COMMAND SHAPING CONTROL OF A CRANE SYSTEM

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Dedicated to my beloved family

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ABSTRACT

Cranes are widely used for transportation of heavy material in factories, warehouse, shipping yards, building construction and nuclear facilities. There are 3 major types of crane system: gantry (overhead) crane, rotary (tower) crane and boom crane. This project will concentrate in controlling of gantry crane. First of all, the equations of motion of the gantry crane system are derived by using Lagrangian approach. Then, the model of the gantry crane system is developed to represent the dynamic equations of motion in state space. SIMULINK is used to simulate the dynamic behaviours of the gantry crane. From the simulation, we noticed that the motion of the payload and trolley are unstable with occurrence of the oscillation. The system became undamped system when the input force is taken off. The system will swing on its varying frequencies in this condition. The challenge of this project is to develop a control algorithm for gantry crane system to reduce the oscillation or vibration of the payload and hook. Input shaping command controller is introduced in this project to control the crane system. Input shaping command controller is a feed-forward controller. This project had studied the performance of this designed controller in the crane system. With this controller the gantry crane system is able to transfer the load from point to point as fast as possible and, at the same time, the load swing is kept small during the transfer process and completely vanishes at the load destination.

ABSTRAK

Kren digunakan secara meluasnya dalam pengakutan and pemindahan barang-barang berat dalam kilang, gudang, pembinaan dan juga kemudahan nuklear. Terdapat 3 jenis sistem kren iaitu: kren *gantry*, kren *rotary* dan kren *boom*. Projek ini akan menumpukan perbinacngan and kajian dalam pengawalan kren *gantry*. Persamaan pergerakan sistem kren *gantry* telah diterbitkan dengan menggunakan kaedah *Lagrangian*. Kemudian, model kren *gantry* dibentuk untuk mewakili persamaan dinamik pergerakan dalam *state space*. SIMNULINK telah dipilih dalam simulasi kren *gantry* untuk mengkaji sifat-sifat dinamik sistem kren *gantry*. Simulasi ini telah menunjukkan bahawa pergerakan beban dan troli akan jadi tidak stabil dengan kewujudan ayunan. Sistem kren akan menjadi sistem *undamped* apabila daya yang dikenakan ke atas kren diberhantikan. Sistem kren akan mengayun dengan pelbagai frekuensinya dalan situasi ini. Cabaran projek ini adalah untuk membentuk satu sistem kawalan untuk sistem kren *gantry* yang dapat mengurangkan ayunan atau getaran beban and tali. Sistem kwalan *input shaping command* telah diperkenalkan dalam projek ini untuk tujuan ini. Sistem kawalan *input shaping command* ialah teknik kawalan *feed-forward*. Projek ini telah mengkaji prestasi sistem kawalan yang diperkenalkan ini. Dengan kehadiran sistem kawalan ini, sistem kren *gantry* akan berupaya untuk menghantar beban ke destinasinya dengan pantas dan pada masa yang sama ayunan beban adalah yang paling minima dalam proses pergerakan ini.

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LIST OF SYMBOLS

Fx	-	Input force (N)
l	-	Length of hoisting rope (m)
M	-	Trolley mass (kg)
m	-	Payload mass (kg)
G	-	Centre point
S	-	Point of suspension
g	-	Gravitational acceleration (9.81ms-2)
rm	-	Position vector of centre point, G
ro	-	Position vector of point of suspension, S
xm	-	Horizontal position of the payload
ym	-	Vertical position of the payload
x	-	Trolley position (m)
$\dot{x}$	-	Trolley velocity (m/s)
$\ddot{x}$	-	Trolley acceleration (m/s^2)
θ	-	Sway angle (rad)
$\dot{\theta}$	-	Sway angle velocity (rad/s)
$\ddot{\theta}$	-	Sway angle acceleration (rad/ s^2)
T	-	Kinetic energy
P	-	Potential energy
ω_n	-	Natural frequency
ζ	-	Damping ratio
A	-	Impulse's amplitude
t_o	-	Time of impulse
t_N	-	Time of last impulse

LIST OF ABBREVIATIONS

DEE	-	Differential Equation Editor
ZV	-	Zero-Vibration
ZVD	-	Zero-Vibration-Derivative
ZVDD	-	Zero-Vibration-Derivative-Derivative
PD	-	Propotional-Derivative

CHAPTER 1

INTRODUCTION

1.1 Introduction

Cranes are widely used for transportation of heavy material in factories, warehouse, shipping yards, building construction and nuclear facilities. In order to lift heavy payloads in factories, in building construction, on ships and etc, cranes usually have very strong structures.

Crane system is tends to be highly flexible in nature, generally responding to commanded motion with oscillations of the payload and hook. The response of this system to external disturbances such as wind is also oscillatory in nature. The swaying phenomenon introduce not only reduce the efficiency of the crane, but also cause safety problem in the complicated working environment.

Previously, all the cranes were manually operated. But manual operation became difficult when cranes became larger, faster and higher. Due to this, efficient controllers are applied into the cranes system to guarantee fast turn over time and to meet safety requirement.

1.2 Project Objective

There are two main objectives for this project. The first objective is to investigate the dynamic behaviour of the gantry crane system. The mathematical model of a gantry crane is obtained by Lagrangian technique. Then, MATLAB and SIMULINK are used to simulate the sway angle and trolley position of the crane system. By observing the motions of the gantry crane system, the dynamic behaviours are studied.

The second objective of this project is to develop an effective control algorithm for the crane system to reduce the oscillation or vibration of the payload and hook. Command shaping control technique is the target controller that will be studied in this project. This designed controller should be able to transfer the load from point to point as fast as possible and, at the same time, the load swing is kept small during the transfer process and completely vanishes at the load destination.

1.3 Project Scope

The scopes of this project are:

- The project topic understanding.
- Search for the relevant material.
- Study and analysis of the mathematical model of the gantry crane system.
- Simulate and investigate the dynamic performance of the gantry crane system.
- Study and understand the concept of an effective control algorithm for the gantry crane system.
- Design and develop the proposed controller mathematically.

- Implement the designed controller by MATLAB.
- Simulate the dynamic performance of the gantry crane system after the designed controller was implemented.
- Performance analysis.
- Project report write-up.

1.4 Methodology

- Gantry crane system literature review.
- Understand the mathematical model developed.
- Study the performance of the response of the gantry crane system.
- Develop effective control algorithms.
- Investigate the performance of the controllers.
- Improve the performance of the developed controllers.

1.5 Thesis Outline

This report can be divided into seven chapters. Chapter 1 is the introduction of the project objective, scope, methodology and the report outline.

Next some information about crane system and also an overview of the literature that has been published in relation to crane control will be covered in Chapter 2.

In Chapter 3 the mathematical model of a gantry crane system will be derived.

The system model will be represented in state space for analysis. Following chapter will describe how the MATLAB and SIMULINK are used to simulate the dynamic behaviors of the gantry crane. The discussion on the simulation results will be described in this chapter as well.

The development and design of the input shaping controller to reduce the vibration of the gantry crane will be included in Chapter 5. This chapter will include the discussion on the performance of the designed controller based on SIMULINK simulation result.

Non-linear gantry crane system will be studied in this project. Chapter 6 will describe the non-linear gantry crane system and its simulation results.

The last chapter, we will conclude the works done in this project and will include the suggestion for improvement.

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