



UNIVERSITI PUTRA MALAYSIA

**DESIGN AND DEVELOPMENT OF AN AUTONOMOUS SYSTEM FOR
AGRICULTURAL TRACTOR**

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AGRICULTURAL TRACTOR**

By
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in Fulfilment of the Requirements for the Degree of Master of Science**

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This study describes the design and modification of a tractor for automatic control. The automated system developed for the unmanned tractor was for the purpose of master/slave operation in the agricultural sector. In this study, an hydrostatic transmission of the Kubota tractor was selected as the research platform. Modifications were carried out in order to automate the manual control tractor. The automated system was capable to direct the tractor to the target location given by the user. The sensing system guides the tractor to move along the path determined by the controller based on the information from the sensors.

The automated system was developed by combining of electromechanical system, multi-sensor integration and control software. The electromechanical system (electro-hydraulic and electro-pneumatic) was used to control the gear, brake, steering and accelerator system. The integration of sensors (Ultrasonic sensor, range sensor, magnetic sensor, encoder and potentiometer) provided the surrounding information to the tractor controller. The controller consists of series I/O modules (ICP 17000) and

also pair of radio modem for data transmission. The graphical user interface software to control the automated system was developed using the Visual Basic.

The automated system developed for ignition, gear, brake, accelerator and steering systems can be control remotely through the use of Graphical User Interface (GUI). The GUI has features, which enable the user to monitor the tractor condition and movement of the tractor by referring to the *simulation layer*. The *simulation layer* consist of pre-determined field map, scaled at 1cm: 1m. The simulation movement of the tractor was configured to coordinate with the real tractor movement. The GUI also enables the user to use keyboard to control the tractor movement. The GUI has a capability to calculate the location of the given target location and plan the tractor movement to the target location and assist the tractor to avoid the obstacle in the tractor path.

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

**MEREKABENTUK DAN MEMBANGUNKAN SISTEM AUTONOMUS
UNTUK TRAKTOR PERTANIAN**

Oleh

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Kajian ini berkaitan dengan rekabentuk dan ubahsuai traktor untuk tujuan kawalan automatik. Sistem automatik untuk kawalan tractor tanpa pemandu di bangunkan untuk tujuan operasi *tuan /hamba* (master/slave) dalam sector pertanian. Dalam kajian ini sebuah traktor Kubota transmisi hidrostatik di pilih untuk pelantar kajian. Beberapa pengubahsuaian telah di lakukan untuk tujuan mengawal traktor secara automatik. Sistem automatik ini berupaya untuk mengarahkan traktor lokasi sasaran yang di berikan oleh operator secara automatik. Sistem penderia yang di bangunkan memandu traktor bergerak di sepanjang laluan yang telah di tentukan oleh alat kawalan. Laluan ini di tentukan berdasarkan maklumat yang di terima oleh alat kawalan dari alat-alat penderia.

Sistem kawalan automatik di bangunkan dengan menggabungkan sistem elektromekanikal, intergrasi pelbagai alat penderia dan juga perisian kawalan. Sistem elektromekanikal(elektrohaidraulik dan elektropneumatik) digunakan untuk mengawal sistem gear, sistem brek, sistem stereng dan sistem pendikit. Integrasi anantara alat

penderia (penderia ultrasonic, penderia jarak, penderia magnetik, enkoder, dan potentiometer) memberikan maklumat keadaan sekeliling kepada alat kawalan. Alat kawalan mempunyai beberapa siri module I/O (ICP 17000) serta sepasang modem radio untuk transmisi data. Perisian antaramuka bergrafik (GUI) yang di gunakan untuk mengawal sistem automatik di bangun menggunakan perisian Visual Basic.

Sistem automatik yang di bangunkan untuk sistem pencucuhan, sistem gegancu, sistem brek, sistem pendikit dan sistem stering boleh di kawal dari jarak jauh melalui penggunaan GUI. Penggunaan GUI membolehkan operator untuk menyelia kondisi traktor dan menyelia pergerakan traktor dengan merujuk pada *paparan simulasi*. *Paparan simulasi* mengandungi peta yang telah di tentukur berskala 1cm : 1m. Pergerakan simulasi traktor telah di konfigurasi supaya selari dengan pergerakan traktor sebenar. GUI juga mempunyai kebolehan menentukan lokasi kawasan sasaran serta merancang pergerakan traktor ke kawasan sasaran serta membantu traktor untuk mengelak halangan dalam laluan.

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CHAPTER 1

INTRODUCTION

In the past decade there has been considerable effort to develop autonomous robotic vehicles for random patrols, barrier assessment, intruder detection, reconnaissance and surveillance, building entry, target detection, building or terrain mapping, and explosive neutralization. Mobile robotic platform with the above capabilities will improve the ability to counter threats, limit risks to personnel, and reduce manpower requirements in hazardous environments.

In agricultural sector, the development of autonomous tractor concentrate on reducing working hour, avoiding hazardous work, tedious work and overcome the unskilled tractor operator. Agricultural vehicles are designed to perform various agricultural operations, and often operated on unprepared and changing terrain at relatively high speed. Human operators use a significant amount of intelligence to combine job functions, visual and audio cues, motion sensations, and experience to maneuver the vehicle. Long hours and repetition easily result in operator's fatigue, which in turn causes safety issues and decrease operation efficiency. Automatically guided vehicles will not fatigue, and can reduce operator's work intensity, resulting in enhanced efficiency, and increased operation safety (Zhang et al. 1999).

In the 21st century it is very important to develop the production technology required to decrease the cost of food production and to ensure a stable food

supply. In advanced countries, the lack of labor and aging work force complicate the situation. To solve these problems, vehicle guidance system that can reduce operator's fatigue will play an important role. In particular, the vehicle systems provide more efficient work and reduction in costs (Noguchi, 1995).

Driving an agricultural tractor in field without overrunning crops is a skill and labor-intensive task. The adoption of new agricultural technologies, such as precision agricultural, makes the maneuvering even more difficult. Meanwhile, the shortage and aging work force in agricultural results in decrease in skilled operators. Therefore, the development of automated or autonomous agricultural tractors is considered to be of societal importance. The rapid progress in guidance sensor and computer technologies makes it possible and affordable automated or autonomous agricultural tractors (Zhang et al. 1999).

Studies on the robotization of agricultural vehicle have been conducted in recent years to achieve the following objectives (Yukumoto, 1995).

1. Labor-saving through completely unmanned operations
2. High-precision work superior to human work, and
3. Improvement of safety and amenity by eliminating operator intervention

Subsequently, new working methods will be developed in response to robotization of agricultural vehicles and the following benefits are anticipated. (Yukumoto, 1990)

1. Single operator can manage and operate many vehicles concurrently.
2. Through continuous day and night work, a small machine can cover a large area and solve problems such as soil compaction, and
3. The ability to detect vehicle positions will enable to obtain information on yield and soil conditions of each part of the field and to execute precision farming.

1.1 Problem statement

In the farming sector of Malaysia, though the use of machines provides immense help to farmers, these machines require highly trained operators to handle. As time goes by, most of the operators of these machines have aged. And with the younger generation's lack of interest, solutions like foreign labors from neighboring countries have to be taken in to fill the reducing number of operators. Most of these labors are half trained labors of a particular field. Because of that, a substantial amount of time is required to train them to perform related work. As a result, high volume of cash flowing out and the production and maintenance costs will rise up.

The mechanization system available nowadays is very reliant on manpower. These use of machines requires work on areas that threatens the safety and health of the labor. With the rise of technology, various new technologies are introduced to the agricultural industry. An example would be the use of GIS (Geographical Information System) and GPS (Global Positioning System). Mechanization

systems available nowadays need to be adapted to enable the use of these technologies. With the availability of unmanned tractors that are controlled with computers, hopefully the lack of expert labors will be resolved. These tractors make minimal monitoring possible without the operator even stepping on the farm. A result would be the reduction on the reliance of foreign workers, less accidents and health threats. This will directly reduce the cost of operation. The system is also able to increase the work done on farms by operating around the clock using automatic monitoring with computers. Hopefully this system has the potential to attract the interest of intellectual people to contribute and invest in the agricultural sector. If this is possible, then the agricultural sector has the potential to rise up on par with the rise of technological advancements in the information technology age.

1.2 Motivation

Mechanization is a very important input in agricultural operations. Automation is one of the important components in the mechanization. Tractor is the most popular machine among the farmers. Until today tractor had been used to do various kind agricultural operations. The purpose of an automated control tractor were:

- To reduce the farmers burden in operating the tractor. For various kind of agricultural operation required a skilled operator. The automated tractor can be operated by the unskilled operator with minimum supervision.

- The automated tractor can also be programmed to work over the normal working hour of the farmer
- In the precision farming practices, an automated tractor is one of the important components. The automated tractor can be used to collect and store various kinds of data that is required for the various agricultural operations started from land preparation until the harvesting operation

The idea of researching was spawned right after following the advancements of technologies used in agriculture especially in the use of automated tractors in countries like Japan and the US. This technology is not available in Malaysia. The technology that is being brought up in Japan and US are based on the agricultural needs of their respective country. This research currently done has also taken into account the agricultural needs in Malaysia because likewise, many factors differ between Malaysia, Japan and US.

Only fellow countrymen will know the exact needs of their own country. This unmanned tractor is constructed according to the compatibility with the farm, crops and also the climate in Malaysia. This research uses a big part of technology that is easily available in Malaysia. Though there are parts and equipment that are taken from overseas, this act allows the use of new technology in Malaysia. This research is not only used to broaden the use of new technology in agriculture, but

also to open roads to Malaysians on the vast use of technology in various areas and sectors especially in the agricultural sector.

1.3 Research Background

Most of the autonomous tractor research, concentrate on field operation such as tilling, spraying, and harvesting. In this research the tractor is going to be design and modify as a traveling device for FFB harvesting robot arm. The task of the autonomous tractor to be studied is to carry and automate the equipments needed for harvesting operation. In completing the task the tractor should be able to recognize the obstacle, and planned the path to avoid the obstacles by taking the shortest path to the target.

The tractor will be equipped with the mechanical actuator, computer, electric and electronic instrumentations. Modification will be carried out on the tractor for unmanned control purposes. The mechanical actuators will be installed to replace the human tasks in controlling the steering, accelerator, gear and brake. The electrical motor will be use to control the accelerator pedal.

Sensors and transducers play an important role in obtaining the information about its environment; the current state of operation of the actuators, the tractor's turning angle, traveling distance, obstacles location and etc. Limit switches and proximity sensors are used to limit the movement of the hydraulic actuator. Photoelectric sensor will be used to determine the rotation of the electrical motor.

To determine the turning angle a potentiometer was used and a sonar sensor was used to determine the obstacle position and distance.

A radio modem was used for signals transfer from far distances. The radio modem is used to monitor the tractor from distance. The modem communicates via RS 232 port. While a computer system will control the whole operation assist by the user interface software. Through the GUI user can be able to control the tractor movement and monitor the data from the sensor on the tractor. There are two types of control movements, remote mode and auto mode. In the remote mode the user control the movement of the tractor by using the computer keyboard, while in the auto mode the user need to give the coordinate of the target location and activate the 'Auto' command button in the GUI. The movement of the tractor can be simulates on the pre-determined map in the GUI. The software will be developed using visual basic programming.

1.4 Objectives

The main objective of this project is to develop the control system for a tractor as an autonomous platform for agricultural operation in the plantation environment.

The specific objectives of this project are:

1. To design the vehicle motion planning system.
2. To design the obstacles detection and avoiding system.
3. To develop the electromechanical and control system for the autonomous operations.

CHAPTER 2

LITERATURE REVIEW

2.1 Autonomous Mobile Robot Systems

Autonomous mobile robot systems are vehicles, which are capable of performing independent movements and operations without following guidance systems or being steered by a remote control. An autonomous vehicle must be able to determine a collision free path from a start position to a goal position, with known or also potential unknown obstacles into consideration. With the help of its sensor technology, the robot must be capable to record information about its own position and the structure of its environment. There are often uncertainties with regard to the position and the identity of objects, which the autonomous vehicle has to handle during its main task, reaching its goal without collision. One advantage of autonomous vehicle compared to robot manipulators is the fact that no such a high positioning accuracy is required.

Spandl (1991). distinguishes several job steps of a mobile robot: the *vehicle control*, the *sensory mechanism*, the *navigation*, the *application of suitable sensor strategies* and the *path planning*. The *vehicle control* is engaged with the movement of the vehicle along a given trajectory with known kinematic and dynamic boundary conditions, whereby the main point is the interpolation of the trajectory and the drive (control) of the motors.