CONTROL OF MOBILE ROBOT

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This report is submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honors

Faculty of Electronic and Computer Engineering

Universiti Teknikal Malaysia Melaka

April 2009

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : CONTROL OF MOBILE ROBOT

Sesi Pengajian : 2005/2009

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To my beloved parents, family and friends

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ACKNOWLEDGEMENTS

I would like to thank Mrs. Noor Asyikin binti Sulaiman for her professional supervision, guidance, encouragement and patience through this two semester's course. It really has been a great experience to learn from her in the period of my project and thesis preparation. Thanks also to my fellow friends and classmates for all their help and support. And not forgotten also to thanks everyone who involve during finishing this project. Finally, a special thanks to my family especially my beloved mother for their love, encouragement and support through these four excitement years at UTeM. They are my inspiration.

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ABSTRACT

Mobile robot is a type of non-holonomic system. This is because the constraints on the velocity of the system cannot be integrated into position constraints that can be used to reduce the number of generalized coordinates. In other words, non-holonomic system is path-dependent and the number of generalized coordinates required to represent a system completely is more than its control degrees of freedom. This project attempts to control a non-holonomic mobile robot to track the desired trajectory. In this project, the combination of a kinematics and a torque controller is used to control the robot. The Lyapunov method is used to prove the stability of the system. It is a simplest and also successful method in kinematics stabilization, while the Lagrange formulism is used to derive the dynamic equations of the mobile robot then rearrange it into torque term. This project is a simulation by using SIMULINK/MATLAB software.

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ABSTRAK

Robot mobil adalah sejenis sistem tidak berholonomi. Ini adalah kerana had terhadap halaju sistem yang tidak boleh disatukan dengan had kedudukan untuk mengurangkan jumlah koordinat sesuatu sistem. Dengan kata lain, sistem tidak berholonomi adalah tidak bergantung pada laluan dan jumlah koordinat yang diperlukan untuk mewakili sesuatu sistem sepenuhnya adalah melebihi daripada kawalan darjah kebebasannya. Projek ini adalah untuk mengawal robot mobil bagi menjejaki laluan berliku yang dikehendaki. Bagi projek ini, kombinasi antara pengawal kinematik dan tork digunakan untuk mengawal robot mobil. Kaedah Lyapunov digunakan untuk membuktikan kestabilan system ini. Ia adalah kaedah yang paling mudah dan berjaya dalam penstabilan kinematik, manakala formula Lagrange digunakan bagi mengembangkan persamaan dinamik untuk robot mobil dan seterusnya menyusun persamaan tersebut dalam sebutan tork. Projek ini adalah simulasi menggunakan perisian SIMULINK/MATLAB.

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CHAPTER 1

INTRODUCTION

Robotics is a study that concerns itself with desire to synthesize some aspect of human function by the use of mechanisms, sensors, actuators, and computers. The main idea of robotics technology is come from various "classical" fields. Robotics is split into four major areas which are mechanical manipulator, locomotion, computer vision, and artificial intelligence.

Mobile robot is under locomotion field because it has ability to moves from place to place like a vehicle. This type of robot could work anytime and anywhere. Sometimes it could be used to save humans life. In other words, mobile robot is suitable for a variety of applications in unstructured environments where a high degree of autonomy is required. Mobile robots have the capability to move around in their environment and are not fixed to one physical location.

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The interest in investigating and developing mobile robots has become increasingly relevant and beneficial to human society and industry. This desired autonomous or intelligent behavior has motivated an intensive research in the last decade. There has been active and rapid development in this area pertaining to its research and implementation. Recent advances in computer and sensor technologies have made it feasible and practical to design and develop new and innovative mobile robots that can effectively serve as utility vehicles and material transporters.

The most important part of a robot is the control systems that control its movement. Without a good control system, a mobile robot is practically useless and ineffective. So, the design of the controller is a major part of a project to build a mobile robot. A variety of theoretical and applied control problems of mobile robot system have been studied and proposed such as kinematics control, dynamic control, intelligent control, adaptive control, and robust control.

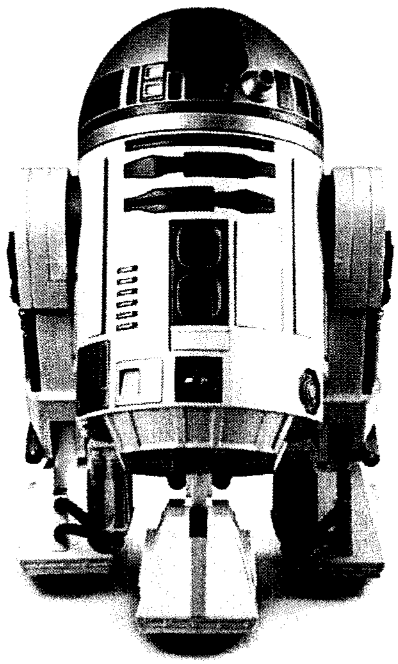

Figure 1.1: R2-D2; a tricycle type mobile robot that introduced in Star Wars film.

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There are many research have been made for solving the problem of motion under non-holonomic constraints using the kinematics model of a mobile robot but a plenty have done on the dynamic part. The main idea behind this research is to convert a steering system command into control inputs for the actual vehicle.

In this project, the dynamics model of the mobile robot will be use besides the kinematics to control the robot.

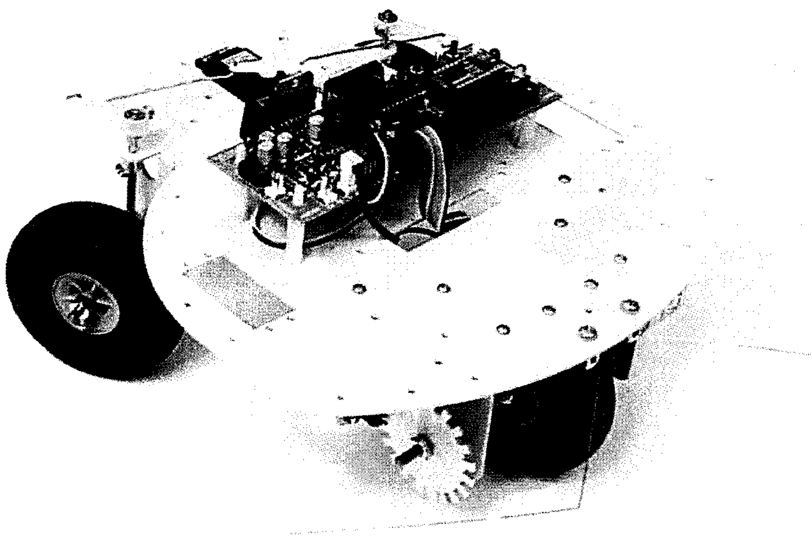

Figure 1.2: tricycle type mobile robot

1.1 PROJECT OBJECTIVE

The objectives of these projects are:

i) To develop a control system of a mobile robot for tracking a reference trajectory by considering the dynamics model of it.

ii) To find the best parameters for the stability of the controller.

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1.2 SCOPES OF PROJECT

The scopes of this project are:

i) The non-holonomic mobile robot considered in this project is a tricycle-type mobile robot.

ii) Both kinematics and dynamics model are used.

iii) There is no gravitational force.

iv) It is assumed that there is no slipping between the wheels and the floor and mobile robot travels at low speed.

v) A controller will be develop for tracking a reference trajectory.

vi) This project is simulated by using MATLAB/SIMULINK software.

1.3 PROBLEM STATEMENT

The main idea of this project is to track a reference trajectory. Initially, errors that cause by the position vector of the mobile robot are calculated. Then, a feedback controller will be used to composite the error, thus the mobile robot will able to track the reference trajectory. By considering the inertia, disturbance and non-holonomic constraints, a controller will be develop to prevent this problem.

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1.4 PROJECT METHODOLOGY

Figure 1.3 depicts the project methodology. There are seven steps with one feedback in the method that used to finish this project. First of all, the literature review is needed to understand each part in this project. Then, the derivation of mathematical equation is made for the controller. After that the best initial value is search from a few literatures that has been read. The simulation on MATLAB will be proceeding after getting the value. If the value of the parameter is not suitable, the process is proceed with finding the best value again. This value is chosen due to its stability for the controller. Finally, all the result will be recorded and analyzed.

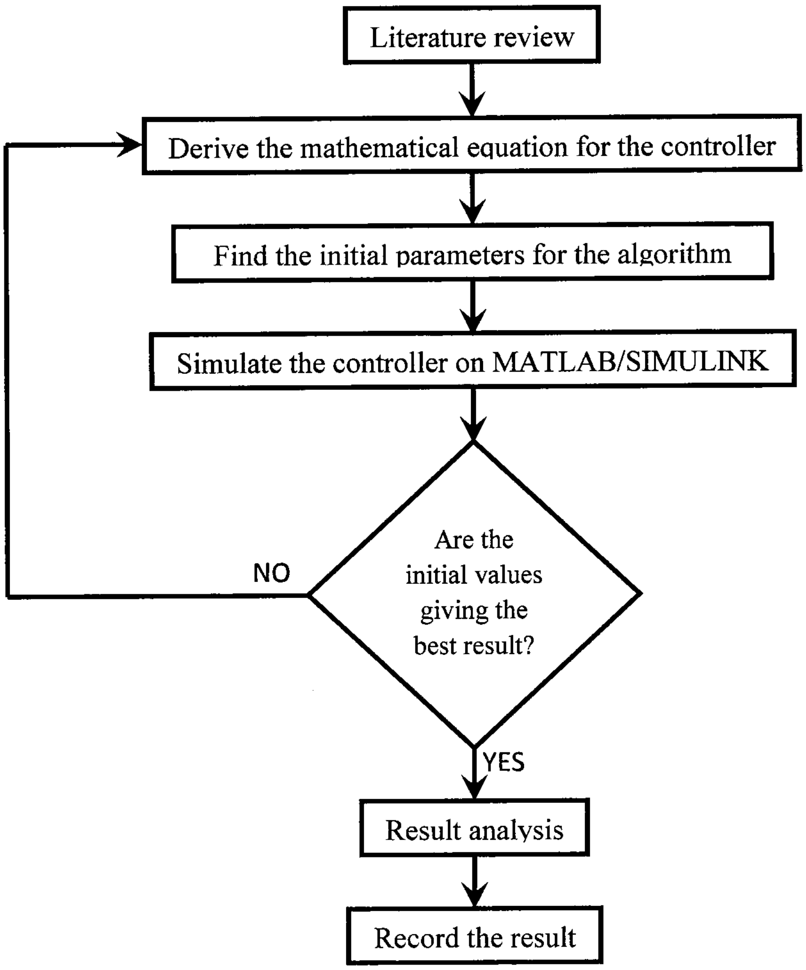

Figure 1.3: Project methodology

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1.5 REPORT STRUCTURE

This report start with the literature review on the non-holonomic mobile robot and the entire component for the controller needed for this project. It is including about the mobile robots, non-holonomic system, kinematics, dynamics, motion planning, and control theory. In kinematics and dynamics part, some kinematics and dynamics type controller is discussed. Then it proceeds with the mathematical model of the WMR which is kinematics and dynamics model. In this chapter, we can see the derivation of the algorithms that used by the previous researchers. In chapter 4, the controller of the wheeled mobile robot is discussed. Every equation used for this controller is included in this chapter such as non-linear control law and torque control. While in chapter 5, the simulation and results are presented. The content of SIMULINK subsystem is showed. This is to show how the equation is used in the simulation. Finally the project is concluded in chapter 6.

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CHAPTER 2

LITERATURE REVIEW

This chapter will briefly explain about wheeled mobile robot and its constraints. Besides that, some of the control techniques applied to the mobile robot that were proposed by some researchers will also be discussed.

2.1 WHEELED MOBILE ROBOT (WMR)

Mobile robots have the capability to move around in their environment and are not fixed to one physical location. In contrast, industrial robots usually consist of

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a jointed arm (multi-linked manipulator) and the gripper is attached to a fixed surface.

Mobile robots are the focus of a great deal of current research and almost every major university has one or more labs that focus on mobile robot research. Mobile robots are also found in industry, military and security environments. They also appear as consumer products, for entertainment or to perform certain tasks like vacuum.

There are many types of mobile robot. The main part of the mobile robot is the wheel and motor. Some mobile robot has three and some has four wheels depending on the application and the function of the mobile robot. Motors are used for the movement of the robot. Usually there two types of motor used for the mobile robots which is stepper motor and servo motor.

2.1.1 WMR AS A NON-HOLONOMIC SYSTEM

Non-holonomic system is a system described by a set of parameters subject to differential constraints, such that when the system evolves along a path in its parameter space, where the parameters vary continuously (in the mathematical sense) and return to the identical values they held at the start of the path, the system itself may not have returned to its original state. It is path-dependent, and the number of generalized coordinates required to represent a system completely is more than its control degrees of freedom.

Non-holonomic property is seen in many mechanical and robotic systems, particularly those using velocity inputs. Non-holonomic constraint is a differential equation on the base of state variables, it's cannot be integrate. So the feasible trajectory is limited. This means that a mobile robot with parallel wheels can't move laterally [1]. Integrable kinematics constraints are essential geometric constraints.

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Due to these constraints, control schemes developed for holonomic system such as robot manipulator are not applicable for non-holonomic systems.

In this project, the non-holonomic mobile robot will be discussed. The concept of non-holonomic system is the degree of freedom generalized coordinate is more than the control degree of freedom. WMR have non-holonomic constraints since it possess only two degrees of freedom which are linear velocity, v and rotational velocity, ω for steering control but in term of positioning, it has three degree of freedom, x, y and θ.

2.1.2 WMR DRIVING MOTORS

The movement of a WMR is controlled by motors. Direct current (DC) electric motors are arguably the most commonly used method for locomotion in mobile robot. DC motors are clean, quiet, and can produce sufficient power for variety of task. It is also easier to be controlled. It is important to select a motor with the right output of power for a desired task.

There are two motors designs which are significantly different from standard DC motors. These are stepper motor and servos. Stepper motors doffer from standard DC motors in such a way that they have two independent coils which can be independently controlled. As a result, stepper motor can be moved by impulses to precede exactly a single step forward or backward, instead of a smooth continuous motion in a standard DC motor.

DC motors are sometimes also referred to as "servo motors" but it is different from term "servo". A servo motor is a high-quality DC motor that qualifies to be used in a "servoing application". Such a motor must be able to handle fast changes in position, speed, and acceleration, and must be rated for high intermittent torque.

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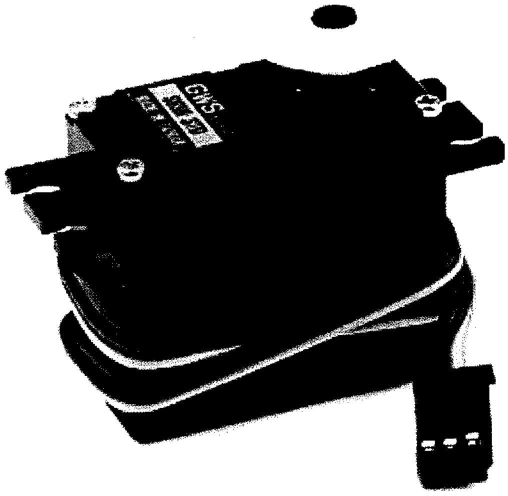

Figure 2.1: Servo

2.2 KINEMATICS

Kinematics is the science of motion that treats the subject without regard to the force that causes it. Robot kinematics deals with aspects of redundancy, collision avoidance and singularity avoidance. Hence, the study of kinematics of a robot refers to all the geometrical and time-base properties of the motion.

2.2.1 KINEMATICS CONTROL

There are many research has been made based on kinematics control of WRM. This controller is only considering the steering system of the WMR while the

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dynamics is neglected. The WMR system is assumed having a perfect velocity tracking to generate the actual vehicle control inputs. Unfortunately, the kinematics controller is not good enough for it stability when the robot is added with the external disturbances and uncertainties.

Kanayama et al. [2] proposed some nonlinear feedback controller which is a stable tracking control method for an autonomous mobile robot. The main objective of the control rule is to find a reasonable target and applying linear and rotational velocities (v, ω) to actuate the WMR for the tracking purpose. By using a Lyapunov function, the control algorithm has been proven in its ability to achieve WMR stabilization with asymptotically stable concept.

According to Kanayama, one of the difficulties of the mobile robot problem lies in the fact that ordinary vehicles groups only two degrees of freedom (linear velocity and angular velocity) for locomotion control, although vehicles have three degrees of freedom x , y and θ in its positioning. Another difficulty is in the non-linearity of the kinematic relation between $(v, \omega)^T$ and $(\dot{x}, \dot{y}, \dot{\theta})^T$. The use of a *Lyapunov* function also resolves these difficulties. Linearizing the system's differential equation is useful to decide parameters for critical dumping for a small disturbance. This equation is very popular in mobile robot literatures and has become a 'standard reference' by many researchers.

2.3 DYNAMICS

Terms of dynamics is used to describe the forces required to cause motion. Obviously, dynamics term cannot be completely covered as it deserved. However, certain formulations of the dynamics problem seem particularly well suited to application of a robot. It is more complicated than the kinematics because it involves a lot of parameters such as mass, centre of gravity, force, torque, speed, acceleration and mass moment of inertia.

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