MECHATRONICS BOOK SERIES
SELECTED PAPERS FROM ICOM'01, ICOM'05 AND ICOM'08

Editors
Asan G. A. Muthalif
Amir A. Shafie
Momoh J.E. Salami

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State Feedback Control Tuning for Flexible Joint Manipulator Using PSO with Constraint

Mahmud Iwan S., Andika A. Wijaya and Wahyudi[+]

Department of Mechatronics Engineering, Faculty of Engineering
International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Malaysia
[+]wahyudi@iiu.edu.my

ABSTRACT

In this work, particle swarm optimization (PSO) is adopted to tune feedback control gains for flexible joint manipulator. Rotary flexible joint is considered as an ideal experiment intended to model a flexible joint in a robot. The problem of feedback control design is conventionally handled by pole placement method or linear quadratic regulator (LQR) method via Riccati equation. Unfortunately, they still possess trial and error approach of choosing some parameters. Particularly, choosing elements of Q and R matrices in the feedback control design using LQR method has to be done by trial. Therefore, an intelligent method to resolve this problem is proposed by adopting PSO algorithm. The experimental work is carried out to validate the effectiveness of the proposed method.
Keywords—particle swarm, optimization, feedback control, flexible joint manipulator

1. INTRODUCTION

It has been recognized that control of robot arm based on rigid body dynamic formulation is not enough to deal with stringent condition. As a result, the joint flexibility should be taken into consideration in order to achieved better performance. In some cases, joint flexibility may lead to instability of the system if it is neglected in the control design.

Rotary flexible joint is considered as an ideal experiment intended to model a flexible joint in a robot manipulator. This experiment is also useful in the study of vibration analysis. The control issue of the flexible joint is to design the controller so that arm of robot can reach a desired position or track a prescribed trajectory precisely with minimum vibration to the arm. To do so, various methods using different technique have been proposed.

Yim [1], Oh and Lee [2] proposed adaptive output-feedback controller based on a backstepping design. This technique is proposed to deal with parametric uncertainty in flexible joint. The relevant work also been done by Ghorbel et al. [3]. Lin and Yuan [4] and Spong et al. [5] introduced non linear control approach using namely feedback linearization technique and the integral manifold technique respectively.

A robust control design was reported by Tomei [6] by using simple PD control and Yeon and Park [7] by applying robust H_∞ control. Among the proposed techniques, the conventional feedback control design handled by pole placement method and LQR method also have been widely used due to its simplicity implementation. Particularly in LQR method, the problem is how to pre-specify Q and R matrices to determine optimal feedback control gain via Riccati equation [8]. There is no general rule to determine the element of Q and R matrices.

In this paper, an intelligent tuning of feedback control gain for flexible joint manipulator is presented. The objective is to transform the trial and error approach in determining some free parameters during controller design into the determination of parameters which can be directly related to desired system performance. This objective is achieved by employing min-max optimization method i.e: particle swarm optimization (PSO) algorithm. Pole region constraint is invoked during the feedback gain optimization to guarantee the close loop control performance. PSO itself is one of the latest evolutionary computation algorithms. Nowadays this method has attracted many researchers and its application is also progressing [9-13]. Experimental study is done to evaluate the effectiveness of proposed controller. The performance then is compared to the LQR method. The performance comparison is taken by observing the ability of the controller in order to damp out the arm's vibration with minimum oscillations. At the same time, it should be able to track the specified command/reference.