MODELING OF A GANTRY CRANE USING REAL TIME COMMAND SHAPING

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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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Universiti Teknikal Malaysia Melaka

April 2009

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Modeling Of A Gantry Crane Using Real Time Command Shaping

Sesi Pengajian : 2008/09

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To my beloved mom and dad

ACKNOWLEDGEMENT

Alhamdulillah, thanks to Allah for His divinity and blessing, I have completed my final year project for courses Bachelor of Electronic Engineering (Industrial Electronics) successfully. I would like to thanks to my lovely family for their encouragement and support. I also would like to thank my supervisors, Pn Azdiana Binti Md Yusop, whose patience, support and help guided me in my work. Thanks also to the people that has helped me along the course of finishing this project. Thank you all.

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. SIMULINK is used to simulate the dynamic behaviors 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. Command shaping technique is introduced in this project to control the crane system. Command shaping technique 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 pengangkutan dan pemindahan barang-barang berat dalam kilang, gudang, sektor pembinaan dan juga kemudahan nuklear. Terdapat 3 jenis sistem kren iaitu: kren *gantry*, kren *rotary* dan kren *boom*. Projek ini akan menumpukan perbincangan dan kajian dalam pengawalan kren *gantry*. SIMULINK telah dipilih dalam simulasi kren *gantry* untuk mengkaji sifat-sifat dinamik sistem kren *gantry*. Simulasi ini telah menunjukkan bahawa pergerakan beban dan troli akan menjadi tidak stabil dengan kewujudan ayunan. Sistem kren akan menjadi sistem tak teredam apabila daya yang dikenakan ke atas kren diberhentikan. Sistem kren akan mengayun dengan pelbagai frekuensi dalam situasi ini. Cabaran projek ini adalah untuk membentuk satu sistem kawalan untuk sistem kren *gantry* yang dapat mengurangkan ayunan atau getaran beban dan tali. Teknik *command shaping* telah diperkenalkan dalam projek ini untuk tujuan ini. Teknik *command shaping* ialah teknik kawalan suapan hadapan. 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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CHAPTER I

INTRODUCTION

1.1 Overview

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

The objective of this project is to apply the technique using real time command shaping to extend the field of system by developing a systematic methodology to control and minimize residual vibration in systems.

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. The fundamental motions of a gantry crane consist of travelling, load hoisting and load lowering. When the gantry crane start or finished the operation, it will give the undesirable result where it is swinging and vibration to the suspended load. Vibration control is an important consideration for rapid repositioning of flexible payloads. The large accelerations and speed needed to move a payload quickly can cause vibration, reducing the throughput of the overall process.

The gantry cranes are highly flexible, responding in an oscillatory manner to external disturbances and motion of the bridge and trolley. Payload oscillation has adverse consequences. Swinging of the hook makes positioning difficult and inefficient. When the payload or surrounding obstacles are of a hazardous or fragile nature, the oscillations present a safety hazard as well.

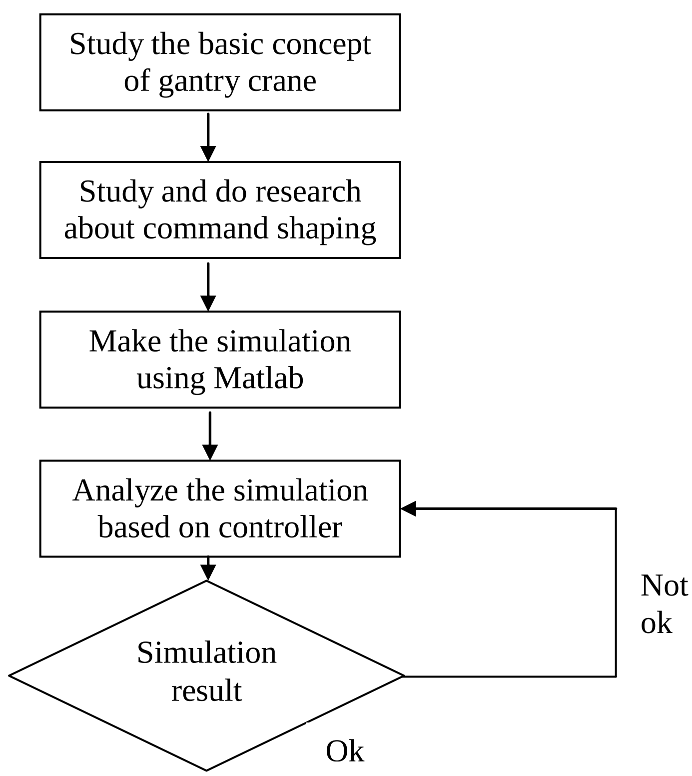
Besides that, to unload, the operator has to wait the load stop from swinging. The residual vibration at the end of a move is the most determination and extent of the residual vibration limits the performance of the system. By that, the command shaping method will be applied to this gantry crane to reduce the vibration of positioning of the crane and also reduces the swing angle of the payload.

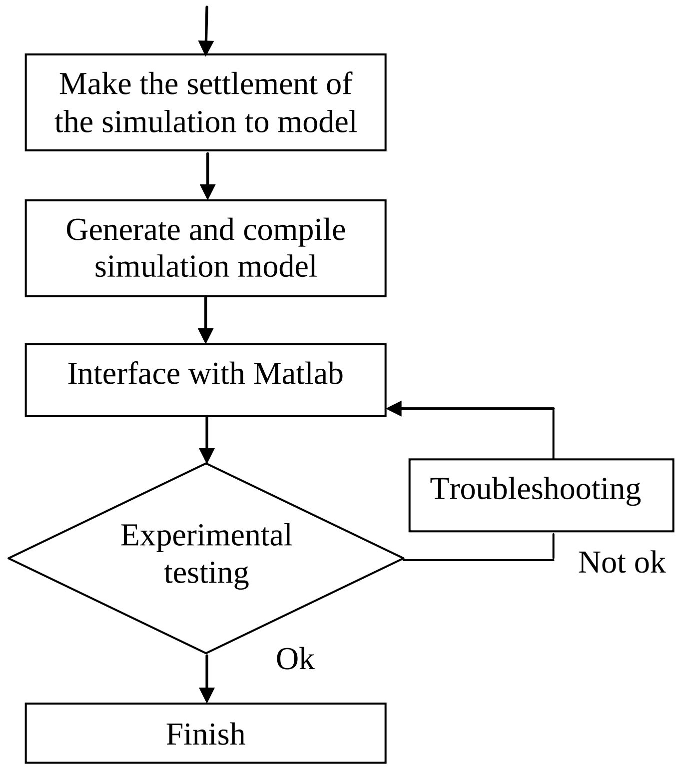
1.4 Project Scope

The scopes of this project are:

1) Study the model of a gantry crane system.
2) Research and study about command shaping technique.
3) Study on real time command shaping to get the output for gantry crane system.
4) Simulate and investigate the dynamic performance of the gantry crane system.
5) Learn more specific about Simulink in the MATLAB.
6) Get some examples for command shaping by using Simulink in MATLAB and then to study how does the command shaping work in the system.
7) Apply the technique to the gantry crane, testing and troubleshooting.
8) Project report write-up.

1.5 Methodology





1.6 Thesis Outline

This thesis describes the command shaping technique and how to apply this technique onto the gantry crane system. This thesis has six chapters. The first chapter will be describe about a brief introduction about the project consist the overview, objective, problem statement and scope of the project. A literature review of recent work on command shaping theory and application is presented in chapter 2. Other than that, the bang – bang control will addition to discussed and compared to command shaping. Chapter 3 describe about real time command shaping technique and illumination about PID controller. The simulation result and discussion about command shaping will be showed and discuss in chapter 4. Chapter 5 introduce detailed about hardware interfacing between hardware and simulation. And finally, chapter 6 summarizes the contributions of this work along with suggesting avenue for future explorations.

CHAPTER II

LITERATURE REVIEW

This chapter consists of some information about crane system and also an overview of the literature that has been published in relation to crane control.

2.1 Types of Crane

A crane consists of a hoisting mechanism such as hook and a support mechanism such as trolley girder. The hoisting mechanism has two main functions. It deposits the payload at the target destination and avoids the obstacle in the path by lifts and lowers the payload. The function of the support mechanism is moves the suspension point around the crane workspace.

Crane can be classified based on the degree of freedom the support mechanism offer the suspension point. There are 3 major types of crane system:

(a) Gantry (overhead) crane
(b) Rotary (tower) crane
(c) Boom crane.

2.1.1 Gantry Crane

Gantry crane is composed of a trolley moving in a girder along a single axis. In some gantry crane, the girder is mounted on the second set of orthogonal railings, adding another degree of freedom of the horizontal plane. Gantry crane is commonly used in factories, Figure 2.1.

Figure 2.1 Gantry Crane

2.1.1.1 Details about Gantry Crane

There are three main components in a gantry crane which are trolley, bridge and gantry. Figure 2.2 shows a typical gantry crane. Trolley with a movable or fixed hoisting mechanism is the load lifting component. It moves on and parallel to a bridge which is rigidly affixed to a supporting structure called gantry. The gantry extends downward from the bridge to the ground where it can be mobilized on wheels or set of tracks. The motion of the gantry on the ground, the trolley on the bridge and the hoisting of the payload provide the 3 degrees of freedom of the payload.

Figure 2.2 Illustration of a Gantry Crane

This type of system tends to be highly flexible in nature, generally responding to commanded motion with oscillations of the payload and hook. The response of these systems 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.

This project will concentrate in controlling of gantry crane to reduce the vibration of the crane system.

2.1.2 Tower Crane

Tower crane is commonly used in construction, Figure 2.3. In this crane, the girder rotates in the horizontal plan about a fixed vertical axis. The trolley that holds the load can move in radial position over the girder. The load is attached to the trolley using a set of cables.

Figure 2.3 Rotary or Tower Crane

2.1.3 Boom Crane

For the boom crane, a boom is attached to a rotating base. The rotational movement of the base along with the elevation movement of the boom places the boom tip over any point in the horizontal plane. The load hangs from the tip of the boom by a set of cables and pulleys. The radial and vertical positions of the load can be changed by changing the elevation angle of the boom. Boom cranes are very common on ships and in the harbors, Figure 2.4.

Figure 2.4 Boom Crane