VIBRATION-FREE POSITIONING OF GANTRY CRANE SYSTEM USING IMPULSE SHAPING METHOD

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"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

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“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for award of Bachelor of Mechanical Engineering (Design and Innovation) With Honours.”

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Date : 10 APRIL 2009

To my beloved mom and my dearest family

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ABSTRACT

Impulse shaping reduces residual vibrations in computer controlled machines. Impulse shaping is implemented by convolving a sequence of impulses, an input shaper with any desired command. The shaped command that results from the convolution are then is used to drive the system. If the impulses in the shaper are chosen correctly, then the system will respond without vibration to any unshaped command. In order to increase the rise time, the impulses are allowed to take negative values, and multihump shaping of the impulses and then can be use to increase the system robustness. The shaped input function is derived from the specified output function so that the designer can choose the speed and shaped of the motion within the limitations of the drive system. This technique is applied to a gantry crane system which is fourth order systems. In this system, the parameters for the system such as trolley mass, payload mass, and hoist length need to be defined first. Simulated responses of the position of the trolley and sway angle are presented using simulink in Matlab.

ABSTRAK

Teknik 'Impulse shaping' digunakan untuk mengurangkan gegaran pada mesin kawalan komputer. 'Impulse shaping' dilaksanakan dengan menggabungkan beberapa turutan denyutan yang dipanggil 'input shaper' dengan apa-apa arahan yang dikehendaki. Arahan yang dibentuk dari konvolusi tersebut akan digunakan untuk memandu sistem. Jika denyutan pada pembentuk dipilih dengan betul, maka sistem akan berfungsi tanpa gegaran pada apa jua arahan yang belum dibentuk. Dalam kaedah untuk meningkatkan nilai masa naik, apabila menggunakan teknik ini, denyutan boleh untuk mengambil nilai negatif dan 'multihump shaping' pada denyutan boleh digunakan untuk meningkatkan ketegapan sistem. Persamaan masukan diperolehi daripada respon keluaran yang dikehendaki supaya pengkaji dapat memilih kelajuan dan bentuk respon yang diperlukan supaya berada dalam had maksima sesuatu sistem. Teknik ini diaplikasikan pada sistem kren gantri yang merupakan sistem 'order' keempat. Pada sistem ini, parameter-parameter termasuklah berat troli, berat beban dan panjang tali pengangkat perlu ditentukan terlebih dahulu. Respon bagi kedudukan troli dan sudut ayunan beban akan ditunjukkan menggunakan 'simulink' dalam Matlab.

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LIST OF SYMBOLS

M	- Trolley mass
m	- Payload mass
l	- Length of the 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 will discuss the overview of the project; mainly about how to reduce the residual vibration in a gantry crane system using the impulse shaping closure. All the details regarding the project, such as introduction, objective, problem statement, scopes, work methodology and thesis outline will be revised thoroughly in this chapter.

1.1 Project Introduction

In our daily life, crane is generally used to lift, transfer and placed workloads that are too heavy or too large to be handled by human bare handedly. By hoisting or lowering desired loads vertically and then moving it horizontally, crane is one the most favor transportation system that is widely used in the industry to place massive loads. Some of the famous crane types are like the gantry crane, overhead crane, tower crane, jib crane and others. In this project, the research done is solely focused on the gantry crane system.

Gantry crane is one of the most simple-structured cranes if to be compared with others of its type. Utilizing the basic principle possessed by every crane, a gantry crane will also positioning loads by hoisting it. When hoisting loads while simultaneously traveling it, the chances for the loads to experiencing vibration is almost unquestionable. However, excessive vibration can cause harm and are environmentally hazardous. Because of that, many studies have been conducted in order to solve this problem and one of it is the impulse shaping method.

Impulse shaping is a simple and effective method for reducing the residual vibration when positioning a lightly damped systems and it remains an active research area until now. In this proposed method the only parameter that needs to be defined is the output speed, which is limited only by the physical constraints of the drive system. The calculation of an optimum speed is demonstrated by simulation example.

In many machines, load positioning is achieved by simple open-loop control. In the case where structural flexibility is significant and the load is lightly damped, the vibration may be unacceptable and a number of papers from previous studies have reported various approaches to use impulse shaping to control the vibration.

In order to increase the rise time when using impulse shaping, the impulse are allowed to take negative values, and multihump shaping of the impulses can be use to increase the system robustness. Of course the flexible system that will be applied on this project is the gantry crane which has been mentioned earlier.

1.2 Objective

The main objective of this project is to design a gantry crane system and to apply the technique of the impulse shaping onto the gantry crane to control the residual vibration in the system. The other objective is to extend the field of input shaping by developing a systematic methodology to control residual vibration in the system.

1.3 Problem statement

In many machines, vibration is a serious problem especially in the mechanical systems that are required to perform precise motion in the presence of structural flexibility. 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. Residual vibration is detrimental whenever the part must be quiescent before it can be accurately placed. Increasing the positioning speed will lead to residual vibration. If the time it takes to sufficiently damp the vibration for accurate placement is greater than the time gained through increasing the maneuver speed, then the overall effect is a reduction in throughput.

The use of the gantry crane systems for transporting payload is very common in industrial application. However, moving 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.

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 the surrounding obstacles are of a hazardous or fragile nature, the oscillations present a safety hazard as well. As of this reason, it will just decrease the efficiency of the crane.

Moreover, the gantry crane needs a skillful operator to control manually to stop the swing immediately at the right position. It is also makes crane work very dangerous when workers or other obstacle exist in the crane workspace. The failure of controlling crane might cause accident and may harm people and the surrounding.

Furthermore, 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.

The impulse shaping method will 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 Scopes

The scope of this project includes:

I. To study the dynamic behavior of gantry crane.
II. To study the impulse shaping method.
III. To design an appropriate way based on impulse shaping method to reduce the residual vibration of the system.
IV. To evaluate the performance of the system.

1.5 Work Methodology

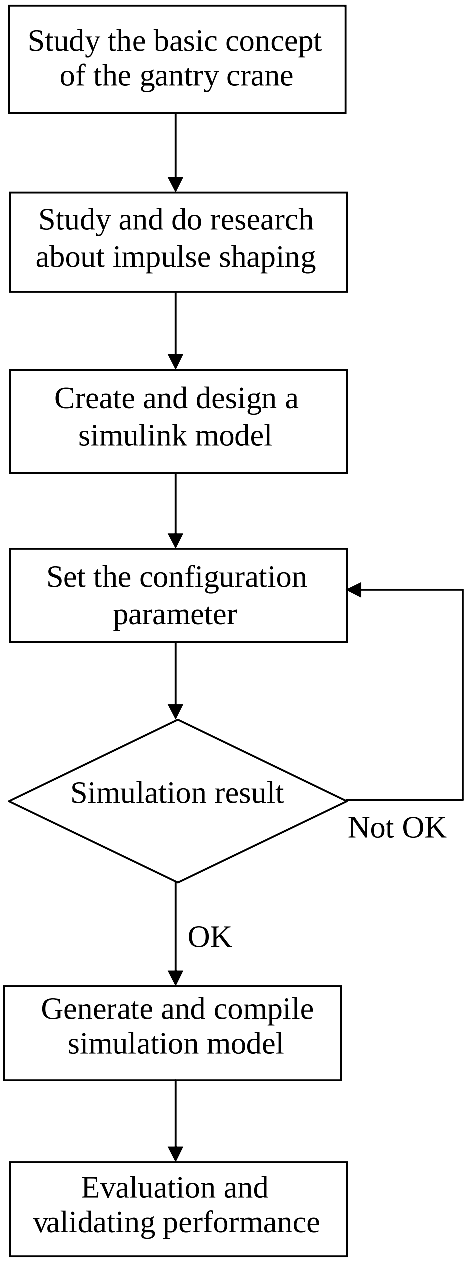

Figure 1.1: Methodology chart

1.6 Thesis Outline

This section will illustrate the rough outlines of the structure of the thesis. Below is the general idea of what each and every chapter in this thesis will convey.

Chapter 1 will discuss the introductory phase of this thesis. The background, objective, scopes and work methodology of this project can be come across here.

Chapter 2 is most likely deal with the literature review of the project. A review of recent work on impulse shaping theory and its application is presented in this chapter. In addition of that, review of the gantry crane also stated here.

Chapter 3 will cover up the methodology of this project. A detail flow chart regarding the course of the project is also presented here.

Chapter 4 gives a detailed description of the derivative of the equations of motion used for the time – domain simulation.

Chapter 5 will discuss the analytical impulse shaping approach for nonlinear excitation terms. Simulated verification of the method is also described in this chapter.

Chapter 6 will conclude this thesis once and for all. Aside from the conclusion, recommendation of the future work also stated in this final chapter.

CHAPTER II

LITERATURE REVIEW

Precise position control and rapid rest-to-rest motion is the desired objective in a variety of applications. The requirement of precise position control implies that the residual vibration of the structure should be zero or near zero. Literature review is done in this chapter to make a review of the several techniques of input shaping that will reduce the vibration and part of it is discussed below.

2.1 Input Shaping Techniques

Input shaping is a simple and effective method for reducing the residual vibration when positioning a lightly damped system. A lightly damped system is a system which oscillates with a damped frequency until it stops and in this project, the gantry crane system is what it refers to as a lightly damped system. In real-world systems, the second law of thermodynamics dictates that there is some continual and inevitable conversion of energy into the thermal energy of the environment. Thus, this oscillations tend to decay (become "damped") with time unless there is some net source of energy into the system. This is the best way to depict the residual vibration that occurs to the gantry crane system when it is moving with the loads attached to it. The vibration will take place relative to the crane movement but will eventually damping upon stationary motion as the crane stop moving.

Input shaping is applicable in real time, and input shapers can be designed to have any desirable robustness level. Input shaping is designed to reduce, or eliminate, command-induced system vibration [1]. A desired reference command given to a flexible system will, in general, result in residual vibration. Input shaping is ability to cancel vibration can be viewed as destructive interference of sinusoidal waves [2]. If two sinusoids of the same magnitude, same frequency and correct phase shift between them are added together, the resulting combination will have no oscillations. This effect can be seen in Figure 2.1.

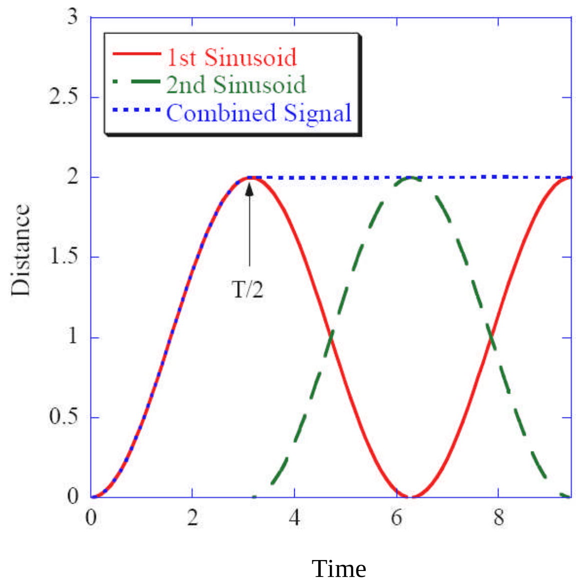

Figure 2.1: Destructive Interference Time

The sequence of impulses, known as the input shaper, is then convolved with a desired reference command to produce a new, modified command that can be used to drive the system.

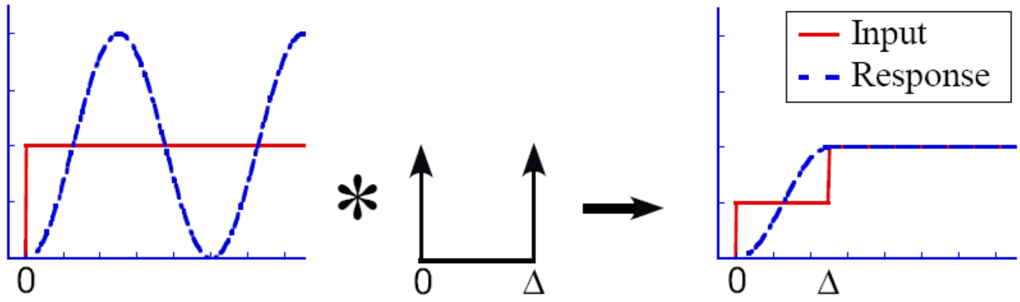

Figure 2.2: Input shaping process.

As shown in Figure 2.2, this modified command will cause the system to move with no residual vibration. The sequence of impulses is chosen such that, when the modified command is applied to the system, certain performance constraints are met. These performance constraints can include the system's desired residual vibration amplitude, robustness to modeling errors, and command rise time, among others.

Some of the well-heard input shaping techniques is such as impulse shaping, posicast control, inverse dynamic and others.

2.1.1 Impulse Shaping

Impulse Shaping is a feed forward control technique for reducing vibrations in computer controlled machines. The method works by creating a command signal that cancels its own vibration. That is, vibration caused by the first part of the command signal is canceled by vibration caused by the second part of the command.