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Book Reviews

Scientific Fundamentals of Robotics 3: Kinematics and Trajectory Synthesis of Manipulation Robots by M. Vukobratovic and M. Kircanski
Scientific Fundamentals of Robotics 4: Real-Time Dynamics of Manipulation Robots by M. Vukobratovic and N. Kircanski
Scientific Fundamentals of Robotics 6: Applied Dynamics and CAD of Manipulation Robots by M. Vukobratovic and V. Potkonjak

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Reviewed by Bernard Roth[1]

These books are the third, fourth, and sixth volumes of the series *Scientific Fundamentals of Robotics* written by Dr. Miomir Vukobratovic and his colleagues. Overall these new volumes uphold the high standard set by the first two volumes of the series. The presentations remain clear and easily understandable, typographical errors remain at a minimum. The essential difference is that whereas the first two volumes were broad reviews of the subject matter (on manipulator dynamics and control, respectively) these new volumes must be regarded as specialized monographs treating essentially material developed by the authors and their co-workers.

Volume 3, copyrighted in 1986, contains 267 pages and 66 figures arranged in six chapters and three appendices. Chapter 1, Kinematic Equations, introduces the basic standard transformations for determining a manipulator's hand position, orientation, and velocity. Most of this material is well known and has already appeared in many books, including the earlier volumes of this series. However, there is also a description called "Rodrigues formula approach" which is not well known and is central to much of what follows in this book and in the other volumes as well. The basic idea is to use coordinate systems which align with the principal axes of inertia of each link. Using such systems would make the equations of motion much simpler than the more common Denavit and Hartenberg system. The proposed new coordinate systems are defined in terms of vectors which transform according to Rodrigues' formula for finite rotations, and hence the name of this formulation.

Chapter 2, Computer-aided Generation of Kinematic Equations in Symbolic Form, introduces the main point of this volume (and also of Volume 4) which is the automatic generation of kinematic and dynamic equations by computer methods. This chapter deals with the symbolic generation of both the direct kinematic equations and Jacobian matrix. The chapter contains several examples and ends with three appendices, which together make it a very clear and detailed treatment.

Chapter 3, Inverse Kinematic Problems, is for my tastes a too cursory treatment of the inverse kinematics problem. Although their treatment is certainly correct and more detailed than in some books, it adds nothing new to the subject and leaves out a lot of very useful results and techniques.

Chapter 4, Kinematic Approach to Motion Generation, and Chapter 5, Dynamic Approach to Motion Generation, both deal with trajectory planning. The dynamic approach is by far the more detailed treatment and certainly contains the more novel material. The final chapter, Motion Generation for Redundant Manipulators, discusses the resolution of kinematic redundancy by use of a generalized inverse of the Jacobian, by minimizing the energy required for the motion, and by moving so as to avoid obstacles.

Overall this is a very good volume. It contains a lot of interesting discussion. The authors do not simply throw results at the reader, they logically discuss the pros and cons of the several different techniques. Even if one does not agree with their conclusions and choice of method, a lot can be learned from studying their arguments.

This volume is certainly required reading for anyone interested in automatically generating symbolic models for manipulator kinematics and will also be of interest to those working on automatic trajectory planning.

Volume 4 consisting of 239 pages and 43 figures was copyrighted in 1985. This book is a must for those interested in real-time dynamics of manipulators. It is the latest salvo in the on-going counting wars; I refer to the by now familiar statement "my dynamics equations have less multiplies and adds than yours do." Of course the authors make several such claims in this book. This volume discusses the problem of automatically generating various forms of the equations of motion. The authors develop a novel system, to automatically and efficiently generate equations of motion, which they feel can be implemented for real-time use on a single microprocessor provided the manipulator has five or less degrees of freedom. At the heart of their method is a novel polynomial matrix and a program optimizer which they refer to as an "expert-program."

The book consists of five chapters whose titles are: Survey of computer-aided robot modelling methods; Computer-aided method for closed-form dynamic robot model construction; Computer-aided generation of numeric-symbolic robot model; Model optimization and real-time program-code generation; Examples.

There are two things I am a little uncomfortable with. I am sorry that (1) the authors deal with only a single microprocessor and never treat the possibility of alternative hardware arrangements, and (2) I regret that in all the discussion about relative computational efficiency the authors never make the point that computation times are very sensitive to specializing equations to particular geometries, and that in

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many cases taking into account the particular geometry makes a much bigger difference in computational efficiency than the choice of equation type. Given the scope of what they do in this volume, these are minor points. There are many interesting ideas discussed about the basic problem of automatically generating the dynamic model, including its linearized versions and sensitivity analysis equations. Whether or not one is interested in their new method – and I do think it will be of interest – there is much basic material on dynamic modeling which can be obtained from reading this volume.

Volume 6 is in my opinion the least successful of the three new volumes. It is good but not quite in the class of the others. It has the most glaring typographical errors, although not enough to cause any real difficulty. Its main problem is its unevenness, some of the material is new and very interesting, yet there is a substantial amount that has already appeared in an earlier volume or in many other places. It contains several pages extolling the virtues of computer-aided design, and that hardly seems necessary. There is a lengthy derivation of Appel's equation which seems out of place in this volume. Much of the presentation seems to be based on various simulation and component CAD packages the authors have developed. The best material is in Chapter 3 which in 89 pages treats the dynamics due to contact between the end of the manipulator system and the environment. There is also some interesting material on the sizing of acutuators.

This Volume contains 305 pages and 187 figures, the copyrighted date is 1985. The first chapter, General About Manipulator Robots and Computer-Aided Design of Machines, contains a description of joint types and basic manipulator geometry. The second chapter, Dynamic Analysis of Manipulator Motion, is mainly devoted to defining four, five and six degree of freedom tasks, and to determining actuator characteristics. The third chapter, Closed Chain Dynamics, is devoted mainly to the effects of environmental gripper motion constraints, including impact. The fourth and final chapter, Computer-Aided Design of Manipulation Robots, gives several examples of component design and selection.

The addition of these three new volumes is most welcome. As this series of books develops, the scope of the achievement of Dr. Vukobratovic and his colleagues becomes more apparent to the English language reader. It is obvious that what they have accomplished is quite extraordinary. The breadth and quality of their work is remarkable. Anyone who reads these volumes is sure to feel both admiration for all they have accomplished, and gratitude that they have undertaken the prodigious task of writing this series.