Chapter 1

Introduction to Robotics

1.1 Introduction

This chapter gives an overview of *robotics*, the engineering discipline which focuses on the study of robots. I will introduce relevant topics from the angle of manufacturing, which serves as a convincing basis to justify the usefulness and importance of robots in industry. For those who are actively undertaking research in the area of artificial intelligence, I also describe a framework from which to understand human intelligence. In the later part of the chapter, I discuss the major concerns of robotics, for the purpose of illustrating the simple, unifying theme, *motion*. An understanding of this theme would make the rest of the chapters easier to read.

1.2 Manufacturing

The word manufacture comes from the combination of two Latin words, *manus* (hand) and *factus* (to make). Thus, the literal meaning of manufacture is, "to make by hand" either directly, by producing handicrafts, or indirectly, by making use of re-programmable machine tools. Since ancient times, our ancestors exercised their creativity to the fullest, in making things by hand. This creativity led to the invention of *tools*, which made the process of "making things" much easier and more efficient. Most importantly, the discovery of *engineering materials*, such as metal, ceramics, and polymers, enlarged the scope of "things" which can be made by hand, with or without the help of tools. This, in turn, fuelled people's creativity in inventing various *processes* for making "things" of different complexity, property, and scale.

A direct consequence of the activity of "making things by hand" was

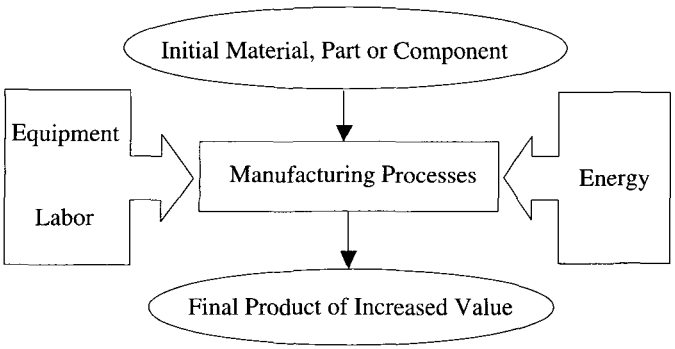

Fig. 1.1 Illustration of basic functional modules in manufacturing.

that craftsmen were able to produce a surplus of goods which far exceeded their needs. As a result, people began to exchange the surplus of one type of goods for the surplus of another type of goods. This led to the creation of commerce, which is a platform for stimulating the production of wealth for people and nations. With the advent and sophistication of finance and monetary systems, commerce has steadily reached a scale, which goes into a dimension far beyond geographical, social, and cultural boundaries. It is not exaggerating to say that today's commerce is the motor which drives all economic, social, and cultural activities. Regardless of the scale and dimension of commerce, the basic fundamentals, the exchange of goods or services, are still the same. Without *exchange*, there would be no commerce; without commerce, there would be no manufacturing.

If manufacturing is the art and science of "making things by hand," directly or indirectly, a formal definition of manufacturing can be stated, as follows:

Definition 1.1 Manufacturing is the application of processes which alters the geometry, property, and appearance of materials for the production of goods of increased value.

Refer to Fig. 1.1. A material, part or component is transformed from the initial state to the final state of product through the interaction among labor, equipment, material, and parts or components. This interaction results in energy consumption.

Growing commercial activities have undoubtedly pushed up the demand for product quality and manufacturing capacity, which is measured by the rate of output products over a fixed period of time. The production of

goods in large volume has propelled manufacturing to evolve into a rigorous scientific discipline covering the following important aspects:

Products

Final products, produced by Manufacturers, can be classified into two categories: a) consumer products and b) capital products. The former are products purchased directly by consumers, such as personal computers, automobiles, TV, video recorders, household appliances, foods, beverages etc. The latter are products purchased by companies, such as industrial robots, mainframe computers, machine tools, construction equipment, processed materials, parts, devices, components etc. Capital products are used in manufacturing as facilities for the production of goods.

Materials

In addition to natural materials, such as wood, bamboo, stones, rocks, petroleum etc., the advent of engineering materials has undoubtedly enlarged the scope of things which can be manufactured. There are three basic categories of engineering materials, namely: metals, ceramics, and polymers. The combination of these three basic engineering materials forms another category called, *composite materials*, such as metal-ceramic composites, metal-polymer composites, and ceramic-polymer composites.

Processes

A manufacturing process consists of the interaction among labor, equipment, and input materials, parts, or components. A manufacturing process will change the geometry, property, or appearance of the input materials, parts, or components. Thus, the interaction in a manufacturing process will consume energy in the mechanical, thermal, chemical, or electrical domains.

Depending on the modes of interaction, a process can be either a serial process or a parallel process. A process is called a serial process if the interaction occurs locally on a material, part, or component while a process is called a parallel process if the interaction occurs globally across a material, part or component.

However, depending on the outcome of the interaction, a process can fall into one of the four categories:

(1) *Removal Process*:
This refers to the operation of removing certain portions of input materials. Examples include cutting, grinding, die stamping etc.
(2) *Addition Process*:
This refers to the operation of adding other materials to input materials, or joining parts or components together. Examples include painting, coating, assembly, 3D printing, welding, soldering etc.
(3) *Solidification Process*:
This refers to the operation of creating objects through the transformation of thermal states of materials. A typical example of the solidification process is injection molding.
(4) *Deformation Process*:
This refers to the operation of altering the shape of a material, part or component through the application of either mechanical or thermal energy. Typical examples include die forging, bending, rolling, heating etc.

Equipment

In order to satisfy the demand for high quality and high volume, it is necessary to use machine tools or automated equipment to operate manufacturing processes. Functionally, the role of manufacturing equipment is to control the interaction in a manufacturing process which will alter the geometry, property, or appearance of the initial material, part, or component.

Factories

The manufacturing industry consists of factories and organizations which produce or supply goods and services.

Refer to Fig. 1.2. A factory is typically composed of the following entities:

- *Production and Automation System*:
This includes the factory layout, process equipment, metrology equipment, material-handling equipment and labor.
- *Manufacturing Support System*:
This includes inbound logistics for ordering materials, parts, components and facilities. On the other hand, outbound logistics deals with distribution of the final products.

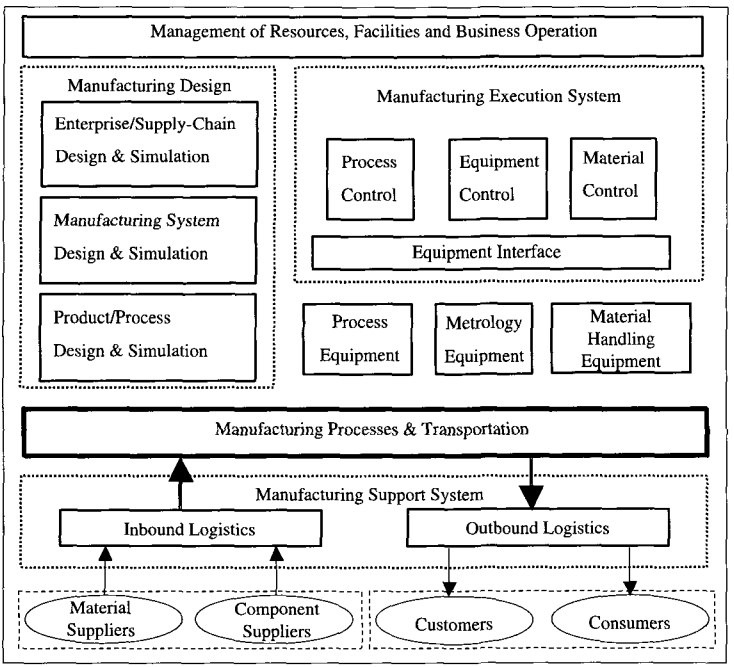

Fig. 1.2 Outline of a factory in manufacturing.

- *Manufacturing Execution System*:
  This includes process control, material flow control, equipment control and deployment of labor.
- *Manufacturing Design System*:
  This includes product design & simulation, process design & simulation and supply-chain design & simulation.
- *Enterprise Information and Management System*:
  This includes the management of resources, facilities and business operations.

1.3 Factory Automation

There are two ways to achieve high yields in manufacturing. The simplest, yet most expensive way is to increase the number of production lines. An alternative and more desirable way is to increase the rate of production in the existing production lines. It is possible to increase the production rate