

Introduction

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1.3 NOTATION

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The history of industrial automation is characterized by periods of rapid change in popular methods. Either as a cause or, perhaps, an effect, such periods of change in automation techniques seem closely tied to world economics. Use of the industrial robot, which became identifiable as a unique device in the 1960s [1], along with computer-aided design (CAD) systems and computer-aided manufacturing (CAM) systems, characterizes the latest trends in the automation of the manufacturing process. These technologies are leading industrial automation through another transition, the scope of which is still unknown [2].

In North America, there was much adoption of robotic equipment in the early 1980s, followed by a brief pull-back in the late 1980s. Since that time, the market has been growing (Fig. 1.1), although it is subject to economic swings, as are all markets.

Figure 1.2 shows the number of robots being installed per year in the major

industrial regions of the world. Note that Japan reports numbers somewhat differently from the way that other regions do: they count some machines as robots

that in other parts of the world are not considered robots (rather, they would be simply considered "factory machines"). Hence, the numbers reported for Japan are somewhat inflated.

A major reason for the growth in the use of industrial robots is their declining cost. Figure 1.3 indicates that, through the decade of the 1990s, robot prices dropped while human labour costs increased. Also, robots are not just getting cheaper, they are becoming more effective—faster, more accurate, more flexible. If we factor these quality adjustments into the numbers, the cost of using robots is dropping even

faster than their price tag is. As robots become more cost effective at their jobs, and as human labour continues to become more expensive, more and more industrial jobs become candidates for robotic automation. This is the single most important trend propelling growth of the industrial robot market. A secondary trend is that, economics aside, as robots become more capable they become able to do more and more tasks that might be dangerous or impossible for human workers to perform.

The applications that industrial robots perform are gradually getting more sophisticated, but it is still the case that, in the year 2000, approximately 78% of the robots installed in the US were welding or material-handling robots

This book focuses on the mechanics and control of the most important form of the industrial robot, the mechanical manipulator. Exactly what constitutes an industrial robot is sometimes debated. Devices such as that shown in Fig. 1.4 are always included, while numerically controlled (NC) milling machines are usually not. The distinction lies somewhere in the sophistication of the programmability of the device—if a mechanical device can be programmed to perform a wide variety of applications, it is probably an industrial robot. Machines which are for the most part limited to one class of task are considered fixed automation. For the purposes of this text, the distinctions need not be debated; most material is of a basic nature that applies to a wide variety of programmable machines.

By and large, the study of the mechanics and control of manipulators is not a new science, but merely a collection of topics taken from "classical" fields. Mechanical engineering contributes methodologies for the study of machines in static and dynamic situations. Mathematics supplies tools for describing spatial motions and other attributes of manipulators. Control theory provides tools for designing and evaluating algorithms to realize desired motions or force applications. Electrical-engineering techniques are brought to bear in the design of sensors and interfaces for industrial robots, and computer science contributes a basis for programming these devices to perform a desired task.

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The following sections introduce some terminology and briefly preview each of the topics that will be covered in the text.

Description of position and orientation

In the study of robotics, we are constantly concerned with the location of objects in three-dimensional space. These objects are the links of the manipulator, the parts and tools with which it deals, and other objects in the manipulator's environment.

At a crude but important level, these objects are described by just two attributes: position and orientation. Naturally, one topic of immediate interest is the manner in which we represent these quantities and manipulate them mathematically.

In order to describe the position and orientation of a body in space, we will always attach a coordinate system, or frame, rigidly to the object. We then proceed to describe the position and orientation of this frame with respect to some reference coordinate system. (See Fig. 1.5.)

Any frame can serve as a reference system within which to express the position and orientation of a body, so we often think of transforming or changing the description of these attributes of a body from one frame to another. Chapter 2 discusses conventions and methodologies for dealing with the description of position and orientation and the mathematics of manipulating these quantities with respect to various coordinate systems.

Developing good skills concerning the description of position and rotation of rigid bodies is highly useful even in fields outside of robotics.