Scientific Fundamentals of Robotics 1: Dynamics of Manipulation Robots, Theory and Application

Scientific Fundamentals of Robotics 2: Control of Manipulation, Robots, Theory and Application

Reviewed by Bernard Roth*

These are the first two monographs in a newly created series dealing with the scientific fundamentals of robotics. The two volumes set a high standard, and it is hoped that subsequent books in this series will maintain this level of quality.

Volume 1 treats the dynamics of manipulators; it consists of five chapters. Chapter 1 contains an introduction to the dynamics of open-loop linkages, an enumeration of kinematic joints, and a summary of previous results.

Chapter 2 is the heart of this volume. It contains a survey of the following topics showing how they are applied to the dynamics of manipulators: Newton-Euler equations, Lagrange's equations, Gauss' principle, Appel's equations, d'Alembert's principle (as elaborated in a technique the authors call "method of general theorems") and a matrix formulation named "method of block matrices."

Chapter 3 deals with computer simulation of rigid-body manipulator dynamics. Two basic problems are treated:

(a) Given different kinematic configurations, determine the types which have better dynamic performance.
(b) Given the joint torques and forces, determine the resulting motion.

Several simple manipulator geometries are considered and the results for the simulation of sample tasks are presented. In addition, the stress in a tubular-shaped link is derived, and the modeling of electric motors and hydraulic actuators is discussed. This chapter closes with a discussion of several trajectory optimization procedures.

Chapter 4 deals with the dynamics of manipulators with elastic members. An algorithm is described whereby the elastic deviation, from the nominal rigid-body position, is computed.

The final chapter deals with evaluating different designs according to dynamic criteria. Optimal energy and optimal velocity criteria are discussed as are the questions of performing constrained minimizations. Two different types of problems are considered:

(a) Given different kinematic configurations, determine which types have better dynamic performance.
(b) Given a type of configuration, determine the optimum dimensions for the inner and outer radii of a link made of a hollow cylindrical tube.

The authors argue in this chapter that simple one- or two-parameter optimizations are sufficient for most practical manipulator structural optimizations.

This monograph is certainly the most complete summary of manipulator dynamics that is presently available in the English language. It is a good summary which presents several new ideas and in addition gives a clear account of some work previously only published in Russian. This is for me by far the most readable account of Professor Vukobratovic's work. For the first time it makes the main thrust of his work clearly accessible to the non-Slavic reader.

There are some language errors; however, the reader will easily be able to substitute "transformation" for "transition," "rod" for "cane," "lower" for "down," and so on. In spite of these, the translation is on the whole good and the book is very readable and nicely produced.

If there is a flaw in this book, it is in the extreme emphasis on the work of the authors and their associates, and the neglect or lack of proper emphasis on some of the work done by others. The second volume has this same characteristic, and to an even larger degree.

Volume 2 treats the control of manipulators. The translation is almost flawless, and except for the use of the word "regulator" instead of "controller" there are none of the mistranslations that appear in Volume 1.

This monograph starts with a long prologue which includes a survey of previous works. There are then three chapters and four appendices.

Chapter 1 is a review of manipulator dynamics, thereby making this book independent of Volume 1. Chapter 2 deals with manipulator control and is the heart of this monograph. It treats the various different types of control from the point of view of computer algorithms for simulating motions to follow certain optimal or suboptimal dynamic states. The basic idea is the use of high-level or global information to determine the nominal dynamic paths and then the use of distributed or local control to actual control joint motions.

Chapter 3 applies the ideas of Chapter 2 to various classes of manipulation problems. These include: control of the trajectory of a manipulator's tip, and moving an object with a desired orientation along a given path. There are also short discussions of force feedback and the peg-in-hole problem.

The appendices treat stability analysis and other mathematical questions. They also present block diagrams of computer algorithms.

Both volumes can be easily read by anyone with some background in mechanics and control theory. They are mainly descriptive and there are relatively large amounts of nonanalytical material. The discussions are bound to be stimulating to students of the areas of design, dynamics, and control. These books are required reading for researchers and designers interested in manipulator mechanics or control. They are certainly a very welcome addition to the growing number of books dealing with mechanical manipulators.

*Professor, Dept. of Mechanical Engineering, Stanford University