Ain Shams University

Faculty of Engineering

Computers and Systems Engineering Department

Optimal Control in Nonlinear Robot Systems

A Thesis submitted in fulfillment

of the requirements of the degree of Ph.D. in Electrical Engineering

(Computers&Systems)

by

Eng. Hassan Elsayed Mohammed Aly Hashad

M.Sc., Higher Technological Institute,

10-th of Ramadan City, Egypt

Supervised by:

Prof. Dr. Abdel-Monem Wahdan.

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Ass. Prof. Dr. Tayel E. Dabbous.

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بسم الله الرحمن الرحيم

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Date : 8 / 2 /1996

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Statement

This dissertation is submitted to Ain Shams University for the degree of Doctor of Philosophy in Electrical Engineering (Computer and Systems Engineering).

The work included in this thesis was carried out by the author at the Computer and Systems Engineering Department, Ain Shams University.

No part of this thesis has been submitted for a degree or qualification at other university or institution.

Date: 8 / 2 / 1996.

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ABSTRACT

Hassan Elsayed Mohammed Aly Hashad. Optimal Control in Nonlinear Robot Systems. Unpublished Doctor of Philosophy dissertation, Computers & Systems Engineering Department, Faculty of Engineering, Ain Shams University, 1996.

The idea : Any significant performance gain in the control of nonlinear dynamical systems requires the consideration of more efficient dynamic model and sophisticated control techniques due to the behavior of these systems. Thus, the main idea of controlling nonlinear dynamical systems using linear control structure is considered in different form. The robot manipulator has a complicated nonlinear equations of motion as well as the redundancy problem of achieving the desired final position of end-effector. So it becomes a good example for application.

The research :In this Thesis our research is divided into four main parts. In the first part, we consider the problem of controlling the nonlinear robot arm dynamics using linear control structure with unknown gain matrices. Using variational arguments we develop the necessary conditions of optimality on the basis of which the unknown matrices can be determined. We also have used the linearized robot arm model and apply the same controller. However, our results indicated that linear control structure applied to a nonlinear model is more stable than the case of linearized model.

In the second part, we consider the problem of adaptive control of nonlinear robot arm model. In this case, we assume that some or all the parameters of the robot are unknowns. A linear control structure with unknown gain matrices was also proposed and the problem has been converted into an equivalent identification problem. Necessary conditions for optimal identification have been developed for computing the unknowns.

The simulation results (upon UNIMATION PUMA 560 ROBOT) indicated that the proposed controller is well adapted to the change in robot arm parameters and it can also drive the arm to the desired position. The same control structure has been applied to the linearized model but again the results of the nonlinear case was much better.

In the third part, we have included in our dynamics the effect of random loading, random inputs and vibrations due to the movement of the arm. This is done by adding Gaussian noise to the linearized state and output equations of the arm. We have considered the filtering problem which include estimating the arm states given the observed process (output process). For this, we have used the well known Kalman filter. Further, Kalman filter equations has been modified to suit the case where the robot arm parameters are unknowns (adaptive filtering).

In the fourth part, we have considered the stochastic control problem for the linearized model of robot manipulator. In this case we have proposed a linear control structure (which depends on the estimating state as well as the driving input signal) with unknown gain matrices. Using similar procedure as that of part one and two, we have been able to determine the unknown gains. Simulation results indicated that with the help of the proposed control the robot manipulator can follow closely the desired trajectory and achieving the obstacles avoidance.

Note that the proposed control structure is simple, easy to implement than the nonlinear controller, and hence it can be useful in application.

Key Word: Robot Manipulator, Configuration Variables, Linear Controller, Optimal Control, Adaptive Control, Kalman Filter, Adaptive Filtering, Stochastic Control.

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