TRACKING CONTROL OF WHEEL MOBILE ROBOT (WMR)

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This thesis is dedicated to my lovely mother, wife, kids and family
for their encouragement and blessing

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ABSTRACT

The objective of this thesis is to present a tracking control of wheel mobile robot based on kinematic mathematical model. At two wheel mobile robot, the purpose of a tracking control is to improve the performance of robot tracking at various time varying paths. Producing backstepping controller algorithm for wheel mobile robot (WMR) is used to minimize the tracking error. In this thesis, robust control technique that based on backstepping theory is presented for control at the wheel mobile robot system. The performance of the wheel mobile robot at various time varying path and the effect of variation d, the distance between centre point to driving wheels axis, have been analyzed by using SIMULINK, MATLAB software. It is found the error of driving, lateral and orientation direction can be minimized and satisfactory performance has been achieved.

ABSTRAK

Tujuan tesis ini adalah untuk mengenengahkan kawalan pengesanan roda asas robot mudah alih pada model matematik kinematik. Dengan menggunakan robot bergerak beroda dua, fungsi utama kawalan pengesanan adalah untuk memperbaiki prestasi robot untuk mengesan jalan yang berbeza-beza yang berkadar terus dengan masa. Penghasilan dan penggunaan algoritma pengawal undur belakang pada robot bergerak roda adalah untuk meminimakan kesilapan pada pengesanan jalan. Di dalam tesis ini, teknik kawalan mantap yang berdasarkan teori undur belakang dikemukakan untuk mengawal sistem bagi robot bergerak roda. Prestasi robot bergerak roda mengesan jalan yang berbeza-beza yang berkadar terus dengan masa serta kesan daripada perubahan jarak diantara titik tengah robot bergerak roda kepada roda pemandu, d telah di analisis dengan menggunakan perisian SIMULINK, MATLAB. Hasil daripada itu, didapati kesilapan pemanduan, arah sisi dan orientasi pada robot bergerak roda boleh dikurangkan dan prestasi yang memuaskan telah dicapai.

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LIST OF SYMBOLS

d	-	Distance between centre point to driving wheel
X_c	-	Centre point of WMRs in x-axis(m)
Y_c	-	Centre point of WMRs in y-axis (m)
L	-	Lateral direction
D	-	Driving Direction
θ ,	-	Orientation Angle (rad)
X	-	Global Cartesian coordinate in x-axis
Y	-	Global Cartesian coordinate in y-axis
R	-	Width of WMRs
r	-	Radius of wheel
v	-	Linear Velocity
w	-	Angular Velocity
x_d	-	Desired posture of WMRs in x-axis(m)
y_d	-	Desired posture of WMRs in y-axis(m)
θ_d	-	Desired posture angle of WMRs in xy-axis
x_c	-	Current posture of WMRs in x-axis(m)
y_c	-	Current posture of WMRs in y-axis(m)
θ_c	-	Current posture angle of WMRs in xy-axis
v_d	-	Reference Linear Velocity
w_d	-	Reference Angular Velocity
x_e , e_D	-	Error in driving direction
y_e , e_L	-	Error in lateral direction
θ_e , e_θ	-	Error in orientation angle
C_1	-	Control Parameter 1

C_2	-	Control Parameter 2
C_3	-	Control Parameter 3
M	-	Manifold of hypersurface

LIST OF ABBREVIATIONS

LQR	Linear Quadratic Regulator
LQG	Linear Quadratic Gaussian
NN	Neural Network
GA	Genetic Algorithm
DOF	Degree of Freedom
MSE	Mean Square Error

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wheeled mobile robots (WMRs) have been an active area of research and development over the past four decades with valuable attentions and innovation part in relevant and beneficial to human society and industry, mobile robots have a wide background of application and its motion control of wheeled mobile robots (WMRs).

This long-term interest has been mainly inspired by many practical applications that can be uniquely addressed by mobile robots due to their ability to work in large potentially unstructured and hazardous domains. Specially, WMRs have been employed for applications such as industry, education, rescue, hospitals, monitoring nuclear facilities, mine detection, and material inspection at warehouses and in security objectives, military tasks such as munitions handling, planetary exploration, materials transportation, vacuum cleaner, automatic guided vehicle exploration and entertainment. In order the wide range applications of WMRs, it is clear that WMR research is multidisciplinary by nature [1].

With increasingly interest in investigating and developing mobile robots, there has been active and rapid development in this area pertaining to its research and implementation due to recently advance in computerization area such as programming and sensor technologies. Figure 1.1 shows Mars Exploration Rover where developed by National Aeronautics and Space Administration (NASA) is one of the examples in an intelligent application in the class of wheel mobile robot. This Mars Exploration Rover consist of six wheel which have own drive system mounted on a special suspension system that ensures wheels remain on the ground while driving over rough terrain. Moreover, the Mars Exploration Rover is also consist communication system, power and electronic system and scientific instrumentation that be able to do their task accurately.

Figure 1.1: Mars Exploration Rover develop by NASA

Mobile robots are always categorized into two groups: wheeled-robots and legged-robots. Legged-robots have advantage over wheeled-robots for moving on very rough surface. For smooth surface, wheeled-robots are always quicker than legged-robots. Wheeled robots have no problem of stability or balance as always occurred in legged-robots. Wheeled mobile robots (WMRs) are more energy efficient than legged robot on hard, smooth surfaces, and will potentially be the first mobile robots to find widespread application in industry, because of the hard, smooth plant floors in existing industrial environments. WMRs require fewer and simpler parts and are thus easier to build than legged mobile robots. Wheel control is less complex than the actuation of multi-joint legs.

High nonlinearity system is the significant term to describe the basic of behaviour model of WMRs. The WMRs have non-holonomic constraints since they have restricted mobility in that the wheels roll without slipping and characteristic of the non-holonomic system is that the constraints, which are imposed on the motion, are not integratable, as example the constraints cannot be written as time derivatives of some functions of the generalized coordinates.

1.1.1 Path Tracking Control

One of the important aspects of the WMR systems is related to its path tracking control. The issue of path tracking control problem is not only dependent on the kinematics and dynamics of the WMRs system but also the actual individual elements of the control itself [2]. WMRs are practically useless and ineffective without a good control system. Therefore, the development of WMRs is significantly influenced by the proper design of the path tracking control system. With substantial research has been devoted to path tracking control. A variety of theoretical and applied path tracking control problems of WMRs system have been studied and proposed such as kinematics control, dynamic control, intelligent control, adaptive control, and robust control.

The path tracking control of the WMRs is particularly relevant in practical application. Tracking control of the WMRs objective is to guide the WMRs to follow the desired trajectory by adjusting or control the WMRs forward and angular velocity respectively and also is to solve the three basic navigation problems; tracking a reference trajectory, path following and stabilization about a desired posture [3]. The strategy by which a vehicle approaches a desired position and implementation controller guarantees the convergence of the tracking error to zero. For the path tracking control of WMRs, the main difficulty of solving stabilization and tracking control of mobile robots is the motion of the systems has more degree of freedom than the number of inputs under non-holonomic constraints.

Most of this thesis has focused on the kinematic equation of WMRs. The velocities of WMRs are treated as control inputs in the kinematic controller level. The vehicle control inputs have been computed with the assumption of a ‘perfect velocity tracking’, thus neglecting the vehicle dynamics. Therefore, it is assumed that there exists a dynamic controller that can produce perfectly the same velocity that is necessary for the kinematic controller.

1.2 Objective

The objectives of this project are:

i) Modeling and control the kinematic model of Wheel Mobile Robot (WMR).

ii) Propose control algorithm for WMR tracking at various time varying path.

iii) To verify the performance of WMR system through Matlab simulation.

1.3 Scope of Project

The scope of work for this project includes:

i) Derivation of the mathematical equation of kinematic system model for WMRs by using the Cartesian coordinate system.

ii) Derivation of the mathematical equation in implementation of Backstepping controller to the WMRs system which are simple and appropriate for the cases with small tracking error.

iii) Simulation study and verification conducted in SIMULINK, MATLAB software to verify the performance of WMRs system by effect in the various time varying path and the distance between centre point of WMRs and driving wheel.

1.4 Methodology

Generally, the method used to accomplish this project is described in Figure1.2. First of all, since to understand the behaviour of path tracking control for nonholomic WMRs is the crucial part in this project. Therefore the first steps are study and do the extensive review on kinematic model of WMRs, their control methodology and also how to improve their path tracking control. Secondly, derivation of the mathematical equation of kinematic system model for WMRs by using the Cartesian coordinate system. For design the path tracking controller of WMRs, the derivation of mathematical equation for Backstepping controller to implementation in the WMRs system and perform the simulation using SIMULINK, MATLAB software to verify the work done. Last but not least, the analysis of the performance of WMRs system by effect in the various times varying path and the distance between centre point of WMRs and driving wheel.

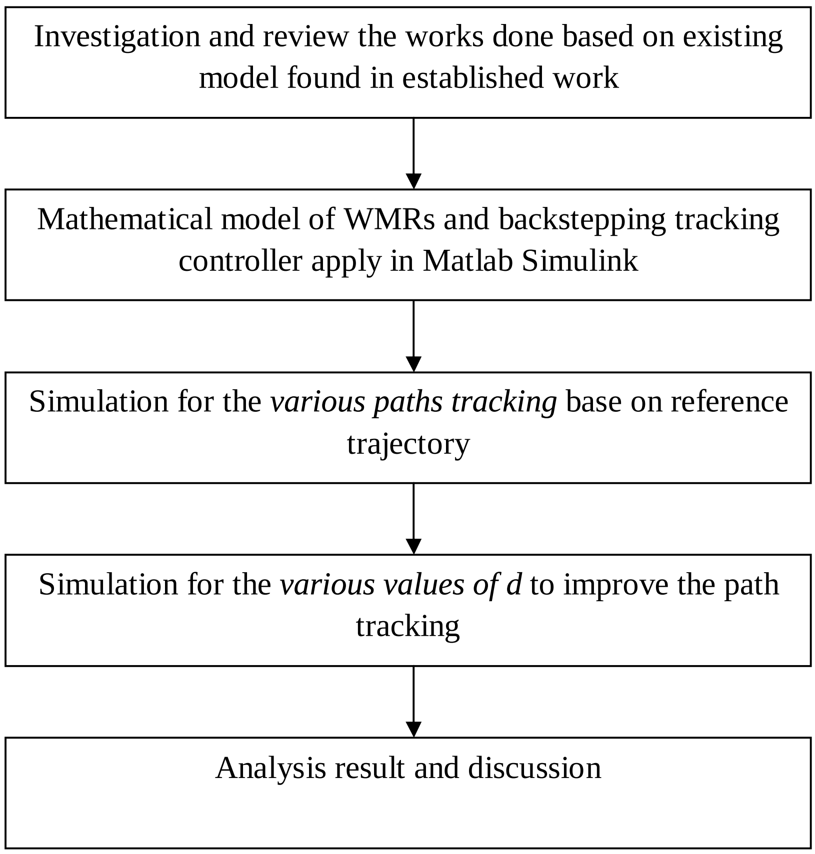

Figure 1.2: Methodology of the project

1.5 Thesis Outline

This thesis consists of six chapters. Chapter I, provide some introduction and background of the project, the objectives, the scope of studies and the methodologies. Chapter II contains the literature review on non-holonomic WMRs system and control techniques applied to the mobile robot that were proposed by some researchers. Chapter III derivation of the mathematical equation of kinematic system model for WMRs by using the Cartesian coordinate system. Chapter IV Derivation of the mathematical equation in implementation of Backstepping controller to the WMRs system which are analyze the controller with local asymptotically stable (Root Locus & Routh Hurwitz Technique) and global asymptotically stable (Lyapunov candidate function). Simulation study and verification conducted in SIMULINK, MATLAB software to verify the performance of WMRs system by effect in the various time varying path and the distance between centre point of WMRs and rear wheel are presented in Chapter V**.** The work is then concluded in Chapter VI with some suggestions and future works.

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