Part III Arm-Type Robots

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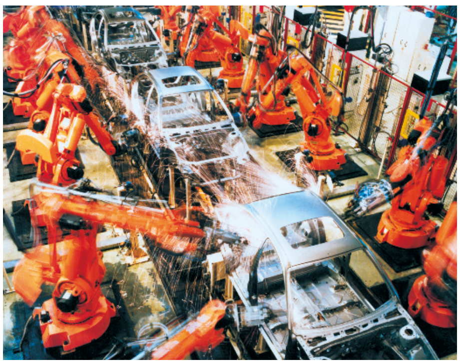

Arm-type robots or robot manipulators are a very common and familiar type of robot. We are used to seeing pictures or video of them at work in factories doing jobs such as assembly, welding and handling tasks, or even in operating rooms doing surgery. The first robot manipulators started work nearly 60 years ago and have been enormously successful in practice – many millions of robot manipulators are working in the world today. Many products we buy have been assembled, packed or handled by a robot.

Unlike the mobile robots we discussed in the previous part, robot manipulators do not move through the world. They have a static base and therefore operate within a limited workspace. Many different types of robot manipulator have been created and Fig. III.1 shows some of the diversity. The most common is the 6DOF arm-type of robot comprising a series of rigid-links and actuated joints. The SCARA (Selective Compliance Assembly Robot Arm) is rigid in the vertical direction and compliant in the horizontal plane which is an advantage for planar tasks such as electronic circuit board assembly. A gantry robot has one or two degrees of freedom of motion along overhead rails which gives it

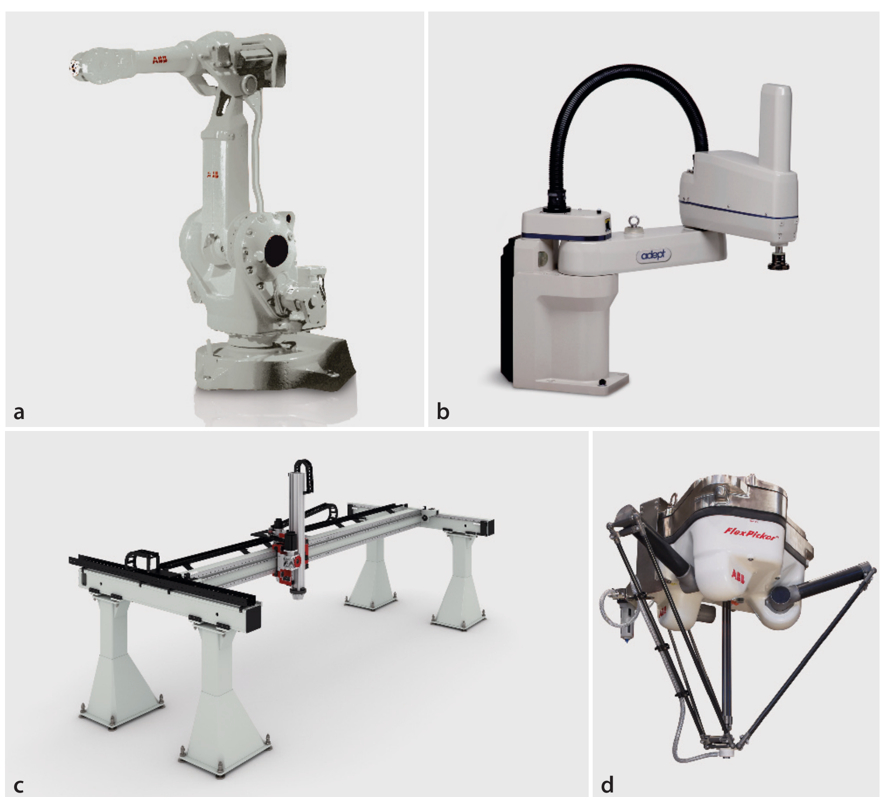

Fig. III.1. **a** A 6DOF serial-link manipulator. General purpose industrial manipulator (source: ABB). **b** SCARA robot which has 4DOF, typically used for electronic assembly (photo of Adept Cobra s600 SCARA robot courtesy of Adept Technology, Inc.). **c** A gantry robot; the arm moves along an overhead rail (image courtesy of Güdel AG Switzerland | Mario Rothenbühler | www.gudel.com). **d** A parallel-link manipulator, the end-effector is driven by 6 parallel links (source: ABB)

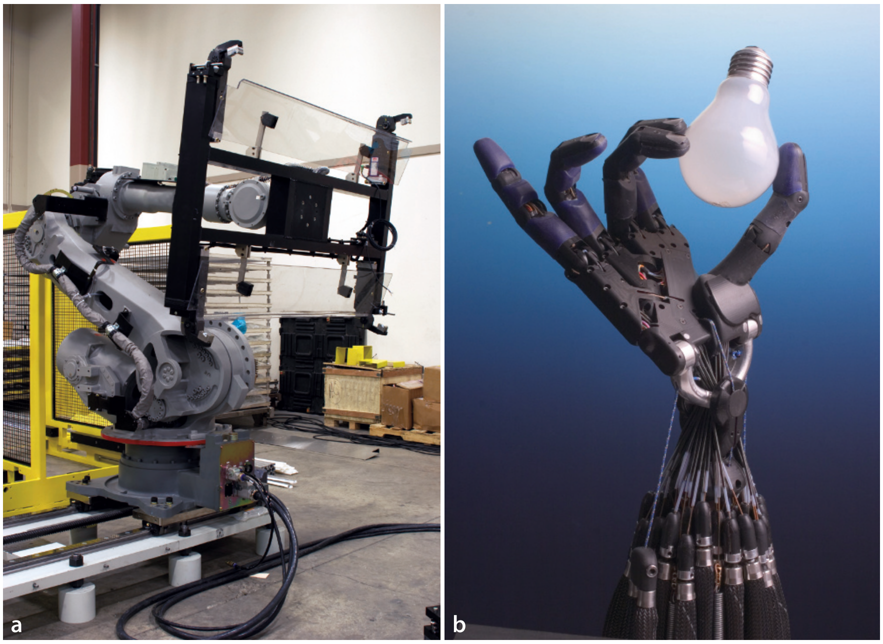

Fig. III.2.
Robot end-effectors. **a** A vacuum gripper holds a sheet of glass. **b** A human-like robotic hand (© Shadow Robot Company 2008)

a very large working volume. A parallel-link manipulator has its links connected in parallel to the tool which brings a number of advantages such as having all the motors on the base and providing a very stiff structure. The focus of this part is serial-link arm-type robot manipulators.

These nonmobile robots allow some significant simplifications to problems such as perception and safety. The work environment for a factory robot can be made very orderly so the robot can be fast and precise and *assume* the location of objects that it is working with. The safety problem is simplified since the robot has a limited working volume – it is straightforward to just exclude people from the robot's work space using safety barriers or even cages.

A robot manipulates objects using its end-effector or tool as shown in Fig. III.2. End-effectors range in complexity from simple 2-finger or parallel-jaw grippers to complex human-like hands with multiple actuated finger joints and an opposable thumb.

The chapters in this part cover the fundamentals of serial-link manipulators. Chapter 7 is concerned with the kinematics of serial-link manipulators. This is the geometric relationship between the angles of the robot's joints and the pose of its end-effector. We discuss the creation of smooth paths that the robot can follow and present an example of a robot drawing a letter on a plane and a 4-legged walking robot. Chapter 8 introduces the relationship between the rate of change of joint coordinates and the end-effector velocity which is described by the manipulator Jacobian matrix. It also covers alternative methods of generating paths in Cartesian space and introduces the relationship between forces on the end-effector and torques at the joints. Chapter 9 discusses independent joint control and some performance limiting factors such as gravity load and varying inertia. This leads to a discussion of the full nonlinear dynamics of serial-link manipulators – effects such as inertia, gyroscopic forces, friction and gravity – and more sophisticated model-based control approaches.