NONLINEAR CONTROLLER FOR GANTRY CRANE BASED ON PARTIAL FEEDBACK LINEARIZATION

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This report is submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours

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To my beloved mom and dad

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ABSTRACT

Gantry crane systems are widely used in harbors' and factories for loading and unloading of goods. The crane systems are desired to be able to move to the required positions as fast as possible while placing the payload at the appropriate position. To get that condition, the payload swing angle should be kept as small as possible. Based on partial feedback linearization, the portion of the dynamics corresponding to the active degrees of freedom is linearized by nonlinear feedback controller. The trajectory tracking control of the linearized system is studied by choosing the active degrees as the systems outputs. The portion of the dynamics corresponding to the passive degrees of freedom is taken as the internal dynamic of the crane system, and the analysis of the resulting zero dynamics shows the control system. Finally, experimental results on the scale crane shows feasibility of the developed controller design scheme.

ABSTRAK

Sistem kren *gantry* biasanya digunakan secara meluas di pelabuhan dan kilang-kilang untuk kemudahan mangangkat dan meletakkan beban dalam keadaan yang baik. Sistem kren yang biasa diperlukan di tempat tersebut adalah satu sistem yang berkebolehan bergerak ke sesuatu posisi dengan cepat dan tepat semasa mengangkat beban ke posisi yang dikehendaki. Bagi merealisasikan keadaan yang dikehendaki, sudut ayunan pada beban mestilah bersudut kecil kerana sudut yang kecil dapat menghindar beban daripada berayun ketika suatu pergerakan dilakukan. Berdasarkan pada suapbalik tak linear sudut yang aktif pada bahagian dinamik diselaraskan dengan menggunakan kawalan suapbalik linear. Di samping itu, kawalan trajektori dalam sistem ini dipelajari dengan memilih sudut yang aktif sebagai sistem output manakala sudut yang pasif pula diambil kira sebagai tenaga dalaman pada sistem kren tersebut dan analisis dibuat terhadap keputusan yang menunjukkan tenaga tersebut bersamaan dengan kosong pada sistem kawalan tersebut. Akhirnya, dengan keputusan ujikaji terhadap skalar kren, satu alat kawalan dapat dihasilkan.

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M	-	Trolley mass
m	-	Payload mass
l	-	Length of hoisting rope
F_x	-	Input force
g	-	Gravitational acceleration = $9.81ms^{-2}$
G	-	Centre point
S	-	Point of suspension
x	-	Trolley position
$\dot{x}$	-	Velocity
$\ddot{x}$	-	Acceleration
θ	-	Sway angle
$\dot{\theta}$	-	Angular velocity
$\ddot{\theta}$	-	Angular acceleration

CHAPTER I

INTRODUCTION

This chapter explains about the introduction to the project, problem statement that related to the project, objectives of the project, scope of the work for the project and some explanation about the methodology that used in this project.

1.1 Introduction to Project

The purpose of this project is to certify that the crane should move the load as fast as possible without coursing any excessive movement at the final position. The uncontrolled pendulum motion of loads suspended from gantry crane endangers both the operating personal and the often fragile load being transported. The operator, by skillful manual drive of the gantry controls, ensures that this unavoidable pendulum motion subsides as quickly as possible, since extended loading and unloading time costly.

Mechanical solutions such as cable bracing or scissor action systems are extremely expensive to install and maintain. Active crane swing composition, on the other hand is a relatively inexpensive means of achieving greater safety and faster transfer of loads.

Many machines, load positioning is achieved by using the closed-loop control system. However, most of the common gantry cranes result in a swing motion when payload is suddenly stopped after a fast motion. The swing motion can be reduced but will be time consuming i.e. reduce the facility availability as well as productivity.

Moreover, the gantry crane needs a skillful operator to control manually based on his or her experiences to stop the swing immediately at the right position. Furthermore to unload, the operator has to wait the stop from swinging. The failure of controlling crane also might cause accident and may harm people and surrounding. Many solutions have been proposed to reduce swing angle by using the partial feedback linearization control technique.

This project will focus on closed loop control system based on the partial feedback model of the gantry crane of relatively fixed coefficients of gantry mass and friction. The controller algorithm is that of a state variable feedback system, where gantry position and speed as well as cable angle and angular velocity are fed back as state variables to be controlled and regulated. The controller is implemented on small scale gantry crane designed.

1.2 Objective of Project

The main objective of this crane is to design a model gantry crane system with partial feedback linearization method that will drive the system from initial position into target position without vibration and reduction swing angle.

1.3 Problem Statement

To move the payload using the crane is not an easy task especially when strict specifications on the swing angle and on the transfer time need to be satisfied. Most of the common gantry crane results in a swing motion when trolley is suddenly stopped after a fast motion. To overcome the problem the partial feedback linearization control is applied to the gantry crane system. The partial feedback modeling of gantry crane, designed to transport a small scale models containers using industrially applicable detection and control of cable swing resulting from very high speed operation, and environmental disturbances such as steady or gusting winds. A state variable feedback controller is designed for the gantry crane position and speed, as well as the load angle and angular velocity in order to move the containers of uncertain mass as quickly, accurately, and safely as possible.

1.4 Scope of Work

All projects have their own scope or limitation as a guideline throughout the completion of the project. The project scope for implementation this project is:

i) Do some researches about gantry crane system using Partial Feedback Linearization. Read up and study related technical knowledge.
ii) Study and learn about mathematical equation that involve in this project.
iii) Study and learn about Simulink in the Matlab Software.
iv) Study and learn about LabVIEW8.5 Software.
v) Apply Partial Feedback Linearization technique onto controller in the Matlab and LabVIEW8.5 Software.
vi) Apply the technique to the gantry crane, testing and troubleshooting.

1.5 Methodology

Phase1:-

Discuss with a supervisor Mrs.Azdiana Binti Md.Yusop and show the project progress. Then get the more information about the partial feedback controller and gantry crane from supervisor, internet, books, journal, thesis, and etc.

Phase2:-

For this phase, I will make a literature review for the project system including study about the component that will be used, their characteristic and understand deeply about the circuit and how it operates and get the datasheet of component involved.

Phase3:-

For this phase, it called as software development, where involve analyze and study to design a partial feedback linearization controller. Then, construct the input simulation and the controller based partial feedback linearization.

Phase4:-

For this phase, it called as hardware construction. Firstly, all the construction held on the breadboard. After finished test circuit on the breadboard, next stage I draw the circuit for etching using the PROTEUS (ARES 6 Professional). After finished it, the circuit was through etching process.

Phase5:-

For this final phase, it called performance test. In this phase the software part and hardware part need to be combining together to get the result and to achieve the objective of project. The final result is then being compared with the theoretical. After that, the circuit that already constructed will be tested its functional, ability and weakness. If there is any error detected, the troubleshooting process will be done in order to make sure the circuit is well functioning.

1.6 Thesis Structure

The thesis structure is about the flow of the project. This thesis is having five chapters such as introduction, literature review, research methodology, result and discussion, and conclusion and suggestion.

Chapter I is about the project overview the introduction of project, objective, problem statement, scope of work, and project methodology are briefly discussed which purposely to provide the reader an understanding of the project.

Chapter II is embracing the literature review of the project which includes the concept, theory, perspective and the method of the project that is used in order to solve the problem occurs and any hypothesis that related with the research of methodology.

Chapter III is design and modeling the gantry crane system. This chapter will discuss about the research methodology of the project. Simulation results, analysis, observation and discussion of the performance of the partial feedback linearization control technique are presented in.

Chapter IV will discuss simulation results, analysis, observation and discussion of the performance of the partial feedback linearization control technique are presented in. Besides that, this chapter also will discuss about the process that already taken in order to complete the project.

Chapter V will discuss detailed about the hardware design contents schematic diagram, PCB layout, and components required. Besides that, this chapter also will discuss about the process that already taken in order to complete the project.

Chapter VI is about the conclusion and suggestion after finished the project. The suggestion is for improvement process in the future research and the conclusion is an overall of the project.

CHAPTER II

LITERATURE REVIEW

This chapter contains the research and information about the project on several important concepts of partial feedback linearization control, technology and tools used in the study. Every facts and information, which found through journals or other references, will be compared and the better methods have been chose for the project. This chapter will also include several types of crane.

2.1 Partial Feedback Linearization

Partial Feedback Linearization is linearizes the nonlinear system in the input-output sense. Exact linear relationship exists between the transform linear inputs and the original outputs of the system. The steps involved in this operation are nonlinear changes of coordinates in the input space and nonlinear feedback. Figure 2.1 shows that the control of the nonlinear system is performed through the transformed linear input-output loop.

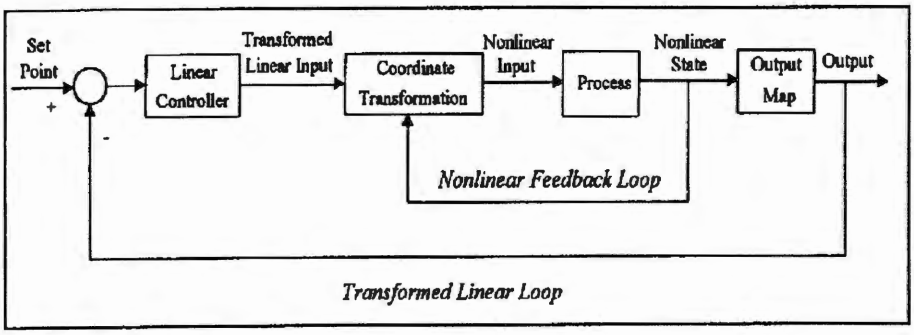

Figure 2.1: The fundamental structure of Partial Feedback Linearization

A control technique where the output y of the dynamic system is differentiated until the physical input u appears in the r^{th} derivative of y. Then u is chosen to yield a transfer function from the "synthetic input", v, to the output y which is:

$$\frac{y(s)}{v(s)} = \frac{1}{s^r}$$

If, the relative degree is less than n, the order of the system, then there will be internal dynamics. If r = n, then input or output and synthetic input linearization are the same.

2.2 Bang-bang Control

Other methods proposed by Meckl and Seering consist of using a multiswitch bang–bang forcing function, which gives time-optimal performance [1], or adding up harmonics of ramped sinusoid functions in order to approximate as close as possible a bang–bang function, but minimizing the energy introduced at system resonance frequencies.

2.3 Time-Delayed Control

This method uses the direct and time-delayed signal to cancel the poles of a system with the intention of attenuating the residual vibration. Robust Time-Delayed Control is the method referred to as the proportional plus multiple delay control, involves the use of multiple time delays in conjunction with a proportional part to cancel the dynamics of the system in a robust fashion.

All the above methods start with a parametric input function, which usually involves magnitude and time delay. The parameter values are calculated in order to reduce the residual vibrations at the final position. The speed of the system is determined mainly by the system dynamics and little control can be exercised on the speed of the response. In all cases, the achievement of robustness or the control of vibration leads to an increase in system delays.

2.4 PIC (Peripheral Interface Circuit)

PIC is used in the stepper motor controller. The Microcontroller is an essential electronic device that changes the electronic design topology since its inception few decades ago. Basically microcontroller is a computer system that is fabricated in a single integrated chip. A microcontroller chip consists of Central Processing Unit (CPU) memory modules and several input or output peripherals. Figure 2.2 shows the block diagram for the microcontroller.

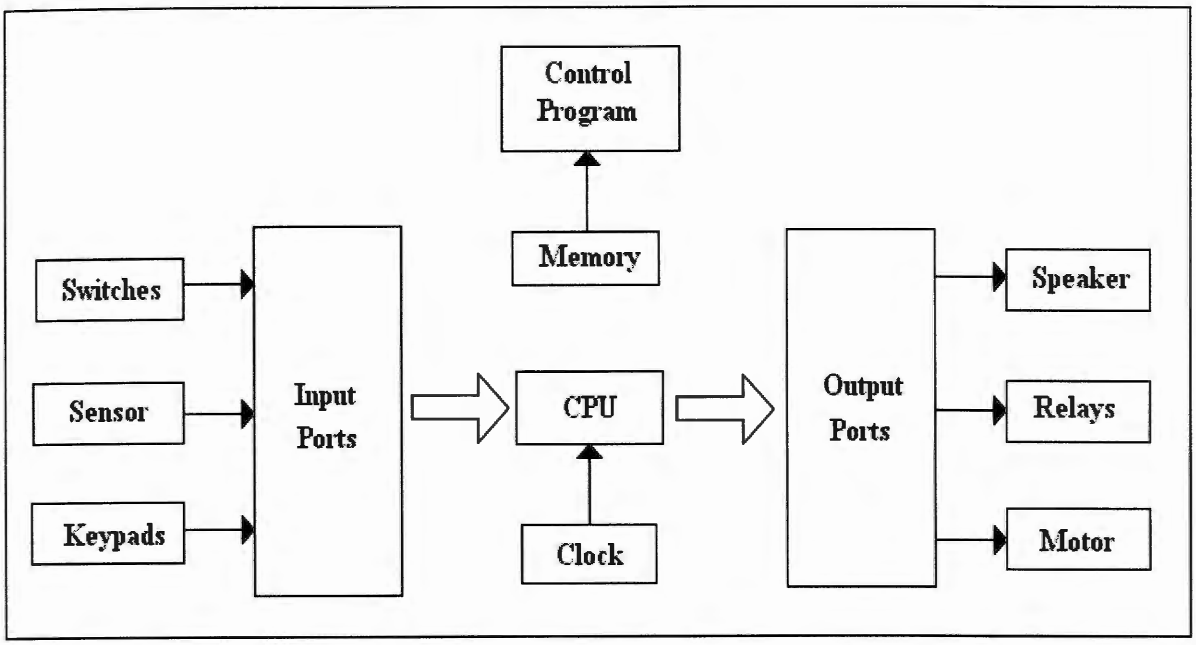

Figure 2.2: Block Diagram for microcontroller

The microcontroller is used as a device that can form the basic embedded system for electronic applications. It provides flexible low-cost solutions to bridge the gap between single chip computers and the use of large numbers of discreet logic chips. Depending on various manufactures, microcontroller is divided into several categories example 8-bit, 16-bit, 32-bit and etc. most commonly used microcontroller is 8-bit microcontroller. It is simple, small in size and capable of doing most things related with control and input or output devices.

As for the manufactures, the competitiveness of the microcontroller market has encourages several big name companies to share a piece of the pie. Those companies are:

i) Motorola (68HC11, 68HC12)
ii) Intel (8051)
iii) Atmel (AVR)
iv) Microchip (PIC Micro)