Introduction to robotics: Mechanics and control

Article *in* IEEE Journal on Robotics and Automation · May 1987

DOI: 10.1109/JRA.1987.1087086 · Source: IEEE Xplore

Frank L. Merat
Case Western Reserve University

Book Reviews

Introduction to Robotics: Mechanics and Control—John J. Craig (Reading, MA: Addison-Wesley, 1985, 400 pp.) *Reviewed by Frank L. Merat, Department of Electrical Engineering and Applied Physics, Case Institute of Technology, Case Western Reserve University, Cleveland, OH 44106 USA.*

I have found Craig's book to be an excellently written robotics textbook. I have actually used it in an introductory graduate course in robotics where I was previously using Richard Paul's *Robot Manipulators.* Overall, I have found the text to be outstanding. The material is developed in a logical manner.

Chapter 2 reviews basic three-dimensional frames and frame orientations (such as RPY or Euler angles) and the transforms between frames. Although this is simple material to the mechanical engineer, this section was simply written and electrical engineering students had no trouble with the material.

Chapters 3 and 4 cover forward and inverse kinematics. Craig uses the Denavit–Hartenberg convention and his examples for assigning frames are well illustrated. The book does not address robot work envelopes and concentrates on mechanics rather than robot specifications. Craig seems to be averse to prismatic joints—almost all of his homework and example problems use rotary joints—which allowed for the instructor's use of prismatic joints in many homework and exam problems. As with most robot textbooks, this one uses several commercial robots as examples—the PUMA 560 and the Yasukawa Motoman L-3 (instead of the usual Stanford robot).

Chapter 5 introduces the Jacobian and static forces and velocities. Craig introduces velocity "propagation" (from one rotating frame to another) which he later uses for dynamics. Again, all examples are for rotary joints with "equivalent formulas" given for prismatic joints.

My favorite chapter of the book is Chapter 6 on robot dynamics. Craig uses the iterative Newton–Euler approach which is intuitively easy for students (particularly electrical engineers) to quickly understand. This is not the case with the Lagrange–Euler approach which many textbooks use. Craig does not, however, acknowledge the existence of other approaches to robot dynamics, and you will not even find the classic closed-form Lagrange–Euler analysis of the two-link planar manipulator.

Chapter 7 develops trajectory generation in joint and Cartesian space. Chapters 8 and 9 discuss robot control. The reader expecting a classical discussion of PID controllers will be disappointed here. There is no discussion of simple control nor of dc motors or any "hard technology." Craig instead uses the idea of a control law which computes forces and which can be used to partition complex control problems into simple servo control problems. This is an excellent approach, particularly for force control, if the student has a good control background. Overall, the control chapters are well written with an excellent discussion of practical limits on control algorithms; however, there are no clear robot control examples in this section, which limits its utility as a textbook.

Chapter 10 on robot programming languages is a simple introduction to programming languages with three six-line program examples. The chapter is very cursory and almost seems to have been added as an afterthought.

Overall, the book is an excellent introduction to robotics. There is very little concentration on technology and, instead, Craig concentrates on robotics. The book is well written, with the examples logically placed. For a new textbook, it is almost error-free—I found only one typographical error in the book. The homework problems covered the text material well, and as an instructor, I appreciated Craig's relative ranking of the difficulty of the problems which allowed me to compose homework assignments rapidly. Unfortunately, there is no homework solution manual to facilitate further the instructor's job. A very nice touch is the inclusion of programming exercises at the end of each chapter. These programs start with implementations of simple transforms and end with complete simulation of a three-link planar manipulator. The programming exercises are well organized and illustrate many of the limitations and advantages of robot simulation; however, there is no way an ordinary class can be expected to perform all 24 programming exercises, and many of the exercises rely upon the solution to previous exercises. Having some form of solution available for the programming exercises would be a definite plus to instructors.

Craig only discusses the Newton–Euler approach to robot dynamics. Having taught both Newton–Euler and Lagrange–Euler approaches, I found that Craig's Newton–Euler was very easy for the students to grasp with well-done examples.

One of my major criticisms of the books is the section on control. As it says on the flyleaf, the book, "...is directly of use to those engineers developing robotic systems...," and this approach shows in his treatment of control systems. There is no review or discussion of simple PID control methods; instead, Craig uses control law partitioning. This is fine for a reference book, but a poor choice for a robotics textbook.

Robot programming languages may as well not have been covered. The chapter gives three six-line-or-less programming examples and briefly mentions several commercial programming languages.

In summary, the book is an excellent textbook or reference for robot kinematics and dynamics. Craig's chapters on kinematics and dynamics are the best written and easiest to follow that I have ever read. The control section is well written but is probably not comprehensive enough for a first course in robotics. Finally, no mention whatsoever is made of robot sensors—especially computer vision—which is now an integral part of many robotics courses.

0882-4967/87/0400-0166$01.00