STEERING CONTROL FOR BICYCLE

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Tajuk Projek : **STEERING CONTROL FOR BICYCLE**

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Supervisor's name : En Ahmad Sadhiqin Bin Mohd Isira

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To my father, my mother and my brother

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ABSTRACT

Bicycle is a clean transportation device towards the environment. However, the bicycle is unstable itself and it will fall down if driven without human assistance using the steering handle or moving upper body. Getting a bicycle to balance by itself without a human riding it is difficult. The physical dynamics of bicycles have been studied by scientists, mathematicians and engineers alike for years. Dynamic model of running bicycle is complicated and it's hard to recognize completely. However, assuming that rider position is fixed, no moments of inertia, the linear equations are valid only for small angles of lean and steer, fixed external forces are limited to gravitational forces and constraint forces from the ground acting on the wheels, and the bike-rider system is symmetrical about a plane passing lengthwise through the rear frame can produce a simple mathematical model of a bicycle. This model will then be used to develop a single input, single output controller. Although the rider controls various inputs, this project briefly examines the possibility only the front wheel steering input to be used to control the bicycle roll angle. This project objective is to implement a simple mathematical model of a bicycle and to measure its output response. In this project, I have assessed the ability of the controller to maintain bicycle stability at constant speeds with various impulse disturbances applied. For SISO system, a suitable controller to use is PID. It is one of the linear controllers that are designed to force the system output states to follow the desired inputs based on error signals.

ABSTRAK

Basikal merupakan satu kenderaan yang bersih dan tidak menjana pada kemusnahan alam sekitar. Bagaimanapun, tanpa pengawasan dari manusia seperti pengawalan hendal atau pergerakan badan,maka basikal tidak mampu untuk stabil. Bagi menstabilkan basikal ini secara sendirinya, tanpa melibatkan manusia adalah sukar. Dinamik fizikal bagi basikal telah dikaji oleh saintis,ahli metematik dan jurutera untuk sekian lama. Dinamik bagi basikal yang bergerak adalah lebih kompleks dan sukar untuk direalisasikan. Bagaimanapun, dengan mengganggap kedudukan penumpang adalah tetap, tiada inertia, semua sudut condong dan pegemdian adlah kecil, daya luaran yang bertindak ke atas basikal adlah tetap dan kedudukan penunggang adlah simetri maka persamaan metamatik yang linear boleh diwujudkan. Model ini menghasilkan satu input dan satu output. Walaupun penunggang megawal pelbagai input, projek ini hanya focus bagaimana hendal depan basikal manpu megawal sudut pergerakan basikal. Objektif dalam projek ini adalah untuk meggunakan persamman matematik basikal bagi megukur output respon. Di dalam projek ini saya telah megenalpasti kebolehan pegawal untuk megekalkan kestabilan basikal pada halaju yang tetap bersma pelbagai ganguan yang dimasukkan. Bagi system SISO, pengawal yang paling sesuai adlah PID. PID merupakan pengawal yang linear yang diciptakan agar output akan mengikut input yang diberikan.

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LIST OF ABBREVIATIONS

CD – Compact Disc

DSP - Digital Signal Processing

DVD – Digital Versatile Disc

FPGA - Field Programmable Gate Arrays

LQG - Linear-Quadratic-Gaussian control

MEMS - Micro-Mechanical Electrical Systems

MPC – Model Predictive Control

PID – Proportional, Integral Derivative controller

LIST OF SYMBOLS

NO	SYMBOLS	DESCRIPTIONS
1	m	Bike & Rider mass [*kg*]
2	I_1	Principal moment of inertia about the roll axis [*kgm*2]
3	h	Height of the centre of mass when the bicycle is upright [*m*]
4	a	Distance from the projection of the centre of mass on the ground plane to the contact point of rear wheel [*m*].
5	b	Distance along the ground between the wheel contact points [m].
6	Vr	Forward velocity of rear frame [*m/ s*]
7	g	Local acceleration due to gravity [2 *m/ s*]
8	δ	Front wheel steering angle. [*Rad*]
9	θ	Bicycle roll angle [*Rad*]

CHAPTER 1

INTRODUCTION

Bicycles are used everywhere for transportation, exercise, and recreation. The bicycle's evolution over time has been a product of necessity, ingenuity, materials, and industrialization. While efficient and highly maneuverable, the bicycle represents a tantalizing enigma. Learning to ride a bicycle is an acquired skill, often obtained with some difficulty; once mastered, the skill becomes subconscious and second nature, literally just "as easy as riding a bike." Bicycles display interesting dynamic behavior. For example, bicycles are statically unstable like the inverted pendulum, but can, under certain conditions, be stable in forward motion. Bicycles also exhibit non minimum phase steering behavior. [1]

1.1 Introduction

Recently, bicycles attract attention as mean of transportation without any environmental burden. The reasons why bicycles attract attention are needlessness of energy supply, high energy efficiency, facility of maintenance and so on. However, bicycle is unstable in itself and it will fall down without human assistance like steering handle or moving upper body. It needs practice to ride a bicycle.

Strict dynamic model of bicycle was proposed by R.S.Sharp in 1971. It is named Sharp model and many researches are based on this model. A problem of this model is that it is complicated and difficult to apply to a bicycle posture controller. However, assuming that a rider doesn't move upper body, dynamics of the bicycle is represented in equilibrium of gravity and centrifugal force. Centrifugal force is risen out from the running velocity and turning radius which is determined by steering angle. Therefore under these conditions, it is possible to stabilize bicycle position by controlling steering [2].

The inherent dynamic instability of two-wheeled vehicles naturally leads to questions of control. The bicycle-rider system itself is a dynamically complex, multiple-degree-of freedom system. The seemingly simple task of riding a bicycle is made possible by the complex control system of the rider. Although the rider controls various inputs, this project briefly examines how only the front wheel steering input may be used to control the bicycle roll angle. If a true controller were to be realized, its design could take various forms. The previously derived single degree-of-freedom model of a bicycle-rider system will be re-stated. The linear model presented by Karnopp was used as a reference in the derivation of this model [3]. This model will then be used to develop a single input, single output controller.

1.2 Objectives of Project

There are several objectives need to be achieved in this project. The objectives are as stated:

i. To implement a simple model of bicycle stability dynamics from a literature survey.
ii. To design a stability controller based on that model.
iii. To implement the stability controller on a bicycle.
iv. To measure its response to a disturbance that is applied in this project.

1.3 Problem Statement

i. Balancing act on a bicycle is not as easy as it looks. In addition, getting a bicycle to balance by itself without a human riding it is even more difficult.
ii. The bicycle is a simple means transportation compared to a car and more environment friendly
iii. However, it is thought that a lot of bicycle falling accidents occur with elderly people, and it is very useful to achieve a safer bicycle."

1.4 Scope of Work

To achieve the objective in this project, several papers, journals and books are reviewed to gain deeper understanding in the field of steering control for bicycle. By doing some researches based on the previous projects, it will help to derive the mathematical model of the bicycle. By choosing the best model, it will be used as a reference in order to make sure this project success. This design is also consider the side wind and external forces as disturbances. Then, the complete design with the disturbances input should be simulated by using the MATHLAB Simulik.

After finished with the simulation, the final step of this project is to simulate the designed controller and compare the output response of the plant with and without the controller.

1.5 Methodology

To ensure that this project achieved the objective all the following steps should be done. At the beginning, the mathematical model of a bicycle needs is to be found and analyzed. The literature study was accomplished and in a meanwhile mastering in simulation tools need to be done**.** The mathematical model that mentioned as above is a form of the system to be controlled, disturbances that may act on the system, the command the operator may issue and desirable or required qualities of the final system. Then, research on steering control for bicycle will help to generate this mathematical equation. Before the mathematical model is derived, various parameters of control will be identified. In the same time, the suitable types of control strategy need to studied. Based on theory, controllers vary widely in complexity and effectiveness. When the mathematical model is established, the next step is to transform the mathematical model equation to state space equation. The state space equation can be simulated by using Simulink in MATHLAB. The simulation of a bicycle includes the disturbance with effects of road and others disturbances. If the simulations verify the mathematical model, therefore the suitable controller can be designed. There are various parameters that should be identified before a controller is chosen. PID is the most suitable since it is expected to control the single input and output. However if the simulation is unsuccessful the mathematical model will be reevaluated. In order to tune the PID, the Ziegler-Nichols method has been used is about using the gain and the location of poles in the s-plane of the system. Finally, the evaluation and verification of the design by using simulation program (MATHLAB) was done. The methodology of this project is shown in the flow chart below.

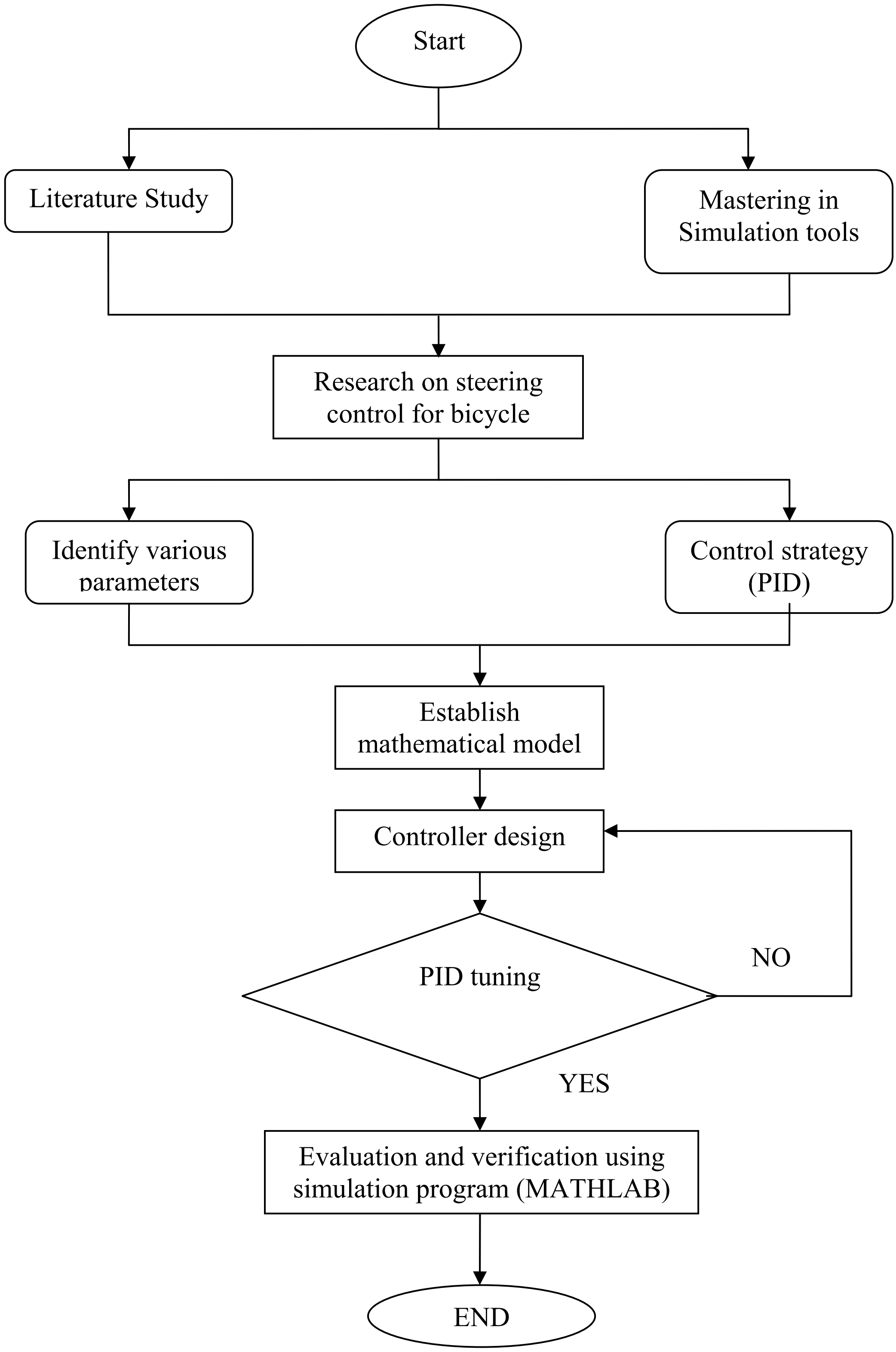

Figure 1.0: Flow chart methodology of the project

CHAPTER 2

LITERATURE REVIEW

There are two general categories of research that are related to this project. The first is the research that has been done on the dynamics of the bicycle itself. The second is the study on the control systems especially on a bicycle. Pertinent literature will be discussed herein, roughly in the order above.

2.1.1 Description of the bicycle model

A familiar bicycle of the familiar construction is considered. The model for the bicycle consists of four rigid bodies that are interconnected by revolute joints. The four bodies are the rear frame with the rider rigidly attached to it, the rear wheel, and the front frame including the front fork and handle bar, and the front wheel. The rear frame and the front frame are joined by the steering head; the rear wheel is connected to the rear frame by the revolute joint at the axle; and the front wheel is connected to the front fork by another revolute joint at its axle.