



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:

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Ain Shams University

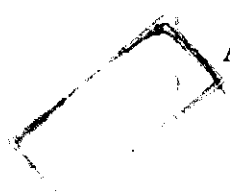
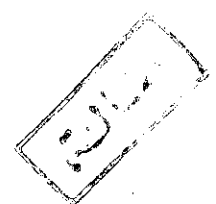
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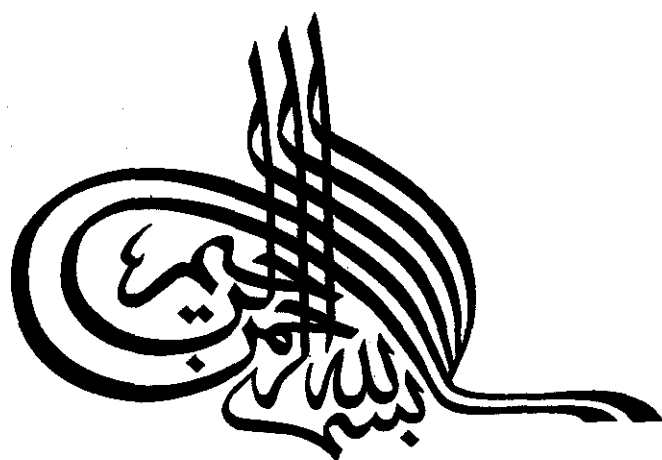
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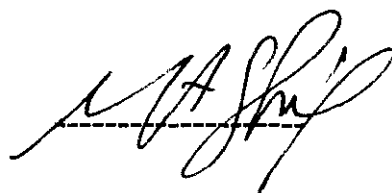
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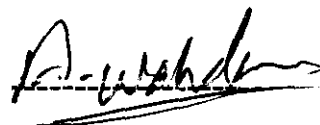
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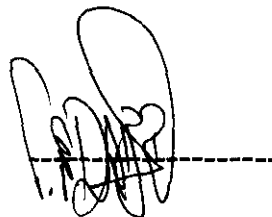
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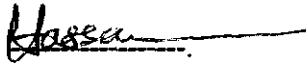
Statement

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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3-My chairman: Prof. Dr. Salah Elhawi.

**4-Technical staff of Electrical Engineering and Computers Department
of Higher Technological Institute, 10-th of Ramadan.**

**5-Staff of Plant Services Department of Arab British dynamics in Arab
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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.

CONTENTS

ABSTRACT	VI
LIST OF FIGURES AND TABLES	X
SYMBOLS AND ABBREVIATIONS	XIII
CHAPTER-1: INTRODUCTION	1
1.1 Robot Manipulator as a Nonlinear Dynamic System.	1
1.2 Stabilization and Tracking Control Problems.	2
1.3 Configuration and Redundancy Control Problems.	4
1.4 Parametric Uncertainties in Control Problems.	5
1.5 Thesis Contribution.	7
1.6 Outlines of the Thesis.	8
 CHAPTER-2: THE MATHEMATICAL MODEL OF THE ROBOT MANIPULATOR	 10
2.1 Introduction.	10
2.2 Robot Manipulator Parameters.	10
2.3 Robot Arm Kinematics.	12
2.4 Robot Arm Dynamics.	20
2.5 Comments.	30
 CHAPTER-3: AN OPTIMAL CONFIGURATION AND POSITION CONTROL FOR ROBOT MANIPULATOR USING LINEAR CONTROL STRUCTURE	 31
3.1 Introduction.	31
3.2 Configuration Variables.	33
3.3 Control Problem Formulation.	35
3.4 Linearized Model for Robot Manipulator.	48
3.5 Concluding Remarks.	64

CHAPTER-4: ADAPTIVE CONTROL FOR ROBOT MANIPULATOR	65
4.1 Introduction.	65
4.2 Adaptive Control Problem Formulation.	66
4.3 Adaptive Control for Linearized Model.	78
4.4 Concluding Remarks.	91
 CHAPTER-5: ADAPTIVE FILTERING AND CONTROL FOR ROBOT MANIPULATOR	 92
5.1 Introduction.	92
5.2 Optimal Filtering.	93
5.3 Adaptive Filtering for Robot Manipulator.	97
5.4 Stochastic Linear Control for Robot Manipulator.	110
5.5 Concluding Remarks.	113
 CHAPTER-6: CONCLUSION	 114
 APPENDIX A	 116
APPENDIX B	122
APPENDIX C	127
REFERENCES	142

LIST OF FIGURES AND TABLES

Figure(2.2-1)	:Link coordinate system and its parameters.	11
Figure(2.3-1)	:Forward kinematics representation.	12
Figure(2.3-2)	:Inverse kinematics representation.	13
Figure(2.3-3)	:Different configuration with the same position.	13
Figure(2.3-4)	:Two-link planer manipulator coordinates.	16
Figure(2.4-1)	:Block diagram of forward dynamics.	20
Figure(2.4-2)	:Block diagram of reverse dynamics.	21
Figure(2.4-3)	:Vector definition in the G-D equation.	25
Figure(2.4-4)	:A two-link planer manipulator example.	28
Table(2.3-1)	:Link parameters for 2-link planer manipulator.	16
<hr/>		
Figure(3.2-1)	:Self-motion of planner 2-DOF arm.	33
Figure(3.3-1)	:Planner two-link mechanism.	36
Figure(3.3-2)	:Schematic diagram for the control system.	40
Figure(3.3-3)	:Flow chart of optimal control .	47
Figure(3.4-1)	:Vertical position of the end-effector.	59
Figure(3.4-2)	:Shoulder angle $\theta_1(t)$.	59
Figure(3.4-3)	:The Performance measure J.	60
Figure(3.4-4)	:Control of joint u_1 and u_2 .	60
Figure(3.4-5)	:Vertical position using k of nonlinear.	61
Figure(3.4-6)	:Vertical position of the end-effector.	61
Figure(3.4-7)	:Shoulder angle $\theta_1(t)$.	62
Figure(3.4-8)	:The Performance measure J.	62
Figure(3.4-9)	:Control of joint u_1 and u_2 .	63
Figure(3.4-10)	:Vertical position using k of nonlinear.	63
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Figure(4.2-1)	:A MRAC system for nonlinear model in two separate conditions.	75

Figure(4.2-2) :Flow chart of two separate adaptive control.	77
Figure(4.3-1) :Vertical position in adaptive control.	86
Figure(4.3-2) :Shoulder angle $\theta_1(t)$ in adaptive control.	86
Figure(4.3-3) :Vertical position in adaptive control.	87
Figure(4.3-4) :Shoulder angle $\theta_1(t)$ in adaptive control.	87
Figure(4.3-5) :Vertical position in adaptive control.	88
Figure(4.3-6) :Shoulder angle $\theta_1(t)$ in adaptive control.	88
Figure(4.3-7) :Comparison for nonlinear and linearized response of $y(t)$.	89
Figure(4.3-8) :Comparison for nonlinear and linearized response of $\theta_1(t)$.	89
Figure(4.3-9) :Comparison between optimal and adaptive control in $y(t)$.	90
Figure(4.3-10) :Comparison between optimal and adaptive control in $\theta_1(t)$.	90
Figure(4.3-11) :Trajectory of $\theta_2(t)$ with change of parameters for nonlinear model.	91
Figure(4.3-12) :Trajectory of $\theta_2(t)$ with k of first period for nonlinear model.	91
Figure(4.3-13) :Trajectory of $\theta_2(t)$ with change of parameters for linearized model.	92
Figure(4.3-14) :Trajectory of $\theta_2(t)$ with k of first period for linearized model.	92
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Figure(5.3-1) :Flow chart of adaptive filtering.	103
Figure(5.3-2) :Actual and estimated vertical position.	109
Figure(5.3-3) :Covariance P .	109
Figure(5.3-4) :Value of S .	110
Figure(5.3-5) :Value of Γ .	110

Figure(5.3-6) :Value of L.	111
Figure(5.3-7) :Element A(2,1).	111
Figure(5.4-1) :Comparison between optimal and stochastic control for $y(t)$.	114

