AN ADAPTIVE ALGORITHM FOR THE TUNING OF TWO INPUT SHAPING METHODS

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Dedicated to my family especially my parent, sister, brothers, and all of my friends.

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ABSTRACT

The project presents an adaptive algorithm for the tuning of two input shaping methods designed to prevent the excitation of oscillatory modes in resonant systems. The first method produces a control signal that is the linear combination of delayed versions of the reference input. The transfer function of the control system has an infinite number of complex zeros, with some of them placed exactly at the locations of the resonant modes of the plant. In contrast, the second method is based on a pole/zero cancellation of the resonant modes using a finite-dimensional controller. An adaptive algorithm is used for the tuning of both methods. In this project, the problem of controlling systems with resonant modes is considered. For simplicity, attention is focused on second-order systems. The system is developed and simulated by using MATLAB software. The control performance is shown graphically to be comparable for both methods and the adaptive algorithm is found to be both simple and effective for fast adaptation.

ABSTRAK

Projek ini mempamerkan satu algoritma adaptif untuk penetapan dari dua kaedah membentuk input yang direka untuk mencegah eksitasi mod ayunan pada sistem resonan. Kaedah pertama menghasilkan isyarat kawalan yang merupakan gabungan linear daripada versi tertunda dari masukan rujukan. Fungsi pemindahan dari sistem kawalan mempunyai jumlah infiniti sifar kompleks, dengan beberapa daripadanya ditempatkan secara tepat di lokasi mod sistem resonan. Sebaliknya, kaedah kedua adalah berdasarkan pembatalan 'pole / zero' dari mod resonan menggunakan pengawal dimensi terhad. Algoritma adaptif digunakan untuk penetapan kedua-dua kaedah. Dalam projek ini, masalah pengendalian sistem dengan mod resonan dikaji. Untuk kemudahan, perhatian difokuskan pada sistem turutan kedua. Sistem ini dibangunkan dan disimulasikan dengan menggunakan perisian MATLAB. Prestasi kawalan ditunjukkan secara grafik untuk dibandingkan terhadap kedua-dua kaedah dan algoritma adaptif didapati memudahkan dan berkesan untuk diadaptasi dengan cepat.

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ω_n	-	Natural frequency
ξ	-	Damping ratio
K	-	Stiffness
u	-	Normalized time
α	-	Speed motion
β	-	Relationship between α and ω_n
M	-	Trolley mass
m	-	Payload mass
l	-	Length of the hoisting rope
F_x	-	Input force
g	-	Gravitational acceleration = $9.81 ms^{-2}$
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

PROJECT INTRODUCTION

This chapter will discuss about the adaptive algorithm for the tuning of two input shaping methods. The project introduction, project objective, problem statement and scopes of work, methodology and thesis outline will also be presented.

1.1 Introduction

This project attempts to design the controller for the gantry crane system and interface it with MATLAB in Real-Time Workshop. The input of the system is using step function. The problem of controlling systems with resonant modes is considered. For simplicity, second-order systems are considered. Two feed-forward control methods are discussed. In the first method, the control signal is a linear combination of two signals: the reference input signal and the signal delayed by a certain time period. In the second method, the control signal is obtained by filtering the reference signal using a transfer function such that the plant poles are cancelled by the compensator zeros.

The first method is referred to as the delayed input method, and the second method as the pole/zero cancellation method. The two methods are compared and an algorithm is proposed for the tuning of the pole/zero cancellation method. This project includes the previous work in three ways. First, the tuning algorithm is made adaptive by replacing the batch least squares algorithm by the recursive least-square algorithm recommended. Second, it is shown that the adaptive algorithm can be used to tune the delayed input method as well as the pole/zero cancellation method. Finally, the adaptive algorithm is shown to be effective for the tuning of the input shaping methods with double zeros placed at the locations of the plant poles instead of single zeros. The results are all demonstrated experimentally using a simulation of MATLAB software. The algorithm has major interest because of its simplicity, thus it is easily implemented in real-time.

1.2 Objective

The objective of this project is to specify a controller function by using an adaptive algorithm for the tuning of two input shaping methods for gantry crane that can move as robustness, quickly, accurately, and safely as possible without vibration from an initial position to target position.

1.3 Problem Statement

Gantry cranes are widely used for factories, transportation, nuclear installation and also construction. The crane has to move the load as fast as possible without causing any excessive movement at the final position or during it moves. 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 swing motion when payload is suddenly stopped after a fast motion can be reduced but very wasting time. Moreover, the gantry crane needs a skilful and experienced operator to control manually for stopping the swing immediately at the right position. Beside this, the operator also needs time to wait the string stop from vibration after

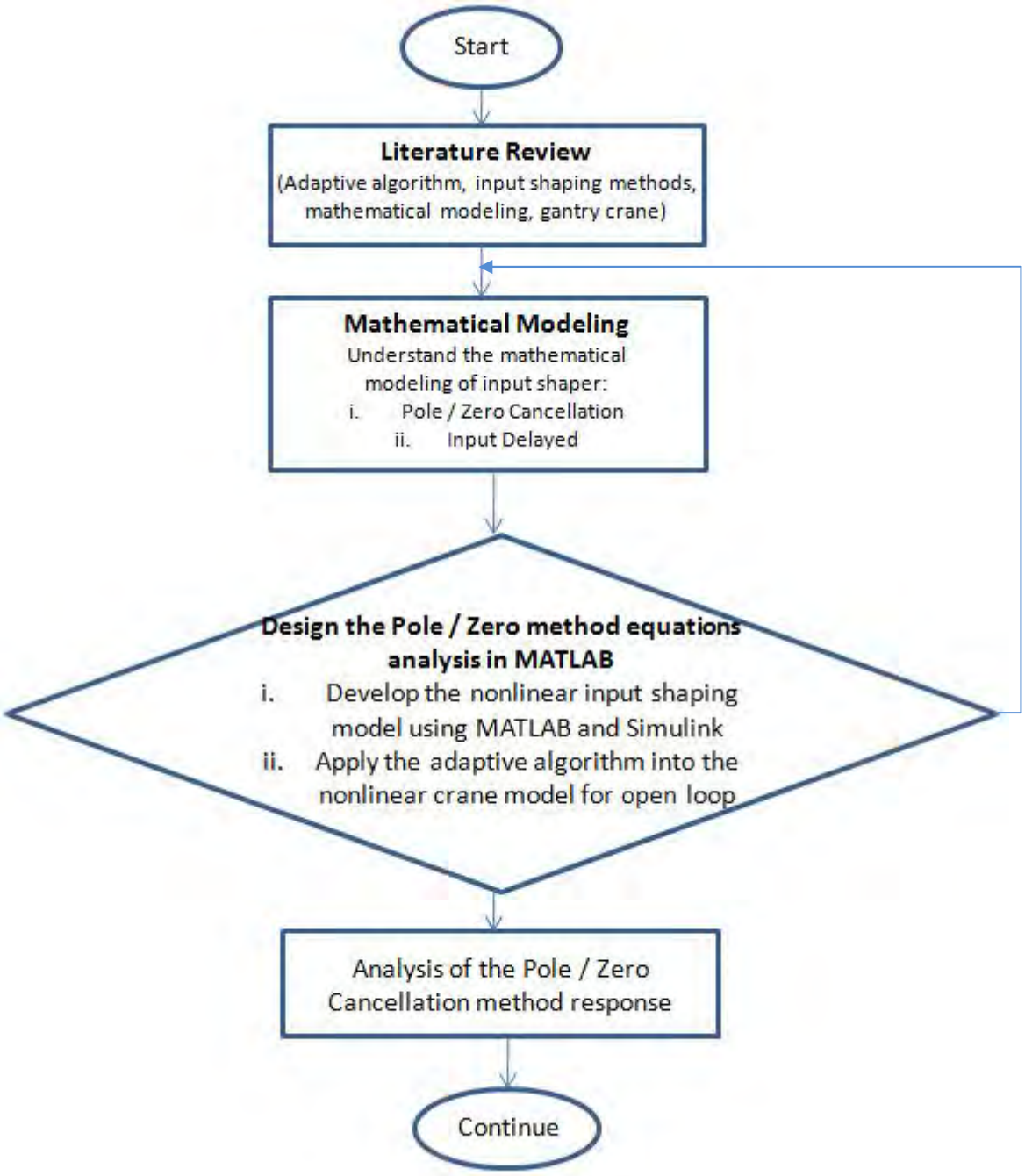
movement the load. Vibration is a serious problem in a mechanical system. The problem can be solved by placing an appropriate controller with input shaping methods to the gantry crane system.

1.4 Scope of Work

While doing the project, the scope of work plays very important role, which is a guidelines for student should attain to fulfil the requirement of the project. For this project, the scopes of work are such as listed below:

i. Study the basic concept of the gantry crane system, input shaping methods and design, and adaptation.
ii. Study the mathematical modelling, nonlinear feedback control of a gantry crane, desired motion, modelling of the gantry crane, derivation of the equations of motion, and linearization.
iii. Understand theoretically about input shaping methods involved.
iv. Analysis and make the comparison between the two input shaping methods.

1.5 Methodology (Flow Chart)



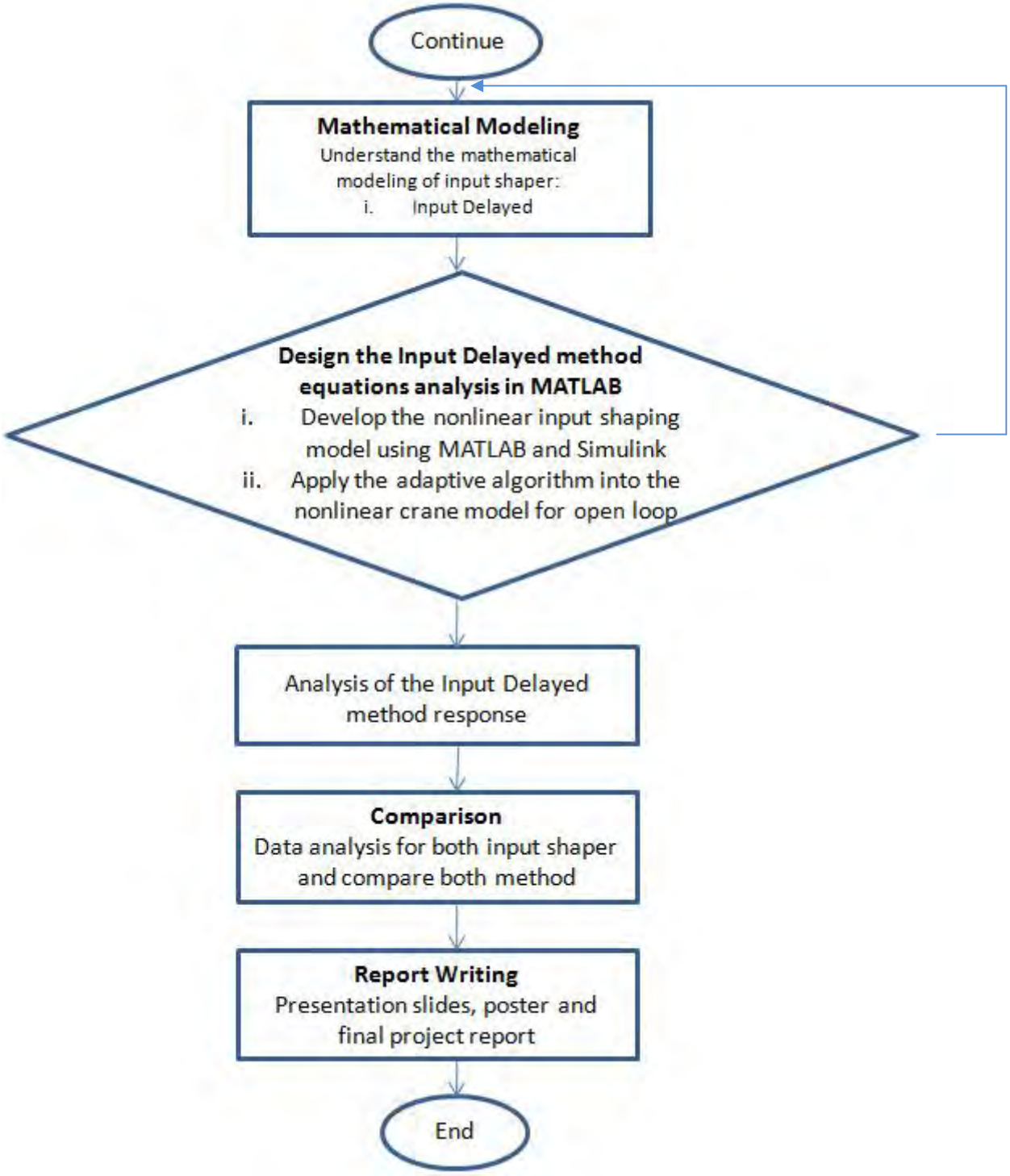


Figure 1.1: Project Flow Chart

The flow of this project can be represented by Figure 1.1: Project Flow Chart. The project started with literature review of the project such as review about adaptive algorithm, input shaping methods, mathematical modelling, and gantry crane. The literature review is usually a theoretical understanding about the project being developed. Next, proceeds with mathematical modelling by which it is an understanding process of the mathematical modelling of input shaper, for this project the input shapers are pole / zero cancellation method, and input delayed method.

Then, the flow is to design the pole / zero methods equations and analysis in MATLAB, where the nonlinear input shaping model is develop using MATLAB and Simulink, and apply the adaptive algorithm into the nonlinear crane for open loop. If the response does not satisfy, the operation will reverse back to the mathematical modelling. The analysis is made based from the simulation results. Two parameters to be analysed – position of the trolley and sway angle of the hoisting rope.

Next, proceeds with mathematical modelling by which it is an understanding process of the mathematical modelling of input shaper - input delayed method. Then, the flow is to design the input shaper methods equations and analysis in MATLAB, where the nonlinear input shaping model is develop using MATLAB and Simulink, and apply the adaptive algorithm into the nonlinear crane for open loop. If the response does not satisfy, the operation will reverse back to the mathematical modelling. The analysis is made based from the simulation results. Two parameters to be analysed – position of the trolley and sway angle of the hoisting rope.

Based from all simulation results, data is analysed for both input shaper and compare which methods produce better performance in terms of position of the trolley and sway angle of the hoisting rope.

1.6 Report Structure

This thesis is a documentary to deliver the generated idea, the concepts applied, the activities done, and the final year project product produced. The thesis consists of six chapters. This paper is organized as follows.

Chapter I is regarding of the background studies of the project including introduction of the project, objective, problem statement, scopes of work and methodology.

Chapter II enclose literature review about gantry crane including history, applications, and working principle. Furthermore, the standard techniques of input shaping that will reduced the vibration for the gantry crane is also covered in this chapter.

Chapter III will introduce the derivation of equations of adaptive version of input shaping techniques explaining the purpose of this study. On the other hand, this chapter will explain how to get equations for the input shaping in s-domain.

Chapter IV will illustrates more on the input shaping analysis. This method will review the process by specifying the system input function.

Chapter V contain the utilized methodology for software. The design flow and construction of the project is introduced. It gives brief description about each procedure in completing the project. It also covered the experimental result, analysis and discussion, for both input shaping methods. Furthermore, the comparison between both techniques is also scrutinized.

Chapter VI is the conclusion of the initial progress of the project and recommendation that can be implemented in the future.