CONTROL OF WHEELED MOBILE ROBOTS

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Tajuk Projek : CONTROL OF WHEELED MOBILE ROBOT

Sesi Pengajian : 2007 / 2008

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I dedicate this report to my beloved family daddy and mummy, my brother and sisters, friends and especially not forgetting Madam Noor Asyikin Binti Sulaiman for all your support and patient.

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ABSTRACT

This project is attempts to controls a stable tracking control for wheeled mobile robot with non-holonomic velocity constraints. Non-holonomic constraints are the constraints on the velocity of the system which cannot be integrated into position constraints that can be used to reduce the number of generalized coordinates. In this project, the application of kinematics controller is examined and analysed. The controller is using Lyapunov method which is a successful method in kinematics stabilization. In order to avoid any slippage, a velocity/acceleration limitation scheme was introduced. The control rule that apply in this project are robot-independent and hence can be applied to various kind of robot. Linearizing the system's differential equation is useful to decide parameters for critical damping for a small disturbance. The wheeled mobile robot used in this project is a tri-cycle type. All simulations in this project are performed using SIMULINK/MATLAB.

ABSTRAK

Projek ini adalah percubaan untuk mengawal kawalan penjejakan stabil untuk robot beroda dengan kekangan-kekangan halaju. Kekangan-kekangan halaju adalah kekangan terhadap halaju sistem di mana ia tidak dapat disepadukan kepada kedudukan kekangan yang boleh digunakan untuk mengurangkan jumlah koordinasi umum. Dalam projek ini, aplikasi pengawal kinematik akan diuji dan dianalisis. Pengawal ini akan menggunakan kaedah Lyapunov di mana ia kaedah yang berjaya dalam keseimbangan kinematik. Untuk mengelakkan gelinciran, satu skim batasan kelajuan/pecutan diperkenalkan. Peraturan kawalan yang diaplikasikan dalam projek ini adalah robot-bebas dan oleh itu ia boleh diaplikasikan ke atas pelbagai jenis robot. Pengelurusan ke atas persamaan pembezaan sistem adalah berguna untuk menentukan pembolehubah untuk redaman genting untuk satu gangguan kecil. Robot beroda yang akan digunakan dalam projek ini adalah jenis beroda tiga. Kesemua simulasi dalam projek ini menggunakan SIMULINK/MATLAB.

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INTRODUCTION

1.1 Introduction

This project attempts to control a stable tracking control for wheeled mobile robot with non-holonomic velocity constraints. Non-holonomic constraints are the constraints on the velocity of the system which can not be integrated into position constraints that can be used to reduce the number of generalized coordinates. In this project, the application of kinematics controller is examined and analysed. The controller is using Lyapunov method which is a successful method in kinematics stabilization. The wheeled mobile robot used in this project is a tri-cycle type. The project will being simulate using the SIMULINK/MATLAB simulation.

In this project a new control rule for determining vehicle's linear and rotational velocities is given. The stability of the control rule is proven using a Lyapunov function. One of the difficulties of this problem lies in the fact that ordinary vehicles possess only two degrees of freedom (linear velocity and rotational velocity) for locomotion control, nevertheless vehicles have three degrees of freedom x, y and θ in its positioning. Another difficulties is in the non-linearity of the kinematic relation between $(v, \omega)^t$ and $(\dot{x}, \dot{y}, \dot{\theta})^t$. The use of the Lyapunov function resolves the difficulties.[1]

By linearizing the system's differential equation, a condition for critical damping which gives appropriate parameters for specific control rules is being found.

This method is useful to the class of autonomous vehicles in which:

- A dead reckoning capability is provided.
- Reference path specification and current position estimation (through dead reckoning) are given separately.
- High precision in positional control is mandatory.

1.2 Objective of the Project

There are two objectives of this project which are:

- To control a non-holonomic mobile robot to track a reference trajectory.
- All simulation performed using SIMULINK/MATLAB.

For the first objective, the robot can track a reference trajectory. There will be two postures that will be used in this project which are current posture and reference posture. The current posture of robot can detect the trajectory the reference posture.

1.3 Problems of Statements

This system can help human to make certain things and works become easier. For example, in the industry carts and trucks are drove by the human to carry products from one manufacturing plant to another which are usually in different buildings or separate blocks. So, by implement this project the cart can follow the track or path and it will be more safe and convenience.

1.4 Scope of the Project

In this project, the non-holonomic wheeled mobile robot used in this project as described in [1]. The robot is a tricycle type which it has two wheels at the back and one wheel at the front. The back wheels are the wheels that will control the wheeled mobile robot.

The simulation that will be used is SIMULINK/MATLAB and all the simulation will be simulate using it.

For this non-holonomic wheeled mobile robot, it consider about the Kinematics modeling only. The dynamics modeling is been considered because it is more complex at the scope is wider.

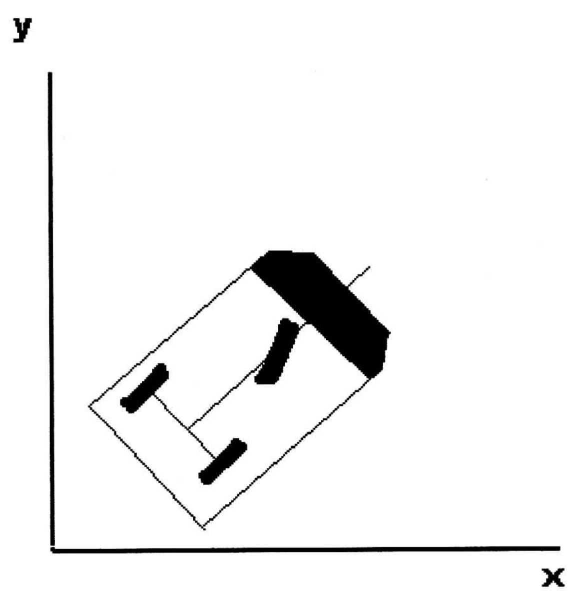
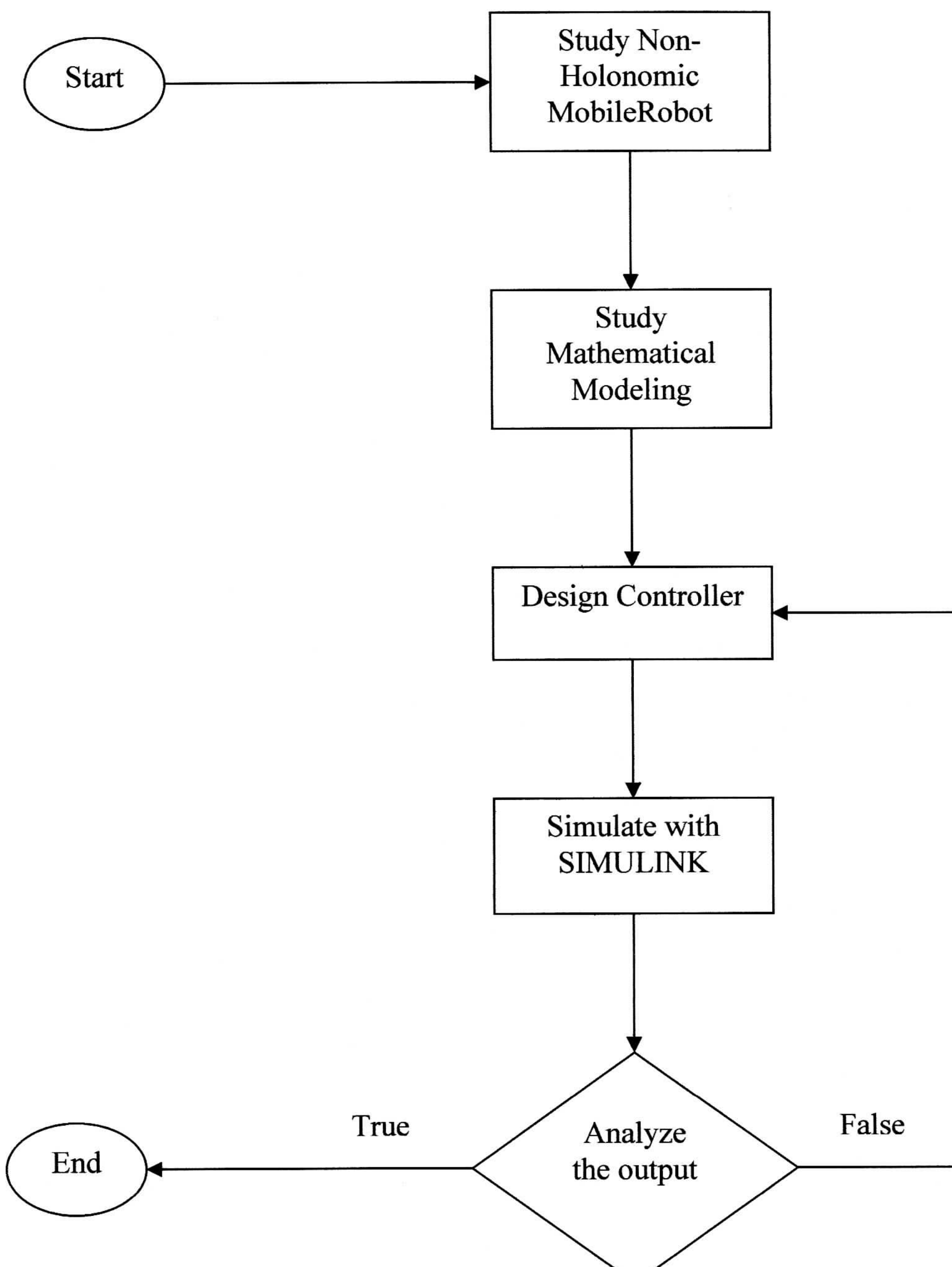


Figure 1.1 Example of the tricycle wheeled mobile robot

1.4 Methodology of the Project

To complete this project, the things that needed to do are:

- Study on non-holonomic mobile robot.
- Study on mathematical modeling.
- Design a controller.
- Simulate using SIMULINK/MATLAB.
- Analyze the output response.



CHAPTER 2

LITERATURE REVIEW

2.1 Lyapunov Function

2.1.1 Definitions

Lyapunov functions are one of interest in mathematics, especially in stability theory. Functions which might prove the stability of some equilibrium are called Lyapunov-candidate-functions. There is no general method to construct or find a Lyapunov-candidate-function which proves the stability of equilibrium, and the inability to find a Lyapunov function is inconclusive with respect to stability, which means, if the system not finding a Lyapunov function doesn't mean that the system is unstable. For dynamical systems (e.g. physical systems), conservation laws can often be used to construct a Lyapunov-candidate-function.

The basic Lyapunov Theorems for autonomous systems which are directly related to Lyapunov (candidate) functions are a useful tool to prove the stability of equilibrium of an autonomous dynamical system. One must be aware, that the basic Lyapunov Theorems for autonomous systems are sufficient, but not necessary tool to prove the stability of equilibrium. Finding a Lyapunov Function for certain equilibrium might be a matter of luck and trial and error is the method to apply, when testing Lyapunov-candidate-functions on some equilibrium.

2.1.2 Paths Planning

There have been a number of theories for path planning in mobile robot navigation like had been discussed in the paper [3]. Two method of path description for vehicles can be considered:

- To describe a path as a sequence of explicitly defined path segments, that may be one of the following: straights line segments, circular arcs, parabolas, cycloids, clothoids, logarithmic spirals and other. In this case, the type of both segment, both end point, (x,y) (with or without orientation θ), and other parameters, like radius in circle, the focus in a parabola and others, should be needed to define in each path segment.
- A path maybe implicitly specified by giving a sequence of postures, (x,y,θ). A local path-solver finds a path segments joining two adjacent postures using some criterion for smoothness. One of the methods which give a path with curvature continuity is by using clothoid curves.

In the either way, the reference posture is updated at a fixed rate and is generated from the path description and the reference velocity. The locomotion controller uses this sequence of posture for traicking.

2.2 Non-holonomic System

2.2.1 Definition

In physics and mathematics, a nonholonomic system is a system in which a return to the original internal configuration does not guarantee return to the original system position. n other words, unlike with a holonomic system, the outcome of a nonholonomic system is path-dependent, and the number of generalized coordinates required to represent a system completely is more than its control degrees of freedom (sometimes called differential degrees of freedom, DDOF). In addition to the motion variables corresponding to the control degrees of freedom, the history of its motion too should be known.

For example, in the case of a vertical wheel which can spin as well as rotate about a vertical axis passing through its centre, the knowledge of these two variables (control variables) need not give knowledge about its precise position from an inertial frame of reference. Similarly, when riding a two-wheeled cart (often confusingly described as a "unicycle-type vehicle"), a return to the original internal (wheel) configuration does not guarantee return to the original system (cart) position.

Nonholonomic systems exist in at least three cases; Rolling, systems with inequality constraints and systems with constraints on velocity. Cars, bicycles and unicycles are all examples of nonholonomic systems.

2.2.2 Unicycle Constraint

The unicycle cart cannot move sideways because it has an angular. Let say that:

$$\dot{p} = \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{pmatrix} \qquad (2.1)$$

Where:

- p is a posture of the vehicle
- x is a movement of the vehicle on X-axis
- y is movement of the vehicle on Y-axis
- θ is angle of the vehicle.

and let

$$w_1 = (\sin\theta, -\cos\theta, 0) \qquad (2.2)$$

So the constraint is written;

$$w_1 \dot{p} = 0 \qquad (2.3)$$

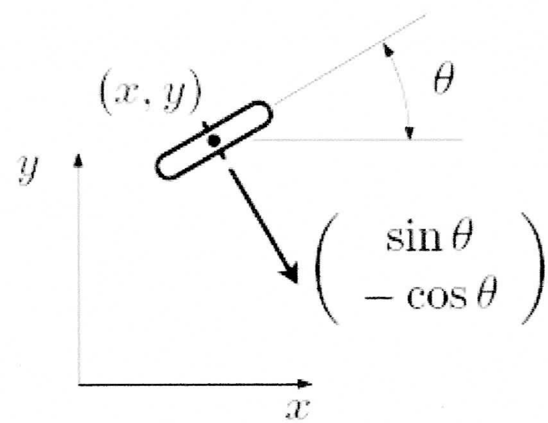


Figure 2.1 Movement of the Unicycle

The unicycle can move in two directions, expressed by defining

$$g_1(p) = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}, \quad g_2(p) = \begin{pmatrix} \cos\theta \\ \sin\theta \\ 0 \end{pmatrix} \qquad (2.4)$$

And noting the unicycle's motion is:

$$\dot{p} = u_1 p_1 + u_2 p_2 \qquad (2.5)$$

Where u_1 and u_2 are arbitrary real and they are the controls. Therefore the unicycle has three DOFs (Degree of Freedom).

2.2.3 Unicycle Vesus Unsteered Cart

Unicycle	Unsteered Cart
One velocity constraint.	Two velocity constraint
Three degree of freedom	One degree of freedom
	Integrable. Equivalent to two configuration constraints

Table 2.1 Differences Between Unicycle and Unsteered Cart

2.3 Non-Linear Control

2.3.1 Definition

Non-linear control is a sub-division of control engineering which deals with the control of non-linear systems. The behaviour of a non-linear system cannot be described as a linear function of the state of that system or the input variables to that system. For linear systems, there are many well-established control techniques, for example root-locus, Bode plot, Nyquist criterion, state-feedback, pole-placement etc.

2.4 SIMULINK/MATLAB Simulation

MATLAB is a numerical computing environment and programming language. Created by The MathWorks, MATLAB allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Although it specializes in numerical computing, an optional toolbox interfaces with the Maple symbolic engine, allowing it to be part of a full computer algebra system.