ROBOTIC BALL BALANCING BEAM (RBBB)

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To my beloved father

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ABSTRACT

The RBBB system is designed to balance and move a ball on two parallel beams in order to automatically control the position of the ball on parallel beams. The ball retains the central position and system tries sine and square waves in different frequencies with or without a human finger push in order to follow input of the system or to respond the current ball position. The prototype control methodology runs lab view program via RS232 serial port which is connected to a multi function deriver board to cover motor and encoder requirements. A lead controller also employed to cover control requirements. The outputs of the system track the inputs however no static frictions and motor backlash exists in simulation results. As a finding of the system, the transient response is very important to overcome the problem of instability in this system .This system is not designed to cover large amplitude input requirements due to instability of these kinds of systems. It is generally linked to real control problems such as horizontally stabilizing an airplane during landing and in turbulent airflow.

ABSTRAK

Sistem RBBB direka untuk menyeimbangkan dan memindahkan bola pada dua selari angka dalam rangka untuk secara automatik mengawal kedudukan bola di selari angka. Bola mempertahankan kedudukan sentral dan sistem cuba gelombang sinus dan persegi di frekuensi yang berbeza dengan atau tanpa dorongan jari manusia dalam rangka untuk mengikuti masukkan dari sistem atau untuk merespon kedudukan bola saat ini. Metodologi kawalan prototaip menjalankan program makmal melihat melalui port siri RS232 yang dihubungkan dengan sebuah papan deriver multi fungsi untuk menutup keperluan motor dan encoder. Sebuah controller mengarah juga digunakan untuk menutup kos kawalan. Keluaran dari sistem pusat masukkan tetapi tidak ada friksi statik dan backlash motor ada di hasil simulasi. Sebagai penemuan sistem, respon transien sangat penting untuk mengatasi masalah ketidakstabilan dalam sistem ini. Sistem ini tidak direka bentuk untuk menutup kos amplitud masukkan yang besar kerana ketidakstabilan dari jenis sistem. Hal ini umumnya berkaitan dengan masalah pengendalian nyata seperti horizontal menstabilkan pesawat saat mendarat dan dalam aliran turbulen**.**

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INTRODUCTION

1.1 Overview of Robotic Ball Balancing

An important set of contemporary industrial processes and systems are unstable by nature and essentially require feedback control for effective and safe performance. However the crucial problem that exits in the study of such real, unstable systems is that they cannot be brought into the laboratory for analyses. Due to its simplistic design and relevant, dynamic characteristics, ball balancing beam has become an ideal model for complex, non-linear control methods (Javaid Iqbal et al, 2005).Ball and beam system is a common feedback control system with a simple construction that includes beam, ball, and a DC motor attached with an encoder. The system is unstable and needs a compensator to stabilize from environmental disturbances.

1.2 Background of the Study

Ball and beam system is one of the most enduringly popular and important laboratory models for teaching control systems engineering (Saul Jimenez and Wen Yu, 2007). Ball and beam system is widely used because many important classical and modern design methods can be studied based on it (Saul Jimenez and Wen Yu, 2007). The under actuated mechanical systems represent a challenge for the control. An active field of research exists, due to the applications of these systems such as aircrafts, spacecrafts, flexible and legged robots (Y. Aoustin and A. M. Formal'skii, 2009).

1.3 Importance of the Robotic Ball Balancing

The control of industrial unstable systems such as exothermic chemical reaction, horizontally stabilizing the airplane during landing and turbulent airflow, etc is usually dangerous and can't be brought into laboratories (Iraj Hasanzade et al, 2008). The ball and beam system is a benchmark problem to test proposed controllers. The ball and beam balancing system is a classical problem with its nonlinear and open-loop unstable characteristics. It is one of the important laboratory models for teaching control system engineering. (Iraj Hasanzade et al, 2008).

1.4 Problem Statement

Ball & beam system has inherently nonlinear and unstable characteristics (C. C. Ker, 1992). This system is commonly used for control theory verification or control system design and implementation practice (Chin E. Lin et al, 2005). Different methods were proposed to control its zero input response and trajectory tracking (Yi Guo et al, 1996). Such a system may be used as a control training tool for engineering students including many industrial processes and their applications (Chin E. Lin et al, 2005).

The control task is to automatically adjust the position of the ball on beam by changing the control input i.e. angle of the beam (M. Amjad et al, 2010). This is a complex task because the ball does not stay in one place on the beam but moves all the way with an acceleration that is proportional to the tilt of the beam (M. Amjad, (M. Amjad et al, 2010). It consists of a beam that pivots at the centre point, and a ball that is free to move along the beam in a vertical plane (Qing Wang et al, 2004). The task of the system's controller is to apply a sequence of torques to dynamically balance the ball from any initial position with any initial speed (Qing Wang et al, 2004).

The motion of the ball essentially is determined by the tilting angle and the force gravitation (Imre J et al, 2006). This means that even if we are in the possession of a very strong actuator the acceleration of the ball along the beam is limited by the above two factors (Imre J et al, 2006).

The position of the ball can be measured using a special sensor. It has a very important property – open loop unstable, because the system output (the ball position) increases without limit for a fixed input (beam angle) (Wen Yu and Floriberto Ortiz, 2005). The control job is to automatically regulate the position of the ball by changing the position of the motor (Wen Yu and Floriberto Ortiz, 2005).

The prototype model of the RBBB system is shown in Figure 1.1. In order to theoretically model the ball and beam system, the assumptions are listed in the following:

- The ball rolls on the beam without slip
- The gearbox embedded in the motor exhibit no backlash effect
- The ball and linear sensor (resistive wire) contact with each other very well
- The base of the system is static with respect to the ground
- The beam is able to rotate between -30 degrees to 30 degrees relative to the horizontal

Figure1.1: Model of the ball balancing beam system

1.5 Project Objectives

The objectives of this project are as follows:

- To design a dynamic model of the system that automatically regulates the position of the ball by changing the angle of the beam to its reference position for the RBBB system.
- To design a controller for the RBBB system.
- To design a prototype hardware model for simulation verification purpose.

1.6 Project Scopes

Literature Review includes all the necessary information in our case study, background of the system, theories related to the problem and references used in this project.

By using MATLAB and Simulink toolbox, there is a quick setting up of feedback control systems and testing of their response to sine wave and square wave inputs which can include disturbances. A numerical model for simulation is also needed. This model is very useful in aiding further control design. Lab view also helps to run the options during the physical test on the prototype.

Motor parameters determine a mathematical relation between input and output of the compensator; however upon obtaining the results of the MATLAB simulation, it will extract which compensator is suitable for the system by comparing the resultant plots. Then the controller will test on the physical system.

1.7 Thesis Organization

This thesis is organized as follows. Chapter 2 provides detailed explanations of robotic ball balancing beam (RBBB) .After that, chapter 3 discusses about step of designing the prototype and specifications of each part of the hardware. Then we continue the dynamic of selected plant in chapter 4 and discuss about simulation results and comparison of them with designed prototype. Chapter 5 ends with conclusions and suggestions for future works. Finally the references are located at the end of this thesis.

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