

# Introduction to Robotics



# **Introduction to Robotics**

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# Preface

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## Objectives of This Book

This book is an attempt to include, in one volume, a useful summary of the many complex technologies that go into a modern robot. Our definition of a robot requires that it be able to operate independently of human control and be capable of movement, either on a mobile base or by the use of a manipulator arm. This definition covers, therefore, industrial robots and the growing category of home robots, office robots, and mobile vehicles or combinations thereof.

This book is entitled, Introduction to Robotics because it is just that. It was written as an introduction to this subject for engineering and computer science students, technology students, and practicing engineers who want to obtain some knowledge of the growing and esoteric field of robotics. It was initiated because the author was assigned to teach a course in robotics and could find no text that covered all the basic information needed. There was one book that discussed the applications of industrial robots, another that was a useful assembly of articles from various periodicals, and an excellent text on the mathematics of kinematics and control. But nothing available was suitable for an introductory course on robotics at the junior or senior level. Since this book was initiated in early 1982 other books have been written, but I believe that this is the most complete one available on the subject. Due to the rapid growth of the robotics field, it is expected that the basic ideas discussed here will last but that many technical details will quickly become obsolete as improved methods and technologies come into being.

It is assumed that all readers have some knowledge of dynamics and statics or at least are familiar with elementary physical concepts such as Newton's laws. Force, mass, acceleration, velocity, centrifugal force, and gravitational attraction are of some importance to robots, as they are to humans. Other subjects touched on are described and defined as necessary before use. In addition, references to more detailed descriptions of each major subject area are provided.

Students coming into robotics courses taught by the author have often had gaps in knowledge that made some robotics concepts difficult to grasp. Mechanical engineers, in many cases, did not understand electronic circuits, logic, or control theory. Electronic engineers, well versed in those subjects, were not familiar with backlash or the static properties of cantilever beams. Except for a few computer science experts, none were familiar with computer vision and terms such as pixel, gray level, and edge detection. And computer science people were unacquainted with most of the mechani-

cal and electrical engineering details discussed. Other important areas—industrial engineering, production engineering, CAD/CAM, simulation, and so on were only of peripheral concern to the average engineer.

It is my conviction that we each need to know enough about the other person's special field to be able to identify the important concepts. If a large percentage of those who read this book learn to identify the concepts discussed, the author's purpose will have been served.

Of course, if many people become interested in and excited by the fascinating field of robotics, even greater joy will result.

I hope you enjoy this book as much as I have enjoyed writing it.

Now to discuss the organization of this text:

Chapter 1 provides an overview of robots: historical background, definitions, a discussion of why robots are valuable, and a preliminary description of how robots work. It also includes a brief description of market, social, and economic factors affecting robots and a prediction of the changes to be expected in the near future.

The early development of robots is described in Chapter 2. Some major industrial and technical developments are described to provide a background for understanding how the modern robot became a practical and viable entity.

Robot technology is described in Chapters 3, 4, 5, and 6, which provide a summary of the mechanical, electrical, electronic, sensing, and control problems that must be solved to make a robot work and adapt it to a particular application. Computer control and interfacing, an important and increasingly complex part of this technology, is reviewed in Chapter 7. Robot software, including programming, is described in Chapter 8. The software area is expected to be a major determinant of robot system capability in the next few years. It should receive much more attention than is now being accorded it. Programming of a robot is expected to be one of the most difficult and demanding areas of development.

Until recently, there were few applications of robot vision. Now it is the most exciting growth area in robotics. Hardware and software for vision are described in detail in Chapter 9, although complete coverage of these important subjects was not possible in the space available. It is hoped that the background provided in Chapter 9 will provide the interested reader with sufficient information to understand the many references to these subjects listed at the end of the chapter. Also, there is a considerable amount of information on the capabilities and limitations of current vision systems and the progress being made in improving vision capability.

Major applications of robots in manufacturing are discussed in detail in Chapter 10, with emphasis on new developments. The use of vision in new applications should be of interest to many readers.

One of the perils of writing a book covering a broad field is that no two users want the same information. This book is especially open to criticism, since it not only covers a broad field but also tries to serve the needs of many types of users. It is hoped, and expected, that people with backgrounds in mechanical, electrical, and industrial engineering will find the book valuable in providing a sound background

in new knowledge areas. In addition, the book should be of help to those who wish to improve their understanding of robotic vision, software, and control.

Feedback from users of this book is encouraged. There are bound to be many errors, some minor and some major. In addition, some topics are not included in enough detail, whereas others are too detailed for some users. Please feel free to send me your comments and criticisms. Between us, we can make the second edition much better.

## **Suggested Uses for This Book**

### **1. Reference Source**

The broad coverage of robotic engineering and technology makes this a useful reference on the operation of robots and robotic systems for the practicing engineer, researcher, or robot technologist. A thorough index and a comprehensive glossary have been supplied to make it easy to find and understand the information presented. In addition, there is an extensive list of references to the widely scattered literature in the many fields that are combined to make robotics possible. Appendixes are supplied to describe some terminology and mathematical concepts that may be new to some readers.

### **2. Educational Use**

There is enough information in this book to cover a two-semester course in introduction to robotics, robotics engineering, or robotics technology. There is also sufficient information for a one-semester course in robot software at the senior computer science or engineering level. With appropriately selected subject matter, the book can support as many as three quarters in one of these subjects. A suggested selection of topics for each type of course is outlined in the following table.

Each chapter is largely self-contained. Basic concepts are introduced at the beginning of the chapter and are elaborated on as the discussion proceeds. Use of the first half of each chapter is a practical way to introduce each subject area. The more difficult concepts may be omitted for an introductory course and followed up in an advanced course.



COURSE CODE (Semester or Quarter)									
A	B		C		D		E		
1	1	2	1	2	1	1	2	3	

### Chapter 3 Mechanical Considerations

3.1	Physical Configurations	X	X	R	X	R	X	X	
3.2	Robot Motions	X	X	R	X	R	X	X	
3.3	Drive Mechanisms	X	R		X	R	X	X	
3.4	End Effectors	X	X	R	X	R	X	X	
3.5	Determining Specifications			X		X			X
3.6	Mobility			X		X			X
	References			X		X	X		X
	Exercises		X	X	X	X	X	X	X

### Chapter 4 Drive Methods

4.1	Hydraulic Drives	X	R		X	R	X	X	R
4.2	Pneumatic Drives	X	R		X	R	X	X	R
4.3	DC Electric Motors	X	X	R	R		X	X	R
4.4	Electric Stepper Motors	X	X	R	R		X	X	R
4.5	Selection of Drive Methods for Different Applications			X		X			X
	References		X	X	X	X	X	X	X
	Exercises		X	X	X	X	X	X	X

### Chapter 5 Sensors for Robots

5.1	Sensory Needs of Robots	X	X	R	X	R	X	X	
5.2	Sensor Evaluation and Selection	X	X	R	X	R	X	X	
5.3	Available Sensory Techniques		X	R	X	R	X	X	
5.4	Conditioning Sensor Out- put			X		X			X
5.5	Analyzing Sensor Data			X		X			X
5.6	Sensors For Special Appli- cations			X		X			X
5.7	Future Work			X		X			X
5.8	Key Terms			X		X	X		X
	Exercises		X	X	X	X	X	X	X
	References		X	X	X	X	X	X	X

### Chapter 6 Controls and Control Methods

6.1	Classification of Robots by Control Method	X	X	R	X	R	X	X	R
6.2	Control of Servo Robots	X	X	R	X	R	X	X	R
6.3	Advanced Control Methods	X	X	R	X	R	X	X	R
6.4	Closed-Loop Servos		X	R	R		X		X



		COURSE CODE (Semester or Quarter)								
		A	B		C		D		E	
		1	1	2	1	2	1	1	2	3
6.5	Servo System Components	X	X	R	R		X		X	R
6.6	Kinematics Analysis and Control		X	R	X	R	X		X	R
6.7	Controller Design Example			X		X				X
	References		X	X	X	X	X	X	X	X
	Exercises		X	X	X	X	X	X	X	X

## Chapter 7 Computer Hardware for Robot Systems

7.1	Hardware Needs for Robot Systems	X	X	R	X	R	X	X		R
7.2	Logic Circuits and Computer Elements	X	X	R	X	R	R	X		R
7.3	Computer System Organization			X	R		R		X	R
7.4	Peripheral Equipment	X	X	R	R		R	X	R	
7.5	Input/Output Operations and Control	X	X	R	X	R	R	X	R	
7.6	Advanced Computer Systems			X		X	X		X	R
	References			X	X	X	X	X	X	X
	Exercises		X	X	X	X	X	X	X	X

## Chapter 8 Robot Software

8.1	Robot Software Requirements	X	X	R	X	R	X		X	R
8.2	Levels of Programming	X	X	R	X	R	X		X	R
8.3	Functions Performed by Programming	X	X	R	X	R	X		X	R
8.4	Present Robot Languages—Features and Problems	X	X	R	X	R	X		X	R
8.5	Programming Examples for Existing Languages			X		X	X		X	R
	References		X	X	X	X	X		X	X
	Exercises		X	X	X	X	X		X	X

## Chapter 9 Robot Vision

9.1	Capturing the Image	X	X	R	X	R	X			X
9.2	Frame Grabbers	X	X	R	X	R	X			X
9.3	Vision Processors			X		X	X			X
9.4	Image Storage and Retrieval			X		X	X			X
9.5	Picture Representation			X		X	X			X

		COURSE CODE (Semester or Quarter)							
		A	B		C		D		E
		1	1	2	1	2	1	1	2 3
9.6	Preprocessing			X		X	X		X
9.7	Edge Detection			X		X	X		X
9.8	Recognizing Objects			X		X	X		X
9.9	Scene Understanding			X		X	X		X
9.10	Interfacing and Control		X	R	X	R	X		X
9.11	Examples Of Vision								
	Systems		X	R	X	R	X		X
	References		X	X	X	X	X		X
	Exercises		X	X	X	X	X		X

## Chapter 10 Applications of Robots

10.1	Machine Loading and Unloading	X	X	R	X	R	X	X	R
10.2	Material Handling	X	X	R	X	R	X	X	R
10.3	Fabrication	X	X	R	X	R	X	X	R
10.4	Spray Painting and Finishing	X	X	R	X	R	X	X	R
10.5	Spot Welding	X	X	R	X	R	X	X	R
10.6	Arc Welding	X	X	R	X	R	X	X	R
10.7	Assembly Applications	X	X	R	X	R	X	X	R
10.8	Inspection And Test	X	X	R	X	R	X	X	R
10.9	Auxiliary Equipment	X	X	R	X	R	X	X	R
10.10	Optimizing Robotic Systems			X		X			X
10.11	The Future Factory			X		X			X
10.12	Management Considerations			X		X			X
	References	X	X	X	X	X	X	X	X
	Exercises	X	X	X	X	X	X	X	X

It is important that the exercises and references be used appropriately by the instructor. Much of the knowledge of robotics is widely scattered in the literature. In the second semester and in advanced topics, it is desirable that the instructor assign reading from references available at his or her facility. Exercises are in the order of the topics covered in the chapters and should be assigned to increase student understanding of text material.

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Sacramento, California

# Acknowledgments

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I owe a great debt to the many scientists, engineers, and others who developed the basic theory and technology of robotics and made them available through published papers. This cooperative effort is the foundation of research and development throughout the world.

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I would also like to thank the reviewers who reviewed this manuscript, in its entirety, and gave me much needed guidance. I have endeavored to mold the text to meet their needs without deviating excessively from my own goals. Finally, the people at Macmillan deserve many thanks for converting the original manuscript into a completed text.

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