STATIC AND DYNAMIC CONTROL OF NETWORK BASED ROTARY INVERTED PENDULUM SYSTEM

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Dedicated to …..

My beloved wife, Kahtijah

Who has so much faith in me

My son Adam

Who is in the phase of growing up perfectly

Love you always

Also to my beloved father and mother, Yaakob and Robisah

I could have never done it without you

To all my friends, who have stood by me through thin and tick

I treasure you all

Thanks for showering me with love, support and encouragement

Life has been wonderfully coloured by all of you

Alhamdulillah...Syukur kepada ALLAH s.w.t

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ABSTRACT

The control of the Rotary Inverted Pendulum (RIP) is a classic control problem that is explored often as a project in control courses due to its easily developed dynamics combined with its complexity of control design. The aim of this project is to delve into the control of this system to achiev2 the control objectives which is balancing the inverted pendulum base on CAN Network Control System. This system is composed of a pendulum attached to the end of a rotary arm controlled by a motor. The motor used is a Quanser SRV-02, whose characteristics are known completely. The motor consists of a servomotor coupled with a gear-chain. The aim is to keep the motor at a particular provided angular position. However, the major disadvantages of using NCS application are the delay introduced by the network traffic and package drop-out. Many researchers have directed their works towards solving these two issues by proposing new control algorithms or optimization of scheduling methods due to the fact that advantages offered by NCS far outweigh its centralized counterpart. In this thesis, investigation of the impact of network induced delays on the step response performance aspects of state space control designs LQR for a NCS with time delays. The vector of state-feedback control gains 'K' is used to deal with the degrade performance of a rotary inverted pendulum and also deal with the network traffic in network control system. Thus s simulation performed to show the effectiveness of the system. Eventually the result prove that the proposed controller gains improve the performance if RIP in a network induce delay.

ABSTRAK

Pendulum Songsang Bermotor adalah masalah kawalan klasik yang sering diterokai sebagai projek dalam kursus-kursus kawalan kerana dinamik yang dibangunkan dengan mudah digabungkan dengan kerumitan reka bentuk kawalan. Dalam projek ini, kami menyelidiki kawalan sistem ini untuk mencapai objektif-objektif kawalan yang mengimbangi asas bandul terbalik dengan menggunakan Rangkaian Kawalan Sistem CAN. Sistem ini terdiri daripada bandul disertakan dengan hujung lengan putar dikawal oleh motor. Motor yang kita gunakan adalah Quanser SRV-02 Loji, yang ciri-ciri yang dikenali sepenuhnya. Motor terdiri daripada servo motor ditambah dengan gear rantai. Tujuannya adalah untuk memastikan motor pada kedudukan tertentu disediakan sudut. Walau bagaimanapun, kelemahan utama menggunakan aplikasi NCS adalah kelewatan yang diperkenalkan oleh trafik rangkaian dan pakej keciciran. Ramai penyelidik telah mengarahkan kerja-kerja mereka ke arah menyelesaikan kedua-dua isu-isu dengan mencadangkan algoritma kawalan baru atau pengoptimuman kaedah penjadualan kerana hakikat bahawa kelebihan yang ditawarkan oleh NCS jauh melebihi rakan berpusat. Tesis ini, mengkaji kesan kelewatan disebabkan rangkaian kepada aspek langkah prestasi sambutan negeri kawalan ruang reka bentuk LQR untuk sistem kawalan rangkaian dengan kelewatan masa. Vektor gain matrik 'K' yang digunakan untuk meningkatkan prestasi system disebabkan kelewatan pada system dan juga pada keaadaan apabila trafik rangkaian tinggi pada rangkaian

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L	-	Length of the pendulum
m	-	Mass of the pendulum arm
r	-	Mass of the pendulum arm
θ	-	Servo gear angle
α	-	Pendulum angle
h	-	Distance of pendulum
J_{cm}	-	Pendulum inertia
V_x	-	Velocity of Pendulum centre x-direction
V_y	-	Velocity of Pendulum centre y-direction
g	-	Standard gravity
η_g	-	Gearbox efficiency
η_g	-	Motor efficiency
K_t	-	Motor torque constant
K_m	-	Back emf constant
K_g	-	Total gearbox ratio
R_m	-	Cylinder differential pressure
V_t	-	Motor armature resistance

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CHAPTER 1

INTRODUCTION

1.1 Background

Networked Control Systems (NCS) accumulates various field of study in control system theory, data transmission and networking. The defining feature of an NCS is that the data containing information is exchanged by a network between control system nodes (sensors, controller, and actuator). Because NCS offers feedback control system via a communication channel it has become one of the main research focuses in academic studies and industry for many decades. Figure 1.1 is an example of a system that incorporates with a communication network in the feedback control loops. As a result makes the design and analysis more complex. Common control theories with many ideal assumptions, such as synchronized control and non-delayed sensing and actuation, must be re-evaluated before they can be applied to NCSs. The issues that needs to be addressed while designing an NCS include, network-induced delays that occurs while exchanging data among devices connected to the shared medium, and packet losses, because of the unreliable network transmission path, where packets not only suffer transmission delays but, even worse, can be lost during transmission

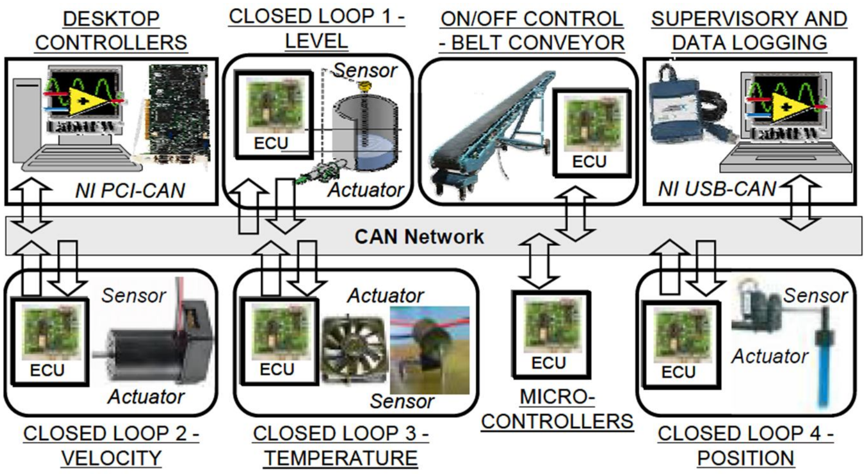

Figure 1.1: Example of a NCS application

Many researchers have directed their works towards solving delay introduced by the network traffic and package drop-out by proposing new control algorithms or optimization of scheduling methods due to the fact that advantages offered by NCS far outweigh its centralized counterpart[1]. This thesis examines the impact of network induced delays on the step response performance aspects of state space control designs with Linear Quadratic Regulator (LQR) for networked control systems with time delays. The vector of state-feedback control gains 'K' is used to deal with the degrade performance of a rotary inverted pendulum and also deal with high network traffic in network control system.

1.2 Problem Statement

The existences of the NCS introduce time delay by the communication messages or data between the NCS components. This delay will lead to the instability of the system performance due to network traffic or data loss during the transmission. Figure 1.2 response feedback control system subject to delay in loop.

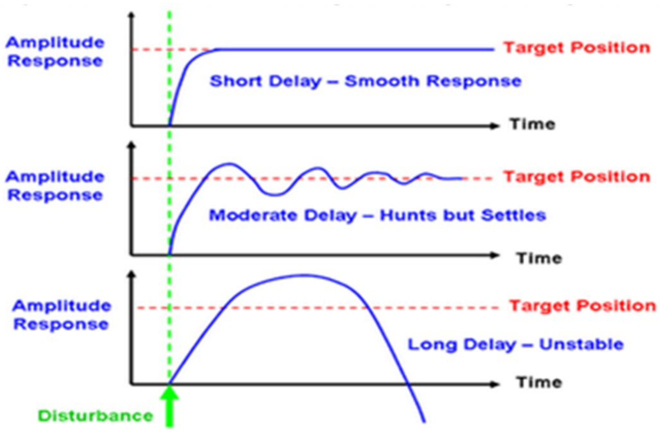

Figure 1.2 Response feedback control system subject to delay in loop

The goal is to identify parameters that can be applied to optimize the performance of the system. The performance of the controllers is illustrated using RIP as it is an ideal experiment device to test the correctness and feasibility of new control theory[2]. Furthermore, with the increasing trend in rising fieldbus and industrial real time Ethernet technology, it is a meaningful research to connect the RIP with the NCS.

1.3 Objectives of Project

The objectives of this project are:

1. To develop a nonlinear model of Rotary Inverted Pendulum
2. To develop a network RIP base on CAN network.
3. To analyze performance of the system for static and dynamic control under various condition

1.4 Scope of Project

The scopes of this project can be outlined as:

1. Modeling of Rotary Inverted Pendulum in NCS based on CAN.

   A motor driven SIMO dynamic system model of NCS based on CAN will be developed. This is done based on existing model found in established work.

2. Comparative Assessment and result analysis.

   Various network-induced delay parameters will be introduced and a comparative assessment between offline controls as reference is done to analyze the control performance.

3. Computer simulation

   The simulation will be performed using MATLAB and TRUETIME Toolbox.

1.5 Significance of Project

The existences of the control loop in network introduce time delay by the communication messages/data between the NCS components. This delay will lead to the instability of the system performance due to network traffic or data loss during the transmission. When applying state space control designs with network control system, parameters determining the state feedback control can be identified and applied to optimize the performance of the system. By using Linear Quadratic Regulation (LQR) method, the state-feedback control gain ‘K’ can be obtained and those parameters will be used to control and achieve the desired performance of Rotary Inverted pendulum with different delay parameter condition in a Network

Control System. In addition, to address the situation where not all state variables are measured, a state estimator is designed and compared with different network bandwidth disturbance percentage.

1.6 Thesis Outline

This thesis consists of five chapters. It begins with the introductory chapter. This chapter gives the brief description of the problem statement and background of the Rotary Inverted Pendulum in Network control system, objectives, scope and significance of the project.

Chapter two discusses the literature review and others related works from previous existing modeling paradigm and technique to calculate and estimate the delay parameters in Network Control System.

Chapter three includes design and methodology of the study. It contains design of the system, modeling and procedure to design the static and dynamic controller based on Rotary Inverted Pendulum.

Chapter four contains the results and discussion of the study for the system. Verification of the plant, delay parameter implementation and propose parameter value to optimize performance is described here.

Then, chapter six describes the conclusion and suggestion of the work for future development.

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