MESSAGE SCHEDULING IN NETWORKED CONTROL SYSTEM ROTARY INVERTED PENDULUM SYSTEM

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To my wife and my two beloved daughter.

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ABSTRACT

Networked Control System (NCS) is a control system that combines two components which computer network and control theory. The main advantage of NCS is combining and connected several control loops together in one network system using less wiring that also reduces cost. This approach is widely used in automotive and manufacturing field. Regarding to the many control loops connected into a NCS system, the major problem that always happen in NCS is the data scheduling that lead to network delay and resulted the task missed their deadlines. This problem also can cause data loss and data collision during the transmission on the network. To analyze this phenomenon and overcome the problem, a NCS system using four Rotary Inverted Pendulum (RIP) as the system plants is created and tested using several scheduling algorithm such as Deadline Monotonic (DM), Earliest Deadline First (EDF) and Mixed Traffic Scheduling (MTS) with different sampling time to observe the effect of the RIP system. The design implementation of this project is performed using MATLAB simulink with specialized library used called Truetime Toolbox. The RIP with NCS approach performs better compare to without NCS approach in terms of fast settling time. For the four RIP plant connected using NCS approach, the Mixed Traffic Scheduling method perform better compare to DM and EDF scheduling method.

ABSTRAK

Sistem Kawalan Berangkaian (NCS) adalah satu system kawalan yang menggabungkan dua komponen yang merupakan rangkaian computer dan teori kawalan. Kelebihan utama NCS adalah menggabung dengan menyambungkan beberapa gelung system kawalan bersama-sama dalam satu system rangkaian dengan menggunakan pendawaian yang kurang sekaligus boleh mengurangkan kos, protocol ini digunakan secara meluas dalam bidang automotif dan pembuatan. Berkenaan dengan gelung system kawalan yang banyak di dalam suatu sistem, masalah utama yang selalu berlaku dalam NCS adalah penjadualan data yang membawa kepada kelewatan rangkaian atau terlepas masa akhir. Masalah ini boleh menyebabkan kehilangan data dan perlanggaran data semasa penghantaran dalam rangkaian. Untuk menganalisis fenomena ini dan mengatasi masalah ini, satu sistem NCS menggunakan empat *Rotary Inverted Pendulum* (RIP) sebagai loji system dan menggunakan beberapa kaedah penjadualan seperti *Deadline Monotonic* (DM), *Earliest Deadline First* (EDF) dan *Mixed Traffice Scheduling* (MTS) dengan masa persampelan yang berbeza untuk melihat kesannya. Pelaksanaan rekabentuk projek ini dilakukan dengan menggunakan MATLAB SIMULINK dengan perpustakaan khusus yang digunakan dipanggil Toolbox Truetime. RIP dengan pendekatan NCS melakukan lebih baik berbanding dengan tanpa NCS dari segi masa penyelesaian yang cepat. Bagi sistem empat RIP yang menggunakan pendekatan NCS, kaedah Penjadualan Trafik Campuran (MTS) menunjukkan prestasi yang lebih baik berbanding dengan kaedah penjadualan DM dan EDF.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NCS	Networked Control System
RIP	Rotary Inverted Pendulum
DM	Deadline Monotonic
EDF	Earliest Deadline First
MTS	Mixed Traffic Scheduling
RM	Rate Monotonic
ISO	International Organization for Standardization
OSI	Open System Interconnection
LQR	Linear Quadratic Regulator

LIST OF SYMBOLS

α	Arm angle
β	Pendulum angle
J_0	Moment Of inertia Arm Section
J_1	Moment Of inertia Pendulum Section
C_0	Viscous Friction co-efficient of Arm section
C_1	Viscous Friction co-efficient of Pendulum section
m_1	Pendulum mass
l_1	Pendulum Length
L_0	Physical distance between pivot of pendulum section and axis rotation of arm section
K_t	Motor Torque constant
K_b	Motor Back EMF constant
K_u	Motor driver amplifier gain
R_a	Motor armature coil resistance
g	Acceleration due to gravity
u	Motor driving command

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1. Introduction

Nowadays, network based communication become trend in control system theory because of its advantage to connect several control system into a centralized network. In modern control theory, Networked Control System (NCS) is one of the research field that focus in network control.

Rotary Inverted Pendulum (RIP) is the basic system that is usually used to study stability and performance of control system.The idea of this system is to stabilize and maintain the pendulum in upright position when external force is applied. This system mostly applied in critical application such as vehicle traction control and rocket stabilization during takeoff. Usually, this application ~~using~~uses more than one system and it must be connected together in a network in order for data exchange between system and the controller. To connect all the RIP system, a NCS approach must be applied to the system.

The most critical part in NCS system is the data scheduling around the network. The data must be schedule properly to avoid packet loss, missed the deadlines and data collision. To overcome this, several scheduling method is proposed such as Rate Monotonic (RM) and Deadline Monotonic (DM) for fixed

priority and (Earliest Deadline First) EDF and Mixed Traffic Scheduling (MTS) for dynamic priority.

This report proposes the scheduling method that most reliable and robust for Rotary Inverted Pendulum plant using NCS control system approach. The RIP is non linear models that need a controller to stabilize the system. In this case, a Linear Quadratic Regulator (LQR) controller is used as feedback to stabilize the system. The RIP and LQR controller is connected using NCS controller to see the data exchange effect in the network by applying fixed and dynamic message scheduling method.

The implementation of designed the RIP system using NCS approach will be performed using Truetime toolbox in Matlab Simulink. The simulation is done by applying various scheduling method to evaluate the performance of the data exchange in the system.

1.2 Objectives

The aim of this project is to analyze the performance of RIP system in NCS approach by using different scheduling method and sampling time and determine which scheduling method that most reliable and robust to the system and verify this result using Matlab simulink application.

(i) Construct a RIP system based on existing model
(ii) Design a LQR controller and apply into the RIP system
(iii) Design a NCS system and integrate with RIP system.
(iv) Analyze the system with different scheduling method.

1.3 Scope of Project

Scope for this project is:

(i) Existing RIP non linear mathematical modeling to represent the system plant in NCS approach. The LQR controller will be derived from the mathematical modelling in state space form.

(ii) Design a NCS control system and implementing the RIP system and the LQR controller together using different scheduling method.

(iii) This project is run through computer simulation by using Matlab Simulink software. The specialized library called Truetime toolbox will be use to simulate the NCS component in this project.

1.4 Methodology

The overall plan for this project is illustrated in Figure 1.1. At the beginning, the structure of RIP is studied including the non linear mathematical modeling. Then, the LQR controller is design as the feedback control of the system based on the RIP state space modelling form. Once the system completed, it will be transfer into computer simulation process using Matlab simulink. A NCS control system is created using Truetime toolbox that available in the Matlab Simulink Library. Once finished, the RIP system will be transplanted into the NCS controller and the analyses of the system based on different scheduling method is began. The data collected from the simulation will be compared to assess the performance of different scheduling algorithm used in the NCS system. Finally, at the end of this project a thesis will be written.

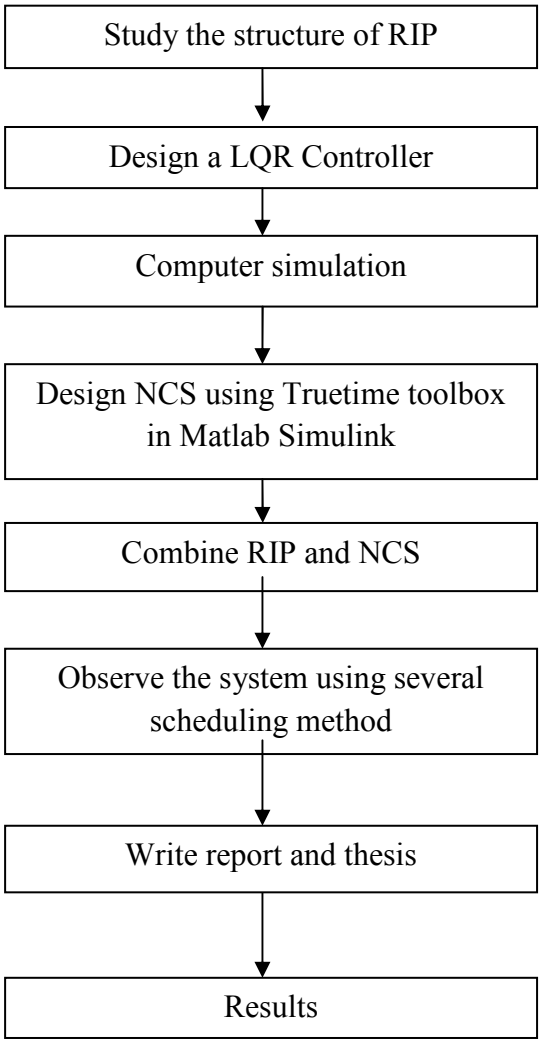

Figure 1.1: Project flowchart

1.5 Thesis Outline

This thesis consists of five chapters. Chapter 1 brief about introduction of the project, main objective for this project and defining the project scope and methodology.

Chapter 2 is about the literature review of the project. This chapter explains in detail about NCS control system that will be use in the project. This chapter also review some scheduling method that proposed by previous researches that will implement in this project.

Chapter 3 is about mathematical modeling derivation for RIP. This chapter also include the LQR controller design based on the state space form.

Chapter 4 introduces the initial setup for the project simulation. This includes the NCS setup whether using one or four system plant. The result also will be discussed in detail in this chapter.

Chapter 5 provides the overall conclusion of this project and suggestion for future works.

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