VIBRATION-FREE POSITIONING OF FLEXIBLE SYSTEMS USING IMPULSE SHAPING

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To my late father and beloved 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. This technique is compared with the bang-bang input.

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 system 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. Teknik ini akan dibandingkan dengan masukan bang-bang untuk melihat keberkesanan teknik yang digunakan.

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CHAPTER 1

INTRODUCTION

1.1 Project Introduction

Impulse shaping is a simple and effective method for reducing the residual vibration when positioning lightly damped systems, and it remains an active research area until now. In the 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 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. One of the examples of flexible system that will be applied on this project is gantry crane. This method will be applied to the gantry crane.

1.2 Objective

The 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 in 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 surrounding obstacles are of a hazardous or fragile nature, the oscillations present a safety hazard as well.

Thus makes the efficiency of the crane work lower. 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 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.

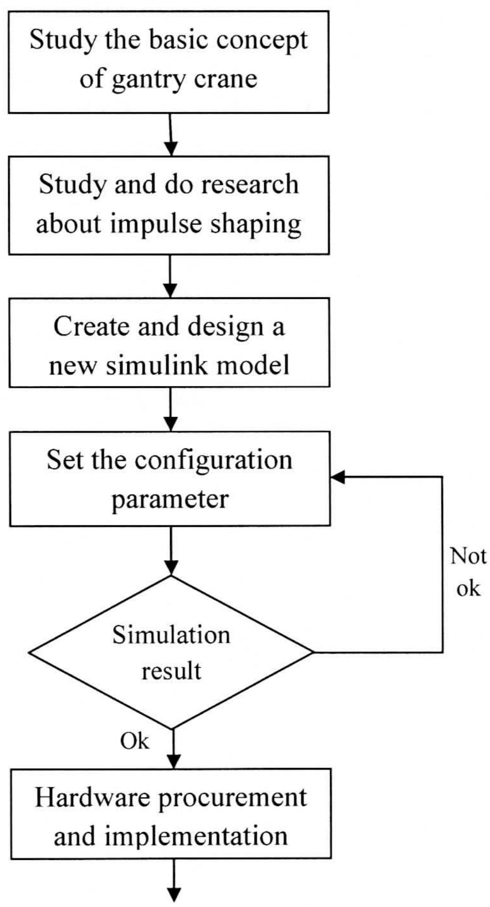
1.4 Scope

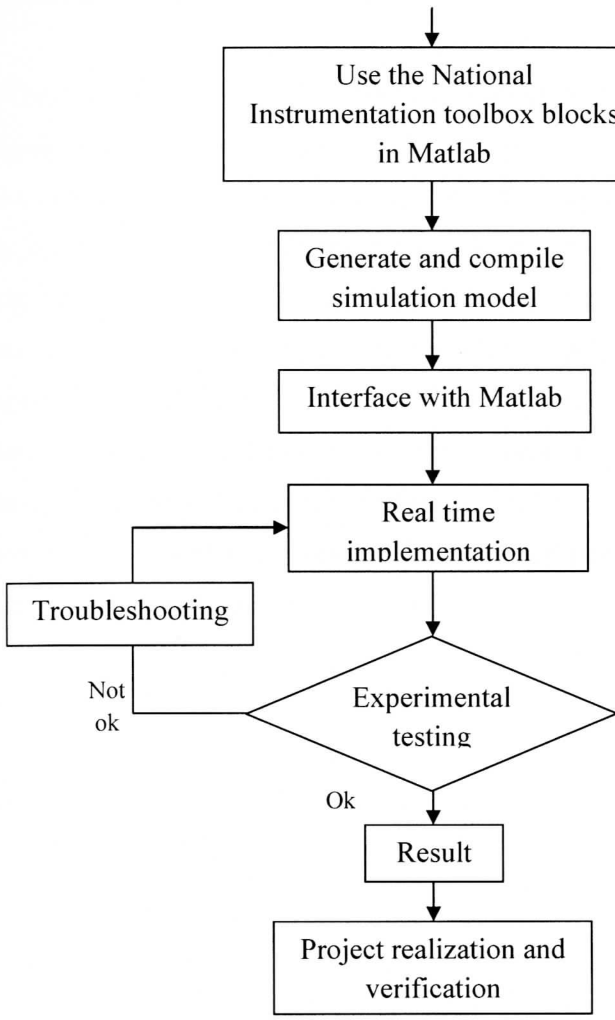
The scope of this project includes:

a. To study all of the vibration control technique and do research about the impulse shaping method.
b. Do some researches about a gantry crane system using impulse shaping method and find the datasheet for motor, sensor, motor control circuit that will be used in the gantry crane model. After that, feasibility study and read up related technical knowledge.
c. Get some literature reviews about impulse shaping method that involve in this project. Also, get some research journal about gantry crane and impulse shaping method to understand this technique.

d. Learn more specific about simulink in the MATLAB software and how to use simulink in the MATLAB.
e. Get some examples for impulse shaping by using simulink in MATLAB and then to study how does the impulse shaping work in the system.
f. Design and build the gantry crane. Use the National Instrument toolbox blocks in the MATLAB to control the system.
g. Apply the impulse shaping to the gantry crane, testing and troubleshooting.

1.5 Methodology




Use the National Instrumentation toolbox blocks in Matlab
Generate and compile simulation model
Interface with Matlab
Real time implementation
Troubleshooting
Not ok
Experimental testing
Ok
Result
Project realization and verification

1.6 Thesis Outline

This thesis describes the impulse shaping technique and how to apply this technique onto the gantry crane. In this thesis, it consists of five chapters. A brief introduction about the project including the objectives, problem statement and scope of the project will be explained in chapter 1. A literature review of recent work on impulse shaping theory and application is presented in chapter 2. In addition, bang – bang control is also discussed and contrasted to impulse shaping. Chapter 3 gives a detailed description of the derivative of the equations of motion used for the time – domain simulation. The analytical impulse shaping approach for nonlinear excitation terms is presented in chapter 4. Simulated verification of the method is described also in chapter 4. And finally, chapter 5 summarizes the contributions of this work along with suggesting avenue for future explorations.

CHAPTER II

LITERATURE REVIEW

This chapter presents all the literature review and some research requiring based on the impulse shaping method and gantry crane. This literature review is primarily restricted to published research results on residual vibration control of flexible systems. Modeling of flexible systems is also included. This literature review is required to study all the characteristic and their algorithm, requirement needed, and general idea of this project. All the information that has been collected is very important to ensure that this project achieved their objectives.

2.1 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.

Input shaping is implemented by convolving a sequence of impulses, an input shaper, with any desired command. The shaped command that results from the convolution is then 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. Figure 2.1 show the application of the impulse shaping onto closed loop system.

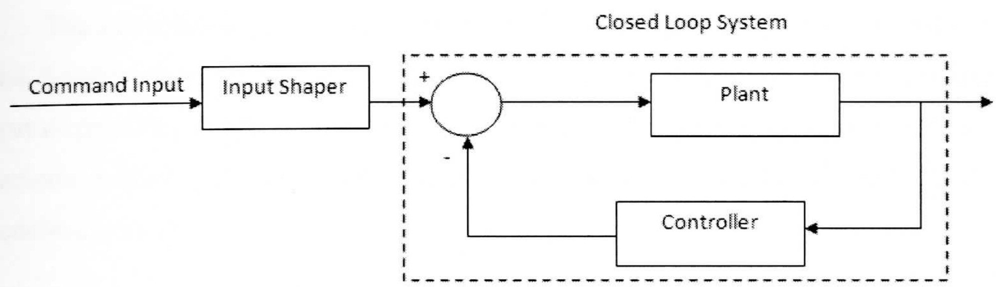


Figure 2.1 General system using impulse shaping.

The process of shaping a step input is demonstrated in Figure 2.2. Instead of using the step input, the staircase command resulting from the convolution is used as the command signal.

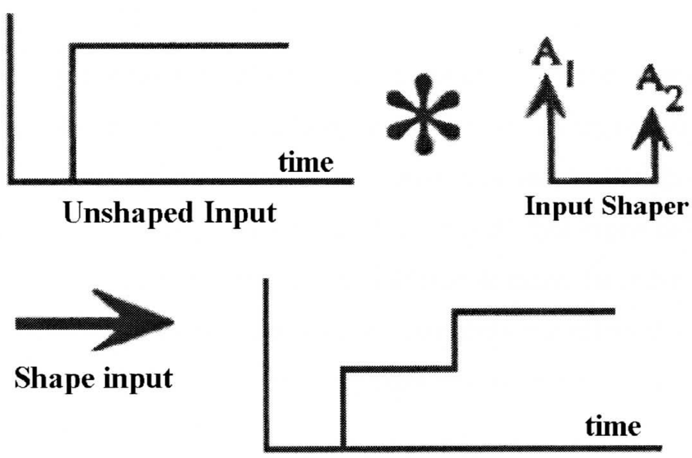


Figure 2.2 The impulse shaping process.

An input shaper is designed by solving a set of equations that limit the dynamic response of the system. There are many types of constraint equations that will yield acceptable input shapers, and several types of shapers have been determined in closed form. Their use only requires evaluating simple equations using estimates of the natural frequencies and damping ratios to obtain the amplitudes and time locations of the impulse which compose the input shaper.

The convolution process lengthens the command signal by an amount equal to the time duration of the input shaper. Therefore, it is desirable to make the input shaper as short as possible, so that the system delays are minimized. However, traditionally design methods require that the input shaper be lengthened if additional insensitivity to modeling errors is required.

During its original presentation [1,2], impulse shaping was explained by a variety of methods, including time domain analysis, vector diagram representation, frequency domain analysis, phase plane description, and pole-zero cancellation in the s-plane. The vector diagram was used to improve insensitivity and cancel multiple modes of vibration. The frequency domain and poles-zero cancellation representations have been investigated in several papers.

The amplitudes and time locations of the impulses are obtained from the system's natural frequencies and damping ratios. Shaping can be made very robust to errors in the system parameters. The impulse sequence is chosen such that in the absence of control input, it itself would not cause residual vibration. Recall that convolution in the time domain is equivalent to multiplication in the Laplace domain. In order to increase the rise time, when using the impulse shaping, the impulses are allowed to take negative value [3] and multihump shaping of the impulses can be used to increase the system robustness [4].

A step shaper is designed by generating acceleration or deceleration pulse profile using step inputs with alternative sign. The main difference between impulse shaper and step shaper is whether it uses the convolution concept or not. Figure 2.3 show the impulse shaper versus the step shaper.