ITERATIVE LEARNING CONTROL OF A FLEXIBLE MANIPULATOR

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This project report is especially dedicated to my dearest father, mother and family for their love, blessing and encouragement ...

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ABSTRACT

Control systems have played an important role in the development of modern life and technology. In many industrial robot applications, they are programmed to do the same task repeatedly. One of the intelligent control methodologies is iterative learning control (ILC). In this thesis, ILC method for a single-link flexible manipulator is proposed to achieve precise tracking control and end-point vibration suppression of the system. The learning is done in a feedback signal and the learning law updates the feed forward input from the error of the previous trial. Three learning algorithms are used: P-type, PI-type and PD-type. The dynamic model of the flexible manipulator is derived using the finite element method. Simulation results of the response of the manipulator with the controllers are presented in the time and frequency domains. The performance of the ILC scheme is assessed in terms of input tracking and level of vibration reduction. It is demonstrated that PD-type ILC provides the highest performance for control of a flexible manipulator.

ABSTRAK

Sistem kawalan telah memainkan peranan yang penting dalam perkembangan teknologi dan kehidupan moden. Terdapat banyak aplikasi robot perindustrian, robot diprogramkan untuk melakukan tugas yang sama berulang kali. Antara methodologi kawalan pintar ialah kawalan pembelajaran secara iteratif (ILC). Bagi thesis ini, method ILC untuk satu pautan manipulator telah dicadangkan bagi mencapai pengesanan kawalan dan titik akhir penyekatan getaran sistem. Pembelajaran dilakukan dengan satu isyarat maklum balas dan kemas kini undang – undang input pembelajaran daripada kesalahan percubaan yang terdahulu. Terdapat tiga kaedah pembelajaran yang digunakan; kaedah-P, kaedah-PI dan kaedah-PD. Model dinamik bagi manipulator fleksibel diperolehi dengan menggunakan kaedah elemen terhad. Keputusan simulasi bagi tindak balas manipulator dengan alat kawalan disertakan dalam domain masa dan frekuensi. Prestasi method ILC dinilai daripada segi input pengesanan dan tahap pengurangan getaran. Ia menunjukkan bahawa ILC kaedah-PD memberikan keputusan yang terbaik bagi mengawal manipulator fleksibel.

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CHAPTER 1

INTRODUCTION

1.1 Overview.

Control systems have played an important role in the development of modern life and technology. Nowadays, control systems are found in many applications such as in manufacturing systems, robotics, automation, network systems, machine tool control, transportation systems, space engineering, military systems, computer science, military systems, social systems, economic systems, biological/medical engineering and many others. Control engineering includes modeling, analysis and controller design. One of the important control schemes in control engineering is the feedback of system, it is used to improve the performance of system dynamic. Several control algorithms have been presented where included robust control, optimal control, classical control, fuzzy logic, neural networks, adaptive control, nonlinear control, and intelligent control and iterative learning control (ILC). Each of these theories has specific methodology and their application depend on properties of the systems to be controlled.

One of the most recent control theories is iterative Learning Control (ILC). ILC can be considered as an intelligent control technique, where ILC improves the performance of systems that operate the same task repetitively in fixed time interval. In particular, if the system is nonlinear, that means it is not easy to get perfect tracking by using traditional control theory. However, ILC can be designed overcome the shortcomings of traditional controllers. An only input/output signal of a system is needed to control by ILC, it is possible to achieve high performance or perfect tracking with little or no information about the system structure and its nonlinearities,

The important task in the design of a learning controller is to find an algorithm for generating the successful next input in such a way that the performance error is reduced on successive trials. The research in ILC area focuses on algorithms that are utilized to update the new input signal. Note that when describing the technique of iterative learning control, the word “iterative “ is used because of the repeating nature of the system operation and using “learning” because of the refinement of the input signal base on the past performance in executing a task or trajectory.

Flexible manipulator is one of the most challenging problems in control system design. The behavior of the flexible manipulator system is to nonminimum phase and it is difficult to get high level performance and robustness in the same time. Many industrial applications of flexible manipulator include iterative or repeated similar tasks. So, it is one of the important things to minimize errors in manipulators, and this can be executed by learning strategies. In iterative learning control (ILC), the controller should learn from previous cycles and perform better every cycle. In this thesis, flexible robot manipulator is chosen because it has many advantages over its rigid counterparts: they require less material, are lighter in weight, have higher manipulation speed, require lower power consumption, require smaller actuators, are more manoeuvrable and transportable, are safer to operate due to reduced inertia, have less overall cost and have higher payload to robot weight ratio. However, the control of flexible manipulators to maintain accurate positioning is a challenging task.

This thesis presents development of flexible manipulator control proportional-derivative (PD) controller finite element method, using hub angle and hub velocity feedback to suppression tracking and end-point vibration of system. The controller developed using adding iterative learning control with three types of learning algorithm theorems (P-type; PI-type and PD-type). These were invented by Arimoto in 1984, 1985 and 1990. This theorem used error feed back to improve output signal using learning parameter. The system performance depends on values of learning parameter to minimize the tracking error. A simulation environment utilizes Simulink and MATLAB to show effectiveness of ILC and evaluate the system performance.

1.2 Definition of Iterative learning control

There are many various definitions of ILC some of them are quoted here:

- “The learning control concept stands for the repeatability of operating a given objective system and the possibility of improving the control input on the basis of previous actual operation data.” Arimoto, Kawamura, and Miyazaki [1].

- ILC is a “... recursive online control method that relies on less calculation and requires less a priori knowledge about the system dynamics. The idea is to apply a simple algorithm repetitively to an unknown plant, until perfect tracking is achieved.” Bien and Huh [2]

- “ILC is an approach to improving the transient response performance of a system that operates repetitively over a fixed time interval.” Moore [3].

- “ILC considers systems that repetitively perform the same task with a view to sequentially improving accuracy.” Amann, Owens, and Rogers [4].

- “ILC is to utilize the system repetitions as experience to improve the system control performance even under incomplete knowledge of the system to be controlled.” Chen and Wen [5].

- ILC is a “... controller that learns to produce zero tracking error during repetitions of a command, or learns to eliminate the effects of a repeating disturbance on a control system output.” Phan, Longman, and Moore[6].

- “The main idea behind ILC is to iteratively find an input sequence such that the output of the system is as close as possible to a desired output. Although ILC is directly associated with control, it is important to note that the end result is that the system has been inverted.” Markusson [7].

All definitions about ILC will have their own emphases. However, a common feature of the definitions above is the idea of “repetition.” Learning through a predetermined hardware repetition is the key idea of ILC.

1.3 Objectives

1. To study and explore the application of ILC in controlling dynamic systems.

2. To develop ILC for controlling a single link flexible manipulator with PD-controller to suppress end-point vibration.

3. To study the types of ILC learning control (P-type; PI-type and PD-type) schemes and performance.

1.4 Problem statement

Control of a flexible manipulator is difficult as it involves hand body motion and structural defection. Additionally, how to design effective ILC to control single link of flexible manipulator to suppression tracking and end-point vibration without detraction of system response, setting time, hub angle velocity and hub angle response. Choosing the perfect learning algorithm and how to tune the parameters of learning algorithm to get high accurate and robustness system.

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