Applications of fast nonlinear control with arbitrary pole placement and resolved acceleration control to a two-link manipulator
by Hatice Sahin

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering
Montana State University

Abstract:
A two link manipulator is simulated on the VAX11/750. Applications of Fast Nonlinear Control with arbitrary pole Placement for Industrial Robots and Manipulators and Resolved-Acceleration Control of Mechanical Manipulators to the two link manipulator are described. Fast nonlinear control masks the nonlinearities of the manipulator, causing the input-output relations regarding joint angles to appear like two decoupled, linear, second-order systems. Results of sensitivity analyses applied to nonlinear control show that the system is very sensitive to parameter variations of the manipulator. Resolved-acceleration control requires large amounts of computation, but the manipulator follows the desired trajectory very closely.

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WITH ARBITRARY POLE PLACEMENT AND RESOLVED ACCELERATION CONTROL
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Hatice Sahin

A thesis submitted in partial fulfillment
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of

Master of Science

in

Electrical Engineering

MONTANA STATE UNIVERSITY
Bozeman, Montana

August, 1986

APPROVAL

of a thesis submitted by

Hatice Sahin

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGEMENTS

The author would like to thank Dr. D.A. Rudberg for his guidance and encouragement with this research. She also wishes to thank Dr. D.A. Pierre for his help and valuable suggestions.

Finally the author wishes to thank her husband, Turgut, for his encouragement and her son, Koray, for his patience.

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ABSTRACT

A two link manipulator is simulated on the VAX11/750. Applications of Fast Nonlinear Control with arbitrary pole Placement for Industrial Robots and Manipulators and Resolved-Acceleration Control of Mechanical Manipulators to the two link manipulator are described. Fast nonlinear control masks the nonlinearities of the manipulator, causing the input-output relations regarding joint angles to appear like two decoupled, linear, second-order systems. Results of sensitivity analyses applied to nonlinear control show that the system is very sensitive to parameter variations of the manipulator. Resolved-acceleration control requires large amounts of computation, but the manipulator follows the desired trajectory very closely.

CHAPTER 1

INTRODUCTION

Robots are computer controlled machines. They are built and programmed to do specific tasks. Robots are mostly used for handling dangerous materials, pick and place tasks, spot welding, arc welding, painting, assembly and inspection tasks.

The planning of motions to solve some previously specified tasks and controlling the robot to execute the commands necessary to achieve those motions are basic problems in robotics. Control of a robot manipulator is the main concern of this thesis.

There are many different methods of controlling a robot manipulator. Linear state-feedback control of manipulators is studied by Golla, Garg and Hughes [1], and several methods for assigning closed-loop poles using centralized control are presented. Arimoto and Takegaki [2] show the effectiveness of a linear feedback of generalized coordinates and their derivatives, and propose a method for task oriented coordinate control. The effects of linear independent joint torque control are analyzed by Luh, Fisher and Paul [3]. A model-referenced adaptive control law is developed by Dubowsky and DesForges [4]. The task of the adaptive controller is to adjust the feedback gains of the manipulator so that its closed loop performance characteristics closely match the set of desired performance characteristics embedded in the behavior of the reference model. The time optimal control of an open-loop system is studied by Kahn and Roth [5], and a suboptimal feedback control, which provides a close approximation to the optimal control, is developed. A hybrid position/force control of manipulators is developed by Raibert and Craig [6]. The "hybrid" technique described combines force and torque information with positional data to satisfy simultaneous position and force trajectory constraints specified in a convenient task-related coordinate system. Sliding mode theory to develop a nonlinear-switching control law with guaranteed tracking and stability is studied by Young [7]. General nonlinear decoupling and control theory has been studied by Freund [8, 9] and a sufficient condition for the observability of a decoupled, nonlinear, time-varying system is derived. A nonlinear control algorithm with arbitrary pole placement has been developed by Freund [10] which provides a decoupled overall-system behavior. Resolved motion-rate control has been studied by Whitney [11, 12]. In this control method, joint velocities are obtained from hand velocities and positions. Luh and Walker [13] extended this idea to include resolved acceleration. The inverse problem technique was investigated by Paul [14], and Raibert and Horn [15]. In the inverse problem technique the joint torques necessary to drive the manipulator are computed as a function of desired and actual joint accelerations, velocities and positions, together with calculated values of inertia, viscous friction, coriolis and centrifugal terms, and gravity terms. Luh, Walker and Paul's resolved acceleration control [16] extends the ideas of resolved motion rate control and the inverse problem.

The subjects of this thesis are the applications of Fast Nonlinear Control with Arbitrary Pole Placement for Industrial Robots and Manipulators [10], and Resolved-Acceleration Control of Mechanical Manipulators [16] to a two link manipulator.

First the dynamic equations of motion of a two-link manipulator are derived. Then, in the next two parts of the thesis, the control methods are described, applications of these control methods to the two-link manipulator are shown and sensitivity analyses are made. For the resolved-acceleration control method, trajectory planning is also included.