Preface

Industrial Robotics Fundamentals: Theory and Applications is an introductory text that explores many aspects of robotics in a basic and easy-to-understand manner. The key concepts are discussed using a "big picture" or systems approach that greatly enhances student learning. Many applications and operational aspects of equipment and robotic systems are discussed.

The development of the computer created what some experts have called the "Second Industrial Revolution." Many consider robots to be the prime movers of this revolution. It is important to have more than a basic knowledge of robots and robotics technology.

This text is a comprehensive approach to learning the technical aspects of robotics. It is divided into four units, covering broad areas of robotic principles; power supplies and movement systems; sensing and end-of-arm tooling; and control systems.

Unit I is devoted to the basic principles of robotic technology. Chapter 1 discusses the development and use of industrial robotics in the area of automation. A new section discusses the Fourth Industrial Revolution (Industry 4.0) and its impact on modern robotics. Chapter 2 prepares a solid foundation for understanding the characteristics and fundamentals of robotics, including basic components and operation. Chapter 3 provides a general safety overview for use in any laboratory setting. Chapter 4 provides an overview of programming languages and techniques used to program industrial robots. Chapter 5 explores the many applications for industrial robots.

Unit II addresses robotic power supplies and movement systems. Chapter 6 provides an overview of the electromechanical systems used with robots. Chapter 7 presents fluid power systems.

Unit III presents robotic sensing systems and end-of-arm tooling. Chapter 8 discusses the various sensors commonly used by robots to gain information about the external environment. Chapter 9 provides information about various end effectors and tools used to move workpieces from one location to another within a robot's work envelope.

Unit IV covers robotic control systems, basic maintenance, and implementation planning. Chapter 10 presents the basics of digital electronics, which includes information on microcomputers and microprocessors. Chapter 11 explains how the robot controller communicates with peripheral equipment found in robotic workcells, including vision systems. Chapter 12 provides an overview of maintenance procedures. Chapter 13 discusses some of the major factors to consider when using robotic systems in an industrial environment. Chapter 14 presents the use of robots outside the factory, artificial intelligence (AI) and expert systems, and suggested coursework and training related to the field of robotics. Chapter 15 provides examples of how to build smaller robots.

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applications engineer. He is the former president of the Kentucky Technology and Engineering Education Association and Kentucky state representative for the International Technology and Engineering Educator Association (ITEEA). Dr. Walach presents annually at national and state conferences on engineering, technology, and aviation topics, and has published work in the *Journal of Technology Education*, *Journal of Aviation/Aerospace Education & Research*, and the *Technology and Engineering Teacher* journal. Dr. Walach was the 2013 ITEEA Rhode Island technology teacher of the year and the 2013 ITEEA distinguished program award recipient.

Reviewers

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New to This Edition

The following changes have been made to the fifth edition of ***Industrial Robotics Fundamentals: Theory and Applications*** to strengthen the instructional design and provide up-to-date information on the latest industry developments.

- The main headings, summary bullets, and end-of-chapter questions are all tied to learning outcomes to allow flexibility in instruction and provide more focused content coverage.
- Updated coverage of relevant industrial robotics topics such as artificial intelligence (AI), collaborative robots (cobots), sensors and applications, programming, serial communications, and more are included throughout the text.
- Special feature images and content are updated to include real-world robotic applications in the industry. Updates include current trends and applications of robotics technology, such as healthcare robots and automated order fulfillment robots.
- A new Workplace Skills Handbook is included in the appendix to help students hone skills that are essential for success in industry.
- An Image Library is now available for instructors to access and download all the figures from the textbook.

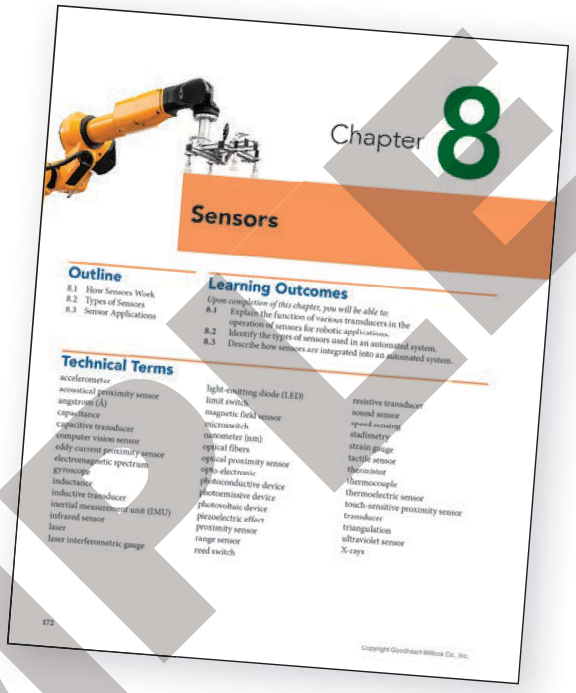
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Features of the Textbook

The instructional design of this textbook includes student-focused learning tools to help you succeed. This visual guide highlights these features.

Chapter Opening Materials

Each chapter opener contains a chapter outline, a list of learning outcomes, a list of technical terms, and an overview. The **Outline** summarizes the topics that will be covered in the chapter. **Learning Outcomes** clearly identify the knowledge and skills to be gained when the chapter is completed. These outcomes are labeled and correlated to related assessment elements to facilitate reporting and remediation. **Technical Terms** list the key words to be learned in the chapter. The **Overview** provides an introduction and preview of the chapter content.


Chapter 8

Sensors

Outline

8.1 How Sensors Work
8.2 Types of Sensors
8.3 Sensor Applications

Learning Outcomes

Upon completion of this chapter, you will be able to:
8.1 Explain the function of various transducers in the operation of sensors for robotic applications.
8.2 Identify the types of sensors used in an automated system.
8.3 Describe how sensors are integrated into an automated system.

Technical Terms

accelerometer
acoustical proximity sensor
angstrom (Å)
capacitance
capacitive transducer
computer vision sensor
eddy current proximity sensor
electromagnetic spectrum
gyroscope
inductance
inductive transducer
inertial measurement unit (IMU)
infrared sensor
laser
laser interferometric gauge
light-emitting diode (LED)
limit switch
magnetic field sensor
microswitch
micrometer (mm)
optical fibers
optical proximity sensor
opto-electronic
photoconductive device
photoemissive device
photovoltaic device
piezoelectric effect
proximity sensor
range sensor
reed switch
resistive transducer
sound sensor
speed sensing
stadimetry
strain gauge
tactile sensor
thermistor
thermocouple
thermoelectric sensor
touch-sensitive proximity sensor
transducer
triangulation
ultraviolet sensor
X-rays

Expanding Your Learning

Inventor Spotlight introduces you to key figures in the development of robotics. **Careers in Robotics** explain different types of careers in robotics, including the education needed and the tasks related to that career. **Robotics Innovations** inform you of current and upcoming robotics technology.


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8.1 How Sensors Work

Sensors allow robots to interact with their environment, respond to changes, and determine a course of action. Sensors help robots respond to different positions and orientations of parts, variations in the shape and dimensions of parts, and unknown obstacles in the work environment. Sensors are "transducers" that respond to various types of physical signals. *Transducers* are devices that convert light, heat, or mechanical energy into electrical energy. The conversion of physical quantities to electrical quantities is a basic sensing function. The signal output by the transducer is used to affect the operation of the machine. For example, a *thermocouple* is a transducer that converts heat energy into electrical energy. A microphone is a transducer that converts sound energy into electrical energy. Transducers may be resistive, capacitive, or inductive, Figure 8-1.

Resistive Transducers

Resistive transducers are devices that convert a variation in resistance into electrical variations. One type works on the potentiometer principle, Figure 8-2. This transducer changes resistance when the position of its movable contact is changed. Increasing the length of wire between terminals increases the resistance between those two points. Resistive transducers are often used to sense physical displacement. Displacement moves the sliding contact, which changes the resistance in the control circuit.

Capacitive Transducers

Capacitive transducers measure a change in *capacitance*, or the ratio of charge on a conductor to the potential difference between conductors. Capacitance exists when two conductive materials (plates) are separated by an insulating material. Capacitance can be increased by increasing the area of the plates or by decreasing the thickness of the insulation. Changing electrical current is a result of physical alteration or movement (mechanical energy) by either affecting plate area or insulation thickness.

Robotics Innovations: Brightpick Robots

Brightpick has a line of warehouse robots designed to help with order fulfillment, which can include order picking and stock replenishment. The Brightpick Autopicker is one of these robots and can operate in an environment built for humans and requires minimal infrastructure changes to be integrated. These features make it an easy solution for businesses to adopt.

Equipped with 3D machine vision and machine learning, these robots can move down aisles and collect parts in much the same way a human with a shopping cart might walk down aisles and pick items. Some companies offer Brightpick robots as a RaaS (Robots as a Service) option and they can be rented out to help warehouses handle busier times of year. These systems reduce the need for large human workforces and they can work 24/7, greatly reducing costs. The introduction of artificial intelligence (AI) into robotic systems is making the integration of robotics into existing environments much quicker and easier. Without the need of supporting infrastructure specific to the operation of the robot, these robots are versatile for many different operations.

Brightpick's warehouse robots are equipped with 3D machine vision, LiDAR (Light Detection and Ranging), unique end effectors, and AI software to perform order fulfillment.

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Chapter 14 Robotic Applications and Innovations 305

Figure 14-25. The Robotic Servicing of Geosynchronous Satellites (RSGS) spacecraft has two dexterous robotic arms used for satellite inspection and repair.

- ***Firefighting Robots*** with Stereo Cameras and Other Sensors Can Be Used to Search Buildings. Advanced vision systems and radar sensors are used for imaging through smoke, **Figure 14-27**.
- Aerial Robot System Can Save Firefighters. These robots are remotely controlled to evaluate hazards inside buildings or other fire locations to isolate and suppress fires.
- Humanoid Robotic Pilot Is Being Developed That Could Potentially Replace Humans in Airplane Cockpits. Korea Advanced Institute of Science and Technology (KAIST) has designed "Pibot" to fly a plane just like a pilot.
- Military Robots Used to Keep Soldiers Out of Life-Threatening Situations. Autonomous or remote-controlled robots can be used for surveillance, reconnaissance, search and rescue, and other hazardous operations to protect personnel, **Figure 14-28**.
- Solar-Powered Microbots, 100–250 Micrometers in Size, Are Being Used. Researchers at Cornell University have created autonomous microbots that are solar powered and able to walk without external controllers.
- ***Submersible Robots*** Are Developed That Can Fly into the Air. These remotely controlled robotic devices can conduct ocean or other underwater research. They are equipped with high-definition cameras, sonar, and audio recorders.

NASA

Figure 14-26. The Soyuz MS-14 spacecraft mid-flight to the International Space Station.

Figure 14-27. This firefighting robot is extinguishing a controlled fire with its water hose.

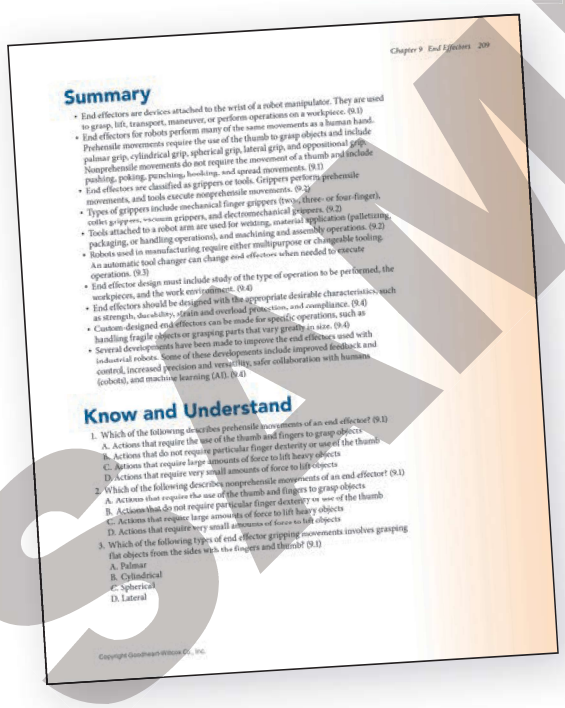
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Illustrations

Illustrations have been updated and are designed to clearly and simply communicate the specific topic. Illustrations have been updated for this edition. Photographic images have been updated to show the latest equipment.

End-of-Chapter Content

End-of-chapter material provides an opportunity for review and application of concepts. A concise **Summary** provides an additional review tool and reinforces key learning outcomes. This helps you focus on important concepts presented in the text. **Know and Understand** questions enable you to demonstrate knowledge, identification, and comprehension of chapter material. **Apply and Analyze** questions extend learning and develop your abilities to use learned material in new situations and to break down material into its component parts. **Critical Thinking** questions develop higher-order thinking and problem-solving abilities.



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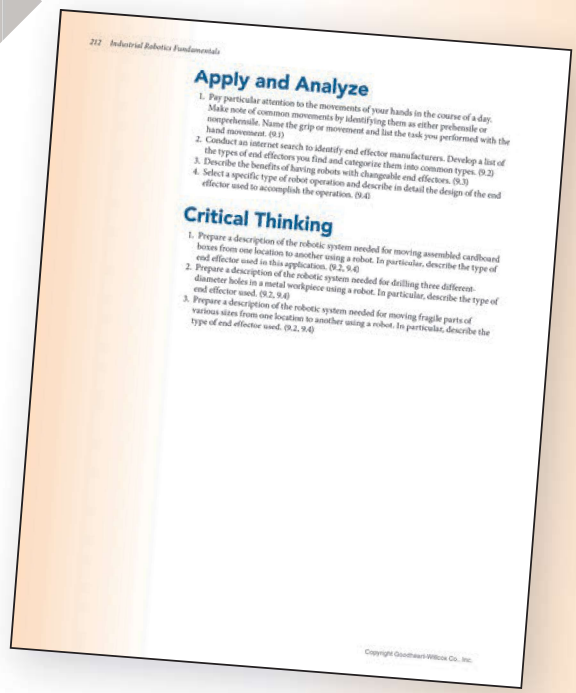
Summary

- End effectors are devices attached to the wrist of a robot manipulator. They are used to grasp, lift, transport, maneuver, or perform operations on a workpiece. (9.1)
- End effectors for robots perform many of the same movements as a human hand. Prehensile movements require the use of the thumb to grasp objects and include palmar grip, cylindrical grip, spherical grip, lateral grip, and oppositional grip. Nonprehensile movements do not require the movement of a thumb and include pushing, poking, punching, hooking, and spread movements. (9.1)
- End effectors are classified as grippers or tools. Grippers perform prehensile movements, and tools execute nonprehensile movements. (9.2)
- Types of grippers include mechanical finger grippers (two-, three- or four-finger), collet grippers, vacuum grippers, and electromechanical grippers. (9.2)
- Tools attached to a robot arm are used for welding, material application (palletizing, packaging, or handling operations), and machining and assembly operations. (9.2)
- Robots used in manufacturing require either multipurpose or changeable tooling. An automatic tool changer can change end effectors when needed to execute operations. (9.3)
- End effector design must include study of the type of operation to be performed, the workpieces, and the work environment. (9.4)
- End effectors should be designed with the appropriate desirable characteristics, such as strength, durability, crash and overload protection, and compliance. (9.4)
- Custom-designed end effectors can be made for specific operations, such as handling fragile objects or grasping parts that vary greatly in size. (9.4)
- Several developments have been made to improve the end effectors used with industrial robots. Some of these developments include improved feedback and control, increased precision and versatility, safer collaboration with humans (cobots), and machine learning (AI). (9.4)

Know and Understand

1. Which of the following describes prehensile movements of an end effector? (9.1)
   A. Actions that require the use of the thumb and fingers to grasp objects
   B. Actions that do not require particular finger dexterity or use of the thumb
   C. Actions that require large amounts of force to lift heavy objects
   D. Actions that require very small amounts of force to lift objects
2. Which of the following describes nonprehensile movements of an end effector? (9.1)
   A. Actions that require the use of the thumb and fingers to grasp objects
   B. Actions that do not require particular finger dexterity or use of the thumb
   C. Actions that require large amounts of force to lift heavy objects
   D. Actions that require very small amounts of force to lift objects
3. Which of the following types of end effector gripping movements involves grasping flat objects from the sides with the fingers and thumb? (9.1)
   A. Palmar
   B. Cylindrical
   C. Spherical
   D. Lateral

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Apply and Analyze

1. Pay particular attention to the movements of your hands in the course of a day. Make note of common movements by identifying them as either prehensile or nonprehensile. Name the grip or movement and list the task you performed with the hand movement. (9.1)
2. Conduct an internet search to identify end effector manufacturers. Develop a list of the types of end effectors you find and categorize them into common types. (9.2)
3. Describe the benefits of having robots with changeable end effectors. (9.3)
4. Select a specific type of robot operation and describe in detail the design of the end effector used to accomplish the operation. (9.4)

Critical Thinking

1. Prepare a description of the robotic system needed for moving assembled cardboard boxes from one location to another using a robot. In particular, describe the type of end effector used in this application. (9.2, 9.4)
2. Prepare a description of the robotic system needed for drilling three different-diameter holes in a metal workpiece using a robot. In particular, describe the type of end effector used. (9.2, 9.4)
3. Prepare a description of the robotic system needed for moving fragile parts of various sizes from one location to another using a robot. In particular, describe the type of end effector used. (9.2, 9.4)

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