Book Review

S. G. Tzafestas: Intelligent Robotic Systems Intelligent Robotic Systems

(Electrical Engineering and Electronics Series/74) edited by Spyros G. Tzafestas. Marcel Dekker, Inc. New York (1991). 720 pp. U.S. $165.00. All other countries $189.75.

Third-generation robotic systems are intelligent in the sense that they can perform a large repertory of complex tasks under conditions not known a priori. They are usually sensor-coupled using multisensory (vision, force, tactile, etc.) information about their initial state and environment, have decision-making capabilities, can monitor and modify their plans learning from past experience. They have the properties of flexibility and artificial intelligence. The aim of the book was to provide wide coverage of these concepts based on the latest developments of well-known experts working in academic and research institutions. The book is addressed to scientists, engineers, postgraduate students and professionals working or having interest in intelligent robotics and control. The book is divided in 5 parts containing 18 chapters.

Part I is devoted to introductory issues and it consists of Chapter 1: *Introduction to Intelligent Robotic Systems* written by Tzafestas (National Technical University of Athens, Greece). The general architecture of intelligent robotic control (consisting of organization, coordination and execution levels), the basic problems of robot modeling and motion control, and the classification of sensors including vision are introduced. Three examples of intelligent robotic systems are selected from the field of sensor-based (Espirit 278 and Pardue system) and mobile (KAMRO) robots.

Part II deals with the structure and programming of intelligent robotic systems. Chapter 2: *Theory and Design of Intelligent Robotic Systems* by Valavanis (Northeastern University, Boston, Massachusetts), presents a general theory of intelligent machines and robotic systems based on a heuristic probabilistic model and entropy functions to describe the system performance of structures composed of organization, coordination and execution levels. Chapter 3: *Hierarchy of Intelligent On-Line Execution* by Kelley (Rensselaer Polytechnic Institute, Troy, New York) deals with a robotic assembly system that allows both automatic programming and execution despite uncertainties in the task environment. The principle of least commitment is followed, and the system is partitioned into off-line (planners, specialists) and on-line (supervisor, specialists, interfaces) modules. Some details are given for the design of the supervisor and its implementation with 4 specialists on VAX running under Unix. Chapter 4: *Skill-Based Expert Systems in Robotics* by Tomovic (University of Belgrade, Yugoslavia), deals with the skill level (functional motion of human extremities) of a hierarchical control structure using both numerical and nonnumerical models. It concentrates on multifinger robot hands and describes the hand mechanics, sensors and local controllers of the Belgrade-USC Hand, and the multilevel manipulator control using computer vision and expert system (for preshaping, grasping mode, etc.). Chapter 5: *The Cellular Robotic System (CEBOT), a Self-Organizing System* written by Fukuda (Nagoya University, Japan) and Kawauchi (Science University

of Tokyo, Japan), presents a construction method of dynamically reconfigurable robotic system. CEBOT consists of (mobile, bending joint, rotating joint and end-effector) cells with coupling mechanisms. It is a hierarchically structured system with task planning, structure planning and coordination levels, active mobile cells and basic cells. More details are given for the realization (including structure planning) and the communication system. Chapter 6: *Programming for Intelligent Robot Systems* written by M. Gini (University of Minnesota, Minneapolis) and G. Gini (Politecnico di Milano, Italy) presents a short overview of robot programming methods and languages. It shows methods and problems in describing models of the robot environment (used in AL, RAPT and CAD based systems). It discusses sensor-based aspects, and high-level robot path and task planning issues on an introductory level.

Part III is devoted to modeling and control of robotic systems. Chapter 7: *Simplification of a Robot Dynamic Model Based on Manipulator System Performance* by Lee and Chang (School of Electrical Engineering, Purdue University, West Lafayette, Indiana), presents an efficient minimax simplification algorithm for the automatic generation of the robot dynamic model in symbolic form while maintaining the prescribed system performance tested under PD control. The significant basic functions (product terms in sin and cos functions of order at most 2) can be selected by using a multilayered decision procedure. A minimax fitting technique is utilized to find the numerical values of the weighting factors for the linear combinations of the selected basic functions. Chapter 8: *Dynamic-Based Control of Robotic Manipulators* written by Leahy (Air Force Institute of Technology, WPAFB, Ohio) and Valavanis (Northeastern University, Boston, Massachusetts) presents an analysis of the performance of dynamic model-based robot controller algorithms (7 types from PD until computed torque with full inertia) under constant and variable payload conditions experimentally tested for PUMA 560. Chapter 9: *Force-Feedback Control in Robotics Tasks* by Merlet (INRIA Sophia-Antipolis, Valbonne, France) describes the wedging and jumming phenomena and the passive complince in robotic assembly, the role of force sensing and the trend to use two kinds of robots (right hand for gross motion and left hand for fine motion) in force feedback control using active complince or hybrid control. It presents a parallel manipulator prototype that was successfully applied to solve peg-in-hole insertion and surface following problems. Chapter 10: *Adaptive, Robust and Fuzzy Rule-Based Control of Robotic Manipulators* by Tzafestas (National Technical University of Athens, Greece) provides a survey of modeling, identification and model-based control algorithms including model reference adaptive control (using the method of Nicosia and Tomei based on hyperstability), self-tuning control (using a time invariant linearized model about a nominal trajectory), model-based predictive control, variable structure method, computed torque with MRAC, and fuzzy rule-based control. The experimental results are obtained on experimentation of real robots or by simulation. Two methods were elaborated for identification, but unfortunately the first uses decomposition and and approximation in the wrist model, while the second uses Newton-Euler method and parameter estimation without testing the independence of the parameters. Chapter 11: *Flexible Robots: Modeling an Control* written by Desoyer, Lugner, Troch and Kopacek (University of Technology, Vienna, Austria) deals with modeling and control of structures, in which elastic deformations occur during the work of the robot as a consequence of the static and dynamic forces. It presents the basic ideas of the kinetostatic and dynamic model (finite element modeling, vibration mode modeling, etc.), a number of control concepts (nonlinear decoupling, MRAC, etc.), and it discusses the problem of path-planning and path-tracking on an introductory level.

Part IV is devoted to vision and tactile systems in intelligent robots. Chapter 12: *Intelligent Robotic Vision Systems* written by Van Gool, Wambacq and Oosterlinck (Catholic

University of Leuven, Belgium), presents a general introduction to vision systems including the interaction between vision system and robotic station, and a short description of hardware structure, object modeling and object recognition strategies for range (3D) images. Chapter 13: *Robot Vision: Geometric Classification for Automated Inspection* written by H.A. Eldin and A.T. Eldin (University of Wuppertal, Germany) briefly reviews the partitioning and hierarchical classification techniques for pattern recognition. It describes the principal coordinate analysis of feature vectors, a classification method in pseudo-Euclidean spaces and a generalized principal coordinate analysis based on an eigenvalue-eigenvector technique in the pattern space. Chapter 14: *Robot Tactile Sensing: Skinlike and Intrinsic Approach* written by Bicchi (University of Pisa, Italy) and Buttazzo (Scuola Superiore S. Anna, Pisa, Italy) deals with skinlike and intrinsic (force/torque sensor based) tactile sensing, it presents their technological differences and describes tactile sensors integrating both principles.

Part V contains four applications. Chapter 15: *Intelligent Robotics for Space Operations* by Schenker (Jet Propulsion Laboratory, Pasadena, California) presents an overview of a research project on intelligent robotic systems for space servicing, assembly, repair and telescience operation. It is a modest contribution to overall needs for technology advances in intelligent robotics. It brings the often separated development of robotics technology into a common, cooperative research environment. The work concentrates on sensing and perception, planning and reasoning, control execution, operator interface, system architecture and integration, telerobot testbed evaluation, and application demonstrations. Chapter 16: *Man-Robot Cooperation: Toward an Advanced Teleoperation Mode* written by Coiffet (Institut National des Sciences et Techniques Nucléaires, Saclay, France) and Gravez (Centre d'Etudes Nucleaires de Fontenay-aux-Roses, France), deals with the 4 (classic, reflex, reflective and human operator) control loops in human-aided and computer-aided teleoperation (CAT) systems, and describes the CAT system more detailed. Chapter 17: *Solving Jigsaw Puzzles Using a Robot* written by Burdea (College of Engineering, State University of New Jersey) and Wolfson (Courant Institute of Mathematical Sciences, New York University) presents an integrated vision manipulation algorithm for the assembly of jigsaw puzzles as a model for the assembly of flat parts with complicated and a priori unpredictable shapes. Using vision information and polygonal approximation, the combinatorial optimization problem was reduced to the traveling salesman problem. The method was tested in small-scale robotic assembly without dexterous hand. Chapter 18: *Flexible Robot Work Cell Design and Simulation* by Ranky (University of Michigan, Ann Arbor, Michigan), provides a set of results obtained through the ROBCAD real-time graphics simulation system during the design of flexible manufacturing cells (FMS). The cases of cell tooling, tool transportation and buffering, part transportation and storage are discussed more detailed. Simulation examples of small-scale and more complex FMS cells are shown using wire frame and solid model graphics.

This is an extremely well produced text which brings together most of the recent research in advanced robotics. The book is not intended to cover elementary topics, but each chapter is self-contained and chapters with special interest can be studied without difficulty. The large number of references at the end of each chapter can help the readers to find additional results and methods.

To the reviewer's knowledge, this book is the first in the field of intelligent robotic systems covering the wide spectrum of modeling, sensing, vision, control, learning and reasoning. In conclusion, this book would be extremely valuable to researchers, practising engineers and postgraduate students in robotics, and it is very highly recommended to all those working in this fascinating and very important field.

About the reviewer

Béla Lantos is Associate Professor at the Department of Process Control at the Technical University of Budapest. He received the Dipl.Ing. degree from Technische Hochschule Ilmenau (1965, GDR), the Dipl.Math. degree from the University of Science Budapest (1972), the Ph.D. (Cand.Sc.) degree from the Hungarian Academy of Sciences (1976). He delivers lectures in Robot Control since 1986. He is the author of the book *Robot Control* (Hungarian Academic Press, Budapest, 1991, in Hungarian). His present research interests are in robot control and distance image processing.

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