# ADAPTIVE NEURO FUZZY MODELLING AND VIBRATION CONTROL OF FLEXIBLE STRUCTURE

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# ADAPTIVE NEURO FUZZY MODELLING AND VIBRATION CONTROL OF FLEXIBLE STRUCTURE

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*To my beloved baba and mama,*
*for your love and courage.*

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# ABSTRACT

Flexible plate structures have broad applications, ranging from industrial area to space technology. The demand for thin, flexible plate structure has rapidly increased due to industrial evolutions. However, this type of structure leads to high vibration. There are numerous research and study that have been conducted to analyze this problem. The aim of this study is to develop a model characterizing the vibration of a 2-dimensional flexible plate using adaptive neuro-fuzzy inference system (ANFIS). In order to construct the model, sets of data were obtained from numerical analysis. Finite difference method was implemented to discretize the dynamic equation of the plate to finite difference equations. Simulation algorithm was then developed and implemented within the MATLAB environment. The results obtained were validated by comparing the first five frequency parameters with values from other researchers. The sets of data obtained were utilized to develop ARX model and ANFIS model. Then, single-input single-output active vibration controller (SISO-AVC) was devised based on recursive least squares (RLS) algorithm and ANFIS algorithm. The performance of these systems was assessed. The results suggest that ANFIS model is a good tool in system modeling and vibration control. ANFIS-AVC scheme significantly lower the vibration compared to RLS algorithm.

# ABSTRAK

Struktur plat yang fleksibel mempunyai aplikasi yang luas, daripada perindustrian hinggalah ke angkasa lepas. Evolusi dalam bidang perindustrian telah merancakkan permintaan terhadap plat yang berstruktur nipis dan fleksibel. Walau bagaimanapun, plat yang fleksibel akan menyebabkan berlakunya getaran yang tinggi. Terdapat pelbagai penyelidikan yang telah dijalankan bagi melakukan kajian terhadap permasalahan ini. Tujuan projek ini dilaksanakan adalah untuk membangunkan model getaran bagi plat fleksibel 2-matra menggunakan *adaptive neuro-fuzzy inference system* (ANFIS). Bagi tujuan tersebut, data daripada analisis berangka telah digunakan. Kaedah pembezaan terhingga (*finite difference method*) telah diaplikasikan untuk peleraian persamaan pergerakan plat kepada persamaan-persamaan pembezaan separa. Berdasarkan persamaan pembezaan separa, algoritma simulasi dibangunkan dan simulasi dijalankan menggunakan aplikasi MATLAB. Parameter frekuensi hasil simulasi bagi lima nilai awal kemudiannya dibandingkan dengan nilai daripada penyelidik-penyelidik lain bagi tujuan pengesahan algoritma. Data simulasi ini kemudiannya digunakan untuk membangunkan model-model ARX (*Auto Regressive with Exogenous Inputs*) dan ANFIS. Kemudian, kawalan getaran aktif satu-masukan satu-keluaran (*single-input single-output active vibration control*) dibangunkan berdasarkan algoritma *recursive least squares* (RLS) dan ANFIS. Prestasi sistem-sistem ini kemudiannya dinilai dan didapati model ANFIS adalah baik dan sesuai digunakan untuk pemodelan dan kawalan getaran aktif.

# TABLE OF CONTENTS

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction to Flexible Structure

Plate structures are widely used around the world, predominantly in engineering fields. The structures have been extensively applied to civil, aerospace and mechanical, automotive and marine engineering. The importance of flexible plate structure has emerged in recent years due to its broad application in industries and also areas where precise operation performances is vital such as automation, aerospace systems, satellites flexible manipulators, solar panel and electronic circuit board design (Benassi and Elliott, 2003; Mat Darus and Tokhi, 2003a).

The increasing usage of flexible plate in various applications leads to the demand of having reliable, light and efficient flexible structure. Requirement for lighter structures is critical in certain engineering field such as aerospace. Satellite for example, needs lighter structure so that it can carry higher payload, and thus reduce costs. The plate materials are now thinner, lighter and larger than before. Therefore industries need automatic handling using robotic manipulator with demanded precision and high efficiency (Arai *et al.*, 1995).

However, thin, light and large structure leads to high vibration. The vibration of the structure is lightly damped due to the low internal damping of material used (Hu *et al.*, 2004). This factor attracts many scientists and researches to study the effects of vibration on flexible structure and thus provide methods to control the

vibration. The study on plate vibration has even started as early as 1787 and has been documented since then (Zhou and Zheng, 2004).

## 1.2 Objective and Scopes

The purpose of this study is to develop a neuro-fuzzy model of a 2-dimensional flexible square plate structure. The model will adapt adaptive neuro-fuzzy inference system (ANFIS) concept. The first part of this project involves developing a model characterizing the vibration of the plate using finite difference (FD) method. The sets of data obtained from this FD model are used to develop and train the ANFIS model. For the purpose of comparisons, conventional modelling technique utilizing Auto Regressive with Exogenous Inputs (ARX) are also developed. Finally, active vibration controller (AVC) is developed utilizing the ANFIS model and conventional method using recursive least squares (RLS) algorithm.

The scopes of this project are:

1. Development of mathematical model characterizing the flexible plate structure based on finite difference (FD) algorithm.
2. Development of neuro-fuzzy model using ANFIS structure based on sets of data obtained from FD simulation of the flexible plate structure.
3. Development of active vibration controller for vibration suppression of the flexible plate structure.

## 1.3 Organization of Thesis

This project report is divided into seven chapters. The next chapter, Chapter 2 gathers information from wide range of sources regarding the flexible plate structure and some applications of AVC on this type of structure. Chapter 3 presents a systematic and detail description of the finite difference method and algorithm development. The subsequent chapters, Chapter 3 and 4 provide methods and steps involved in the development of system identification and AVC algorithm, respectively. Chapter 6 presents comparative assessment conducted between conventional AVC with intelligent method. Finally, the conclusions of this study are presented in Chapter 7.

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