 32,166 | 38.7 | 25,818 | -19.7 | 26,137 | 1.2 |
| Public consumption | 20,059 | -8.9 | 23,776 | 18.5 | 24,185 | 1.7 | 27,059 | 11.9 | 28,172 | 4.1 |
| Public investment | 23,204 | -8.4 | 26,902 | 15.9 | 32,249 | 19.9 | 37,232 | 15.5 | 36,117 | -3.0 |
| Exports of goods and non-factor services | 187,415 | 0.5 | 212,484 | 13.4 | 246,773 | 16.1 | 228,141 | -7.6 | 236,571 | 3.7 |
| Imports of goods and non-factor services | 162,212 | -18.8 | 179,778 | 10.6 | 223,294 | 24.2 | 204,129 | -8.6 | 212,710 | 4.2 |
| GNP at purchasers' value | 172,786 | -5.2 | 179,688 | 4.0 | 190,324 | 5.9 | 192,352 | 1.1 | 198,272 | 3.1 |

*Source : Eight Malaysia Plan*

Nevertheless, in absolute terms, the total value added of the sector continued to increase significantly from RM 17,512 million in 1998 to RM 18,315 million in 2002.

Employment in the agriculture sector decreased further during the plan period, from 1.5 million in 1995 to 1.4 million in 2000, a average decline of 1.2 per cent per annum, as shown in Table 2.1. Productivity gains were recorded in several sub sectors, particularly padi, tobacco, vegetables and poultry, through the application of various labor-saving technologies and better farming practices in large-scale commercial production. Value added per worker in the agriculture sector improved further by 2.4 per cent per annum, from about RM11, 500 in 1995 to about RM12, 900 in 2000. This was slightly lower than the Plan target of 3.3 per cent per annum due to the relatively slow process of mechanization in several sub sectors such as oil palm, rubber and cocoa (Eight Malaysia Plan, 2001).

**Table 1.2 - Employment and productivity in agriculture, 1995 - 2005**

**EMPLOYMENT AND PRODUCTIVITY IN AGRICULTURE**

| | | | | *Average Annual Growth Rate (%)* | | |
|---|---|---|---|---|---|---|
| | *1995* | *2000* | *2005* | *7MP Target* | *7MP Achieved* | *8MP Target* |
| Employment in Agriculture ('000) | 1,493 | 1,408 | 1,307 | -3.6 | -1.2 | -1.5 |
| Percent to Total Employment | 18.7 | 15.2 | 12.0 | | | |
| Value Added Per woker (RM in 1987 prices) | 11,466 | 12,898 | 16,088 | 3.3 | 2.4 | 4.5 |

*Source : Eight Malaysia Plan*

During the Eighth Malaysia Plan period, new and innovative measures has been undertaken to increase the contribution of the agriculture sector to the national economy. Domestic food production will be further enhanced by encouraging large-scale and organized farming, intensifying land use, improving agronomic practices as well as using modern technologies and management. Production of primary commodities will be reoriented to improve productivity and competitiveness through an integration program with livestock, wider crop mix practices and mechanization. In addition, production of specialty natural products such as medicinal plants as well as non-wood forest products will be promoted as new sources of growth.

The application of machines to agricultural production has been an outstanding development in Malaysian Agriculture. To ensure that Malaysia's agriculture cultivation continues to stay attractive in the growing commodity market, extensive research and development effort are being carried out to increase production, overcome labor shortage and to develop new technology for the industry.

Automation system, artificial intelligence and bio-production robots are among the new technologies that must be introduced in the agriculture industries. By using a super-computer it is possible to integrate satellite information for future application to the agriculture cultivation industries.

Industrial background has been traditionally the application field for robotics. Robots perform well in structured environments where working positions as well as obstacles are somehow predictable. Robotics' application field is spreading to reach

non-traditional areas like medical robots, agricultural and post -harvesting robots and so forth. Critical aspects of these new applications are robot-environment interaction and robust sensing in an outdoors and aggressive background, and as a consequence new overall designs are required.

Agricultural tasks have been an important application area for different kinds of technologies to improve crop production, farms and their related operations. In this century, the achieved progress has reduced the manpower devoted to these activities in the developed countries by a ratio of 1/80. (Pons et al, 1996). One of the most significant contributions is due to machinery developments and the corresponding automation techniques for a wide set of tasks: soil and farm treatments, sowing, harvesting and post-harvest processing, management, etc.

Nevertheless, agricultural workplaces are a clear example of unstructured environments, mainly owing to the innumerable forms and topologies of fields, plants and products. This fact makes it very difficult to implement fully automated solutions for mobile harvesting robot, and thus this is one of the non-mechanized and most expensive tasks for a variety of fruits including oil palm, cocoa and similar fruit groves. Robotics approaches have been applied since the late 1970s with more and more advanced devices and strategies.

The recent growth of the World Wide Web provides unique opportunities to bring robots closer to people. The vision behind such endeavors ranges from relatively simple web-based inspections and surveillance applications to highly versatile

applications that use robots connected to the web to establish a remote "telepresence" in dynamic and populated environments. In the latter scenario, robots play the role of a physical mediator, enabling remote people to acquire information, explore, manipulate, communicate, and interact physically with people far away.

Off-road equipment such as road graders, agricultural tractors, and mining vehicles are becoming increasingly computerized and automated. Local control networks are increasingly common in cars, trucks, and equipment and are increasing in implementation (Nieminen et al, 1993). At the same time, the number of sensors and actuators on the vehicles are also increasing. In agricultural applications, the amount of information and data needed and collected during harvesting operations is growing exponentially. The need to process this information, as well as the need to observe or control the vehicle itself lend well for the solutions int connectivity and networking.

Agriculture has always depended to a great extent on the weather and other natural forces, so the application of information technology (IT) to agriculture fields planted with food crops, pasturage, and so on has been difficult and farming has clearly lagged behind other industries and sectors in seeing the benefits of IT. Especially in Japan, where the agricultural labor force is shrinking and aging rapidly, finding ways to improve the productivity of the nation's agriculture and saving labor are more imperative than ever before. These were the main concerns inspiring researchers to investigate how farmers might benefit from the application of IT and computers.

It is difficult to apply wired networks in the agricultural sector particularly to farm fields and livestock pastures, considering the high construction cost and the disruption to farm work caused by such construction. Wireless system are highly recommended solution which has much lower initial startup costs.

Considering their great popularity in recent years and the fact that they could be applied to agriculture fields, this project first inclination was to use mobile phones. Although there are several viable systems currently available, we concluded that the calling charges would probably make the cost too high and the data transfer rate are too low for real-time video streaming.

A wireless LAN solution seemed especially appealing considering its transmission range of several kilometers and the fact that it is well supported by international standards. Wireless LANs have also come into use over the last few years to support hot-spot services in urban areas, and this has helped reduce the cost of wireless LAN equipment. Applying a wireless LAN to agriculture fields raises the issue of how it could be modified to consume less power, nevertheless concluded that a wireless LAN-based network is a key technology for applying IT to agriculture sector.

Overall, the major problem currently faced by the plantation industry such as oil palm, rubber and cocoa is the unavailability or inadequate labor supply. Currently the younger generation would prefer to work in the clean and nice environment instead of the hazardous plantation.

By introducing the robotic technology couple with wireless LAN communication more manpower can be reduce in agriculture sector. In addition it will reduce labor shortage and aging worker problem.

Another major problem faced by the agricultural and plantation industry in Malaysia is the inadequate technology input and technology expertise. Mechanization or the use of new technology will also reduce manpower, lighten the burden, increase productivity as well as making agricultural jobs more interesting. Along with the paradigm shift hopefully more investor will venture in to the modernize agriculture sector to create more high tech agriculture job for the young generation. The agriculture sector also will grow inline with the technology edge.

Robotic and wireless technology in agricultural industry, especially in Malaysia is still new and still under research and development. Robot and wireless LAN communication should be introduced and developed immediately in the agricultural sector especially in solving the harvesting, collection and transportation of the oil palm fresh fruit bunches and cocoa pod, tapping, collection and transportation of rubber latex. 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 design of these interfaces specifically to sensing and positioning, the mover and robot arm.

Monitoring the robot movement through the real-time video system is also one of this research task. The interfaces have been tested extensively using a hydrostatic tractor and a pneumatic robot arm, which were combined as a mobile harvesting robot with the help of the CMOS web Camera.

This research also discusses trade offs and limitations of wireless LAN mobile harvesting robots that interact with people, show examples of mobile harvesting robot control in web-based and virtual-based environments. Finally, present about expansion of the wireless technology and it's applications for future work.