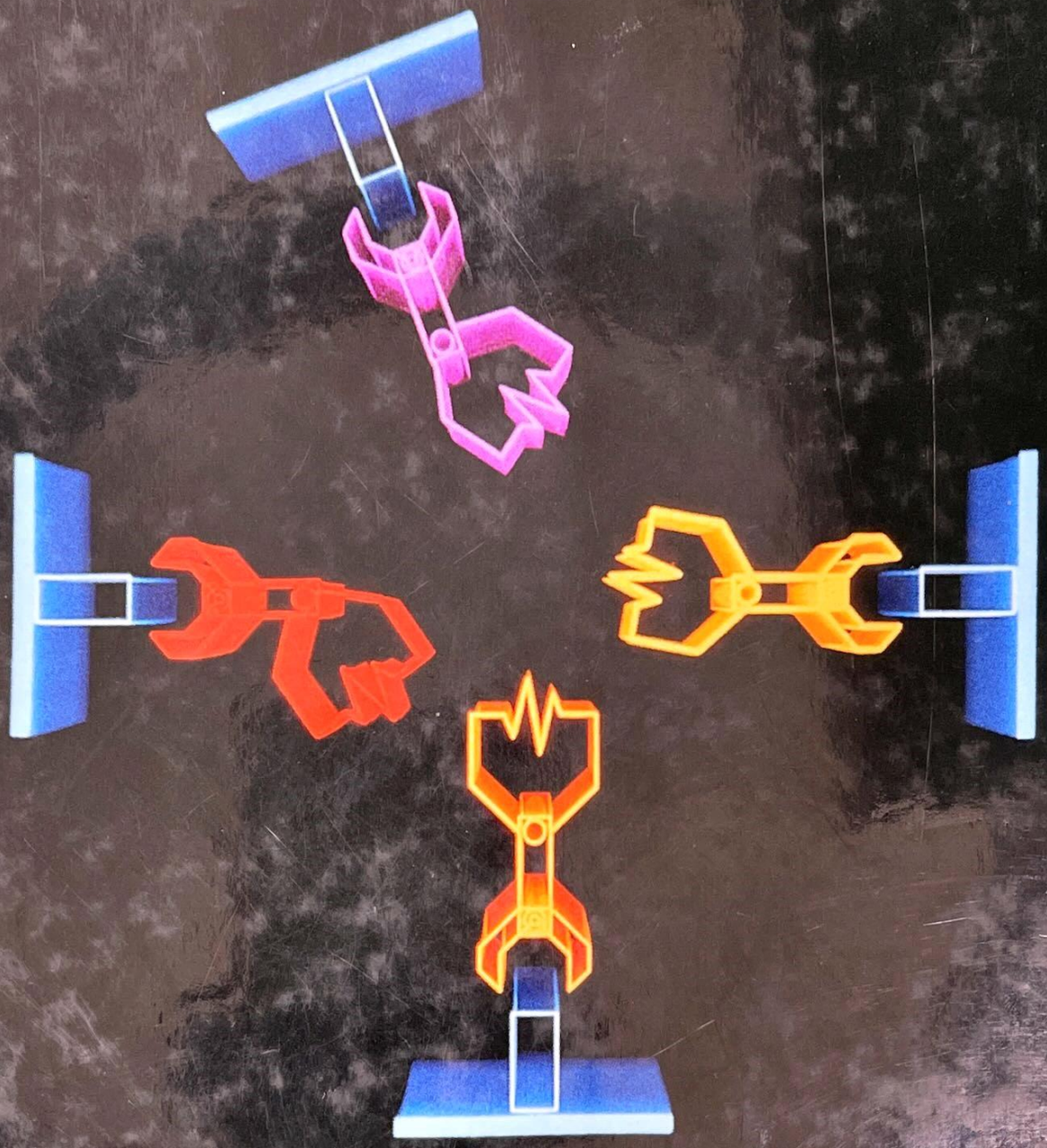
SECOND EDITION

ROBOTS AND MANUFACTURING AUTOMATION

C. RAY ASFAHL



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C. RAY ASFAHL

University of Arkansas, Fayetteville

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PREFACE

This book is about robots, but not *just* about robots. The industrial robot has become the standard bearer for the manufacturing automation movement. But, as sensational as industrial robots are, they are not the most significant development in manufacturing automation today. Behind the scenes, programmable controllers, microprocessors, process control computers, and industrial logic control systems are enjoying even more acceptance and application in manufacturing automation than are industrial robots. All of these devices should be considered members of the family of *flexible* automation equipment that is changing the way in which products are manufactured. This book describes the relationships among all of these devices in a manufacturing automated system.

This book is intended for the student's first course in manufacturing automation. In an industrial engineering curriculum, the ideal level for introduction of robots and manufacturing automation topics is at the junior level. Then the student who wants to specialize can take follow-on courses at the senior level on topics such as CAD/CAM, CIMS, FMS, and digital electronics, or specialized robotics courses, depending upon laboratory facilities. This book is also appropriate for upper division technology and industrial management curricula and has been used successfully in graduate level courses in industrial engineering and operations management.

The focus of this book is on how to *apply,* not how to *design,* robots and manufacturing automated systems. Hence, the book is appropriate for engineers, manufacturing technologists, and industrial managers. Calculus and computer programming backgrounds are not required for comprehension of this book, but some of the end-of-chapter exercises are designed to challenge students who possess such backgrounds. These exercises can be comfortably omitted with no loss of continuity in courses that are aimed at students who do not have technical backgrounds. The accompanying instructor's manual explains the end-of-chapter exercises and provides a basis for selecting classroom assignments suitable for the intended audience.

The revised edition of this text has been updated to recognize rapidly developing technology and its application to manufacturing automation. Two chapters—Chapter 8, "Machine Vision," and Chapter 16, "Computer Integrated Manufacturing"—are new in this edition. Included in Chapter 16 is up-to-date material on interfacing and networking, especially local area networks (LANs).

In the 1990s, industry is finding alternatives to the purchase of turnkey, commercially available robots. Today's students are learning to build manufacturing automation ap-

plications from basic components, such as sensors, switches, vision systems, and microprocessors. This book emphasizes these alternatives, especially programmable logic controllers (PLCs) and the application of industrial logic control systems. Additional design tools for analyzing logic control systems have been added to this revised edition. Safety has also been given increased emphasis, as have process control and quality. Case studies and exercises have been added for classroom use.

Accreditation bodies, in particular ABET, are placing increased importance upon design content in engineering and technology curricula. Design problems must challenge students to use their creativity to seek solutions to problems that are open-ended and have multiple solutions. This book and the accompanying *Instructor's Manual* identify several "design case studies" for strengthening the design content of courses in which this book is used. All examples, case studies, and design case studies are numerated as "examples" for consistency, but the "case studies," examples that are complex or are based upon real industrial applications, and the "design case studies," examples that have multiple solutions and design content, are further designated as such.

In addition to supporting ABET design criteria, the expanded *Instructor's Manual* that accompanies the revised text contains lecture outlines, audiovisual suggestions, projects for the laboratory, and sample examination questions with solutions. The questions and solutions are keyed to the appropriate page numbers in the book, so that examinations can be focused and solutions can be conveniently justified. In the case of design problems, sometimes multiple solutions are shown in the *Instructor's Manual*. Computer disks containing a limited version and tutorial for TISOFT™ and a tutorial for STAGE™ programming concepts are available to instructors who adopt this course for their classes.

This book can be used in a course either with or without a laboratory. Even without any equipment, the reader should be able to work all the exercises and understand each topic. If the course does have a laboratory, specific equipment manuals will be beneficial supplements to the textbook. Robots are expensive, but industrial-grade programmable controllers, microprocessors, and process microcomputers are not, making the provision of an interesting laboratory a feasible option. Low-cost, tabletop experimental robots are also available.

Many industrial readers want to know how to get started with robots and manufacturing automation, and there are some prerequisites. Chapter 1 describes product design and process control features that enhance automation potential. Sometimes the preparation for automation is more beneficial to the efficiency of the company than is the automation itself, and the text documents cases of this phenomenon. Chapter 2 uses simple language to describe the electrical and mechanical building blocks comprising the robots and automated systems presented in subsequent chapters. Mechanized parts feeding, handling, and orientation (Chapter 3) are essential for many robot applications, and the principles studied in this chapter can be applied to manual operations, too. Chapter 4 covers automated production and assembly lines and includes the analysis of the reliability of integrated automated systems. This analysis capability is needed for subsequent chapters on robotics. Chapter 5 is about NC machines, the forerunners to industrial robots and the originators of flexible automation, and this chapter includes material on CAD/CAM. Chapters 6 and 7 concentrate upon robotic manipulators, their characteristics, and their programming, and include a new section on AML. Chapter 8 is the new chapter on machine vision. Chapter 9 covers implementation, including safety. Chapter 10 is for robotic applications and includes analysis of economics. Chapters 11 and 12 describe and analyze industrial logic control systems, the most versatile and widely used tools in manufacturing automation today. These systems are even used as controllers for industrial robots themselves, though the public usually sees only the robot. Chapter 13 introduces

programmable logic controllers, the most popular way of implementing industrial logic control systems. Upon completion of Chapter 13, readers should be able to configure custom robots in-house from standard components as an alternative to purchasing turnkey, commercially available robots. Process control computers (Chapter 14) are used to control banks of robot workcells, whole production lines, and even whole factories. At the opposite extreme are the decentralized systems controlled by tiny, low-cost microprocessors (Chapter 15), the technology of which has been the driving force behind the automation and robotics movement. Chapter 16 addresses computer-integrated manufacturing, and the new material in this edition on interfacing and networking is included in this chapter. The final chapter considers the ethical issues associated with the robotics and automation movement.

Many people contributed to the second edition. I acknowledge the conscientious reviews of Professors Alec Chang, Warren Liao, Michael Diesenroth, Y. S. Chadda, John Nazemetz, and James Rice. Michael Diesenroth provided many helpful suggestions for appropriate laboratory support in addition to his valuable suggestions for the text. John Nazemetz provided editorial assistance and pointed the way to significant material to be added.

Earnest Fant acted as my consultant on machine vision in electronics manufacturing, and Rajiv Mehrotra, Eric Webb, Sylvia Tran, and Gary Shepard were helpful in providing real examples for the new chapter on machine vision. David Boyster and Matthew Walker advised and assisted me in integrated circuits and microprocessors. Frank Broadstreet assisted with solutions to exercises. Other colleagues who were helpful are Robert Sims, William Boyd, and Eric Malstrom.

Thanks go to ARTRAN, Texas Instruments, Intel, General Dynamics, IBM, Singer, and a host of robot manufacturers not only for their hardware and software but also for the industrial case studies that enhance the second edition. Special thanks go to Margi Berbari, Marc Langston, Tom Jacoway, Kevin Price, Caile Spear, Rebecca Fant, Kay Fowler, Lois Giles, Genevie Payne and Dale Batson.

Finally, I acknowledge the assistance of my very capable secretary, Nancy Sloan, whose talents, thoughtfulness, and enthusiastic effort far surpassed her expected role.

C. Ray Asfahl

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