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Internal Assessment Test 4 – Feb. 2022

Sub:	Automation and Robotics				Sub Code:	18ME732	Branch:	ME
Date:	03.02.22	Duration:	90 min's	Max Marks: 50	Sem / Sec:	VII/A&B		OBE

Answer any FIVE FULL Questions

		MARKS	CO	RBT
1	Define automation? Explain basic elements of an automation system with a neat sketch	[10]	CO1	L2
2	Define automated assembly system? Explain automation assembly configuration systems with suitable sketches	[10]	CO1	L2
3	What is an Industrial robot? Explain common robot configurations with suitable diagrams	[10]	CO3	L2
4	What is an automated production line? Explain general configurations of an automated production line and its system configurations with suitable diagrams	[10]	CO2	L2
5	Explain briefly end effectors and applications of industrial robots	[10]	CO3	L2
6.	Explain different types of control systems used in automated systems	[10]	CO2	L2

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Scheme of Evaluation

Question number	Particulars	Marks distribution
1.	Definition Diagram of basic elements Explanation of basic elements	2 marks 2 marks 6 marks
2.	Definition 4 configurations= Diagram Explanation	2 Marks 4x1= 4Marks 4x1= 4Marks
3.	Definition 4 configurations= Diagram Explanation	2 Marks 4x1= 4Marks 4x1= 4Marks
4.	Automated production line System configurations Diagrams	2 marks 4 marks 4 marks
5.	End effectors Applications of Industrial Robots	5 Marks 5 Marks
6.	Different control system 4 Continuous control system Diagrams Explanation	2 marks 4x1=4marks 4x1=4marks

1. *Automation* is the technology by which a process or procedure is accomplished without human assistance. It is implemented using a *program of instructions* combined with a *control system* that executes the instructions.

Basic elements of an automated system

An automated system consists of three basic elements:

(1) *power* to accomplish the process and operate the system.

(2) a *program of instructions* to direct the process, and

(3) a control system to actuate the instructions.

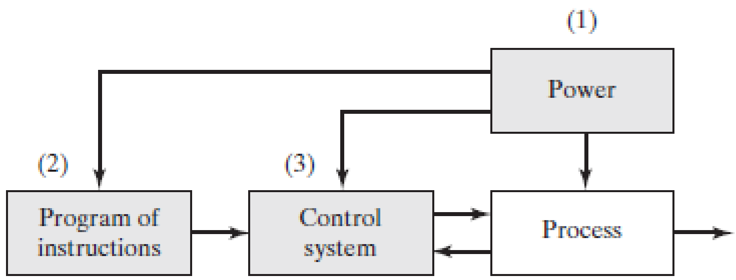


Figure 4.2 Elements of an automated system: (1) power, (2) program of instructions, and (3) control systems.

Fig.1 Basic elements of an automated system

1. Power to accomplish the automated process

An automated system is used to operate some process, and power is required to drive the process as well as the controls. The principal source of power in automated systems is electricity. Electric power has many advantages in automated as well as non-automated processes.

In addition to driving the manufacturing process itself, power is also required for the following material handling functions:

• *Loading and unloading the work unit.* All of the processes listed in Table 4.1 are accomplished on discrete parts. These parts must be moved into the proper position and orientation for the process to be performed, and power is required for this transport and placement function. At the conclusion of the process, the work unit must be removed. If the process is completely automated, then some form of mechanized power is used. If the process is manually operated or semi automated, then human power may be used to position and locate the work unit.

• *Material transport between operations.* In addition to loading and unloading at a given operation, the work units must be moved between operations.

Power for Automation.

Above and beyond the basic power requirements for the manufacturing operation, additional power is required for automation. The additional power is used for the following functions:

• *Controller unit.* Modern industrial controllers are based on digital computers, which require electrical power to read the program of instructions, perform the control calculations, and execute the instructions by transmitting the proper commands to actuating devices.

• *Power to actuate the control signals.* The commands sent by the controller unit are carried out by means of electromechanical devices, such as switches and motors, called *actuators* The commands are generally transmitted by means of low-voltage control signals. To accomplish the commands, the actuators require more power, and so the control signals must be amplified to provide the proper power level for the actuating device.

• *Data acquisition and information processing.* In most control systems, data must be collected from the process and used as input to the control algorithms. In addition, for some processes, it is a legal requirement that records be kept of process performance and/or product quality. These data acquisition and record-keeping functions require power, although in modest amounts.

2. Program of instructions

The actions performed by an automated process are defined by a program of instructions. Whether the manufacturing operation involves low, medium, or high production, each part or product requires one or more processing steps that are unique to that part or product. These processing steps are performed during a work cycle. A new part is completed at the end of each work cycle (in some manufacturing operations, more than one part is produced during the work cycle: for example, a plastic injection molding operation may produce multiple parts each cycle using a multiple cavity mold). The particular processing steps for the work cycle are specified in a work cycle program, called *part programs* in numerical control.

3. Control System

The control element of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function, which is to perform some manufacturing operation.

The controls in an automated system can be either closed loop or open loop. A ***closedloop control system***, also known as a *feedback control system*, is one in which the output variable is compared with an input parameter, and any difference between the two is used to drive the output into agreement with the input.

2. An automated assembly system performs a sequence of automated assembly operations to combine multiple components into a single entity. The single entity can be a final product or a subassembly in a larger product.

Automated assembly systems can be classified according to physical configuration. The principal configurations are (a) in-line assembly machine, (b) dial-type assembly machine, (c) carousel assembly system, and (d) single-station assembly machine.

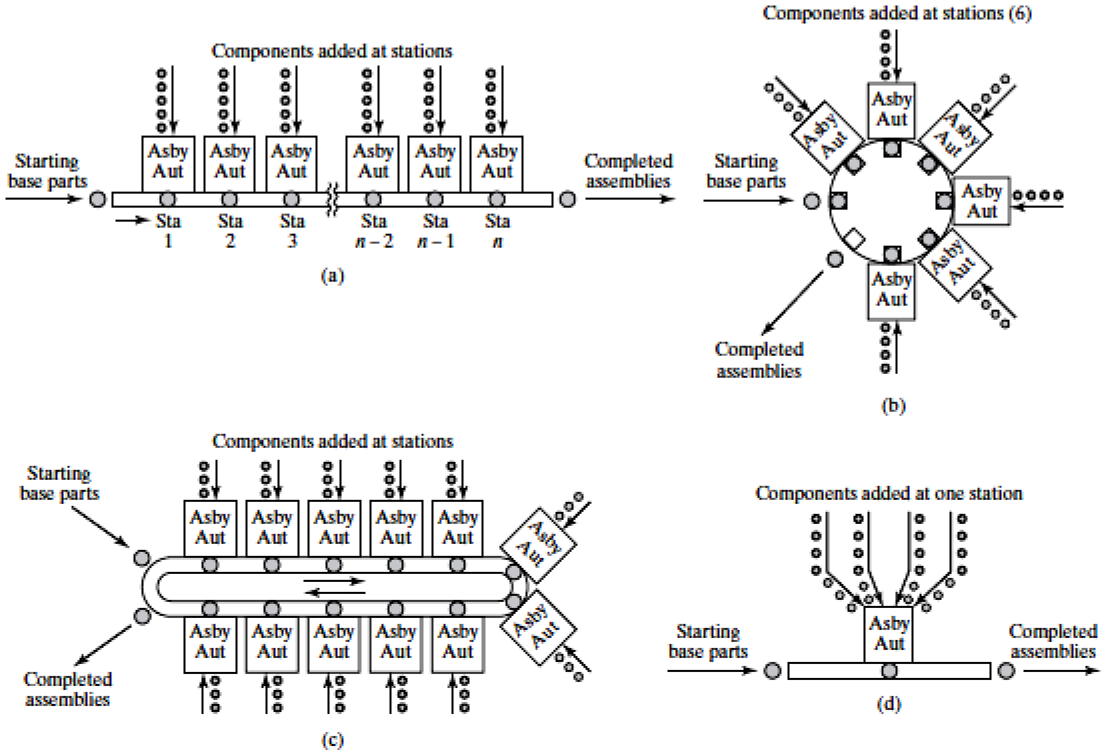


Figure 17.1 Types of automated assembly systems: (a) in-line, (b) dial-type, (c) carousel, and (d) single station.

The in-line assembly machine, Figure 17.1(a), is a series of automatic workstations located along an in-line transfer system. It is the assembly version of the machining transfer line. Synchronous and asynchronous transfer systems are the common means of transporting base parts from station to station with the in-line configuration.

In the typical application of the dial-type machine, Figure 17.1(b), base parts are loaded onto fixtures or nests attached to the circular dial. Components are added and/or joined to the base part at the various workstations located around the periphery of the dial. The dial-indexing machine operates with a synchronous or intermittent motion, in which the cycle consists of the service time plus indexing time. Dial-type assembly machines are sometimes designed to use a continuous rather than intermittent motion. This is common in beverage bottling and canning plants, but not in mechanical and electronics assembly.

The carousel assembly system represents a hybrid between the circular work flow of the dial-type assembly machine and the straight work flow of the in-line system. The carousel configuration can be operated with continuous, synchronous, or asynchronous transfer mechanisms to move the work around the carousel.

In the single-station assembly machine, Figure 17.1(d), assembly operations are performed on a base part at a single location. The typical operating cycle involves the placement of the base part at a stationary position in the workstation, the addition of components to the base, and finally the removal of the completed assembly from the station. An important application of single-station assembly is the component placement machine, widely used in the electronics industry to populate components onto printed circuit boards.

3. A robot is a reprogrammable multi functional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of variety of tasks.

Common robot configurations

1. Polar configuration
2. Cylindrical Configuration
3. Cartesian Configuration
4. Jointed Arm configuration
5. SCARA

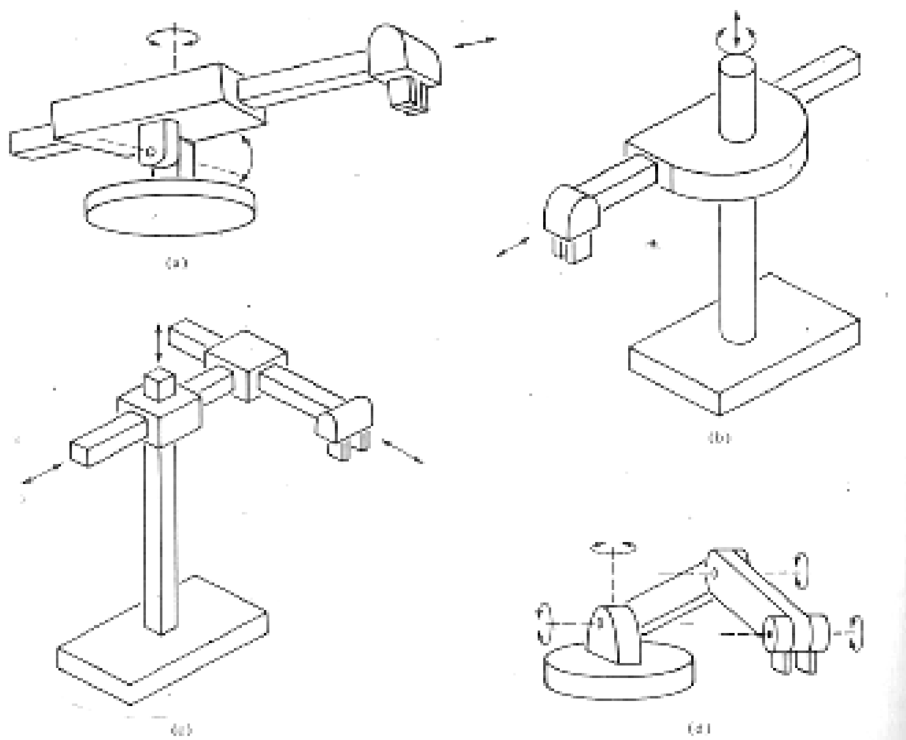


Figure 2-1 The four basic robot anatomies: (a) polar, (b) cylindrical, (c) cartesian, and (d) jointed-arm. (Reprinted from Reference [7].)

1. Polar configuration/Spherical configuration

Notation: [**LTR**]: Linear, Twisting and Rotational joint

This configuration also called as Polar coordinate configuration. It goes by the name "spherical coordinate" also because the workspace within which it can move its arm is a partial sphere as shown in figure. The robot has a rotary base and a pivot that can be used to raise and lower a telescoping arm.

i) Operate within a **spherical** work volume

ii) Has 1 prismatic and 2 revolute axes.

iii) First motion is a base rotation, Second motion correspond to an elbow rotation and Third motion is radial or in-out motion

iv) Elbow rotation and arm reach limit the design of full spherical motion.

v) Rarely used in industries but common in automated cranes.

Notation: [**TLL**]: Twisting, Linear and Linear.

This also has 3 degrees of freedom, 2 prismatic and 1 revolute joints. It moves linearly along X and Y axes and rotaion about at its base i.e. Z- axis. The robot body is a vertical column that swivels about a vertical axis. The arm consists of several orthogonal slides which allow the arm to be moved up or down and in and out with respect to the body. This is illustrated schematically in figure.

Features:

- i) Operate within a **cylindrical** work volume
- ii) 2 prismatic and 1 revolute joints.
- iii) Position is specified by Y value (height) extension of arm X axis and angle of rotation of Z axis (θ)
- iv) Recommended for pick and place operation such as machine loading and unloading.
- v) Lower repeatability and accuracy
- vi) Require more sophisticated control
- vii) Rigid structure & high lift-carrying capacity

3. Cartesian / Rectangular configuration

Notation: [**LOO**]: Linear, Orthogonal, Orthogonal

Cartesian configuration is also called as **Rectilinear or Rectangular** configuration as the joints allow only translational or linear relative motion between the adjacent links of the joint. A robot using such a configuration is called as X-Y-Z robot. Other names are xyz robot or Rectilinear robot or **Gantry robot**. Any point in X, Y and Z coordinate system can be reached using this configuration. By appropriate movements of these slides, the robot is capable of moving its arm at any point within its three dimensional rectangular spaced work space.

Features:

- i) Operate within a **rectangular** work volume
- ii) Three prismatic joints are used.
- iii) The position is specified by X, Y and Z locations.
- iv) Easy to visualize motion
- v) Easy to program the motions
- vi) Adapted in gantry crane and CNC milling machines.
- vii) Gantry type can handle heavy loads.
- viii) Addition axes can be incorporated to the wrist action.
- ix) Difficult to protect the sliding axes from contaminants such as dust and moisture as it is open.

4. Revolute / Articulate / Jointed-arm configuration:

Notation: [**TRR**]: Twisting, Rotational and Rotational joint

It is combination of cylindrical and articulated configurations. This is similar in appearance to the human arm, as shown in fig. the arm consists of several straight members connected by joints which are analogous to the human shoulder, elbow, and wrist. The robot arm is mounted to a base which can be rotated to provide the robot with the capacity to work within a quasi-spherical space.

Features:

i) Operate within a **quasi-spherical** work volume.
ii) All 3 are revolute joints.
iii) Can reach above, below and around obstacles.
iv) Joints can be sealed easily.
v) Difficult to calculate angular motion of the axis for a given top or end motion.

5. SCARA (Selective Compliance Assembly Robot Arm)

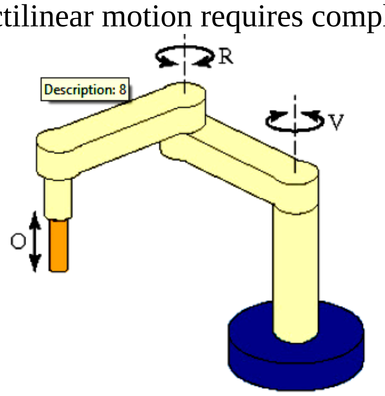
Notation: [**VRL**]: Revolving, Rotational and Linear joint

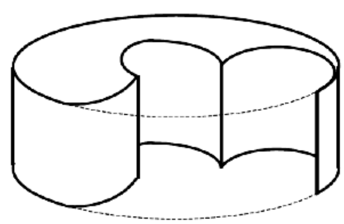
This configuration consists of 1 prismatic and 2 revolute joint. The important features being the relative motion of all the links at the joints are about vertical axes.

SCARA stands for Selective Compliance Assembly Robot Arm. This joint is similar to jointed-arm robot except that vertical axes are used for shoulder and elbow joints to be compliant in horizontal direction for vertical insertion tasks.

Features:

i) Work volume is **cylindrical** in nature
ii) Most common in assembly robot
iii) Arm consists of two horizontal revolute joints at the wrist and elbow and a one prismatic joint
iv) Can reach at any point within horizontal planar defined by two concentric circles
v) Most assembly operations involve building up assembly by placing parts on top of a partially complete assembly
vi) Floor area is small compare to work area
vii) Rectilinear motion requires complex control of the revolute joints





4. An automated production line consists of multiple workstations that are automated and linked together by a work handling system that transfers parts from one station to the next, as depicted in Figure 16.1. A raw work part enters one end of the line, and the processing steps are performed sequentially as the part progresses forward (from left to right in the drawing). The line

may include inspection stations to perform intermediate quality checks. Also, manual stations may be located along the line to perform certain operations that are difficult or uneconomical to automate. Each station performs a different operation, so all operations must be performed to complete each work unit. Multiple parts are processed simultaneously on the line, one part at each station. In the simplest form of production line, the number of parts on the line at any moment is equal to the number of workstations, as in the figure. In more complicated lines, provision is made for temporary parts storage between stations, in which case there are more parts than stations.

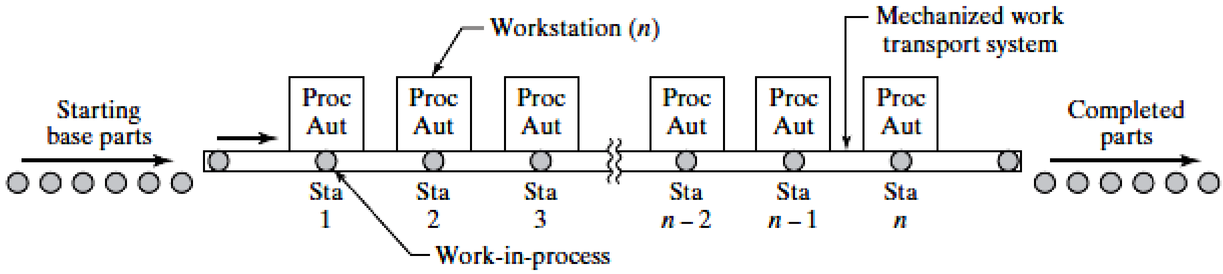


Figure 16.1 General configuration of an automated production line. Key: Proc = processing operation, Aut = automated workstation.

Work Part Transport

The work part transport system moves parts between stations on the line. Transport mechanisms used on automated production lines are usually either synchronous or asynchronous but rarely continuous. Synchronous transport has been the traditional means of moving parts in a transfer line. However, asynchronous transport provides certain advantages over synchronous transport: (1) they are more flexible, (2) they permit queues of parts to form between workstations to act as storage buffers it is easier to rearrange or expand the production line. These advantages come at a higher first cost. Continuous work transport systems, although widely used on manual assembly lines, are uncommon on automated lines due to the difficulty in providing accurate registration between the station work heads and the continuously moving parts.

System Configurations

Although Figure 16.1 shows the flow of work to be in a straight line, the work flow can actually take several different forms: (1) in-line, (2) segmented in-line, and (3) rotary. The in-line configuration consists of a sequence of stations in a straight line arrangement, as in Figure 16.1. This configuration is common for machining big work pieces, such as automotive engine blocks, engine heads, and transmission cases. Because these parts require a large number of operations, a production line with many stations is needed. The in-line configuration can accommodate a large number of stations. In-line systems can also be designed with integrated storage buffers along the flow path

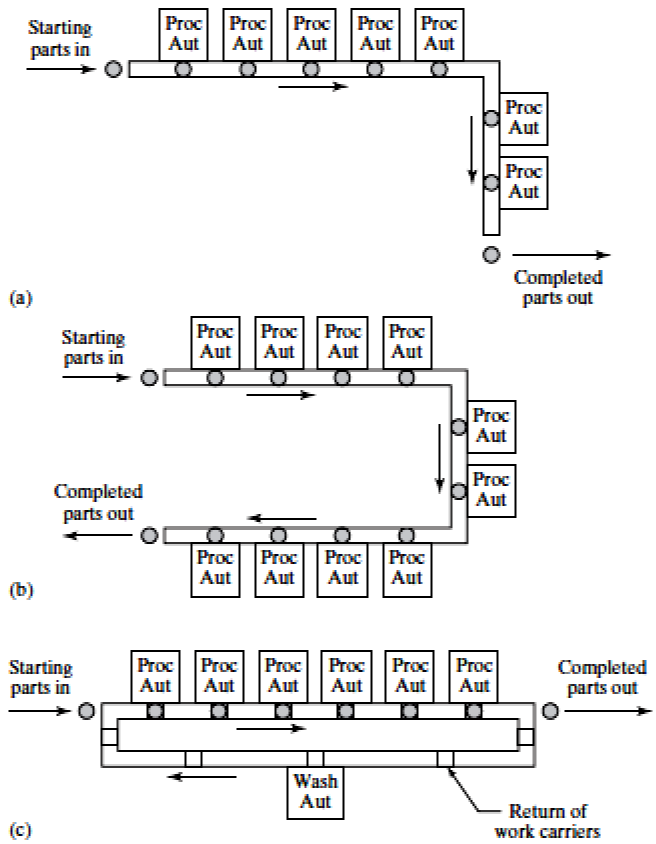


Figure 16.2 Several possible layouts of the segmented in-line configuration of an automated production line: (a) L-shaped, (b) U-shaped, and (c) rectangular. Key: Proc = processing operation, Aut = automated workstation, Wash = work carrier washing station.

The segmented in-line configuration consists of two or more straight-line transfer sections, where the segments are usually perpendicular to each other. Figure 16.2 shows several possible layouts of the segmented in-line category. There are a number of reasons for designing a production line in these configurations rather than in a pure straight line: (1) available floor space may limit the length of the line, (2) a workpiece in a segmented in-line configuration can be reoriented to present different surfaces for machining, and (3) the rectangular layout provides for swift return of work-holding fixtures to the front of the line for reuse.

Figure 16.3 shows two transfer lines that perform metal machining operations on automotive castings. The first line, on the left-hand side, is a segmented in-line configuration in the shape of a rectangle. Pallet fixtures are used in this line to position the starting castings at the workstations for machining. It is a palletized transfer line. The second line, on the right side, is a conventional in-line configuration. When processing on the first line is completed, the parts are manually transferred to the second line, where they are reoriented to present different surfaces for machining. In this line the parts are moved individually by the transfer mechanism, using no pallet fixtures. It is a free transfer line.

5. ROBOT END EFFECTORS

An end effector is a device that attaches to the wrist of the robot arm and enables the general-purpose robot to perform a specific task. It is sometimes referred to as the robot's "hand."

Types of end effectors

The End effectors can be divided into two major categories:

1. Grippers
2. Tools

Grippers are end effectors used to grasp and manipulate objects during the work cycle. The objects are usually work parts that are moved from one location to another in the cell. Machine loading and unloading applications fall into this category. Owing to the variety of part shapes, sizes, and weights, most grippers must be custom designed. Types of grippers used in industrial robot applications include the following:

• *Mechanical grippers*, consisting of two or more fingers that can be actuated by the robot controller to open and close on the work part (Figure 8.10 shows a two-finger gripper)
• *Vacuum grippers*, in which suction cups are used to hold flat objects
• *Magnetized devices*, for holding ferrous parts
• *Adhesive devices*, which use an adhesive substance to hold a flexible material such as a fabric
• *Simple mechanical devices*, such as hooks and scoops.

Tools are end effectors designed to perform work on the part rather than to merely grasp it. By definition, the tool-type end effector is attached to the robot's wrist. One of the most common applications of industrial robots is spot welding, in which the welding electrodes constitute the end effector of the robot. Other examples of robot applications in which tools are used as end effectors include spray painting and are welding.

Applications of Robots

Robots are used in a wide field of applications in industry. Most of the current applications are in manufacturing. The applications can usually be classified into one of the following categories: (1) material handling, (2) processing operations, and (3) assembly and inspection.

Material Handling Applications

In material handling applications, the robot moves materials or parts from one place to another. To accomplish the transfer, the robot is equipped with a gripper that must be designed to handle the specific part or parts to be moved. Included within this application category are (1) material transfer and (2) machine loading and/or unloading. In many material handling applications, the parts must be presented to the robot in a known position and orientation. This requires some form of material handling device to deliver the parts **Material Transfer.** A more complex example of material transfer is ***palletizing***, in which the robot retrieves parts, cartons, or other objects from one location and deposits them onto a pallet or other container at multiple positions on the pallet. Other applications similar to palletizing include ***depalletizing***, which consists of removing parts from an ordered arrangement in a pallet and placing them at another location (e.g., onto a moving conveyor); ***stacking*** operations, which involve placing flat parts on top of each other, such that the vertical location of the drop-off position is continuously changing with each cycle; and ***insertion*** operations, in which the robot inserts parts into the compartments of a divided carton.

Machine Loading and/or Unloading. In machine loading and/or unloading applications, the robot transfers parts into and/or from a production machine. The three possible cases are (1) machine loading, in which the robot loads parts into the production machine, but the parts are unloaded from the machine by some other means; (2) machine unloading, in which the raw materials are fed into the machine without using the robot, and for a robot palletizing operation into the work cell in this position and orientation. the robot unloads the finished parts; and (3) machine loading and unloading, which involves both loading of the raw work part and unloading of the finished part by the robot. Industrial robot applications of machine loading and/or unloading include the following processes:

Processing Operations

In processing applications, the robot performs some operation on a work part, such as grinding or spray painting.

Spot Welding. Spot welding is a metal joining process in which two sheet metal parts are fused together at localized points of contact. Two electrodes squeeze the metal parts together and then a large electrical current is applied across the contact point to cause fusion to occur. The use of industrial robots in this application has dramatically improved the consistency of the welds.

Arc Welding. Arc welding is used to provide continuous welds rather than individual spot welds at specific contact points. The resulting arc-welded joint is substantially stronger than in spot welding. **Spray Coating. Spray coating** directs a spray gun at the object to be coated. Fluid (e.g., paint) flows through the nozzle of the spray gun to be dispersed and applied over the surface of the object. Spray painting is the most common application in the category, but spray coating refers to a broader range of applications that includes painting.

Assembly and Inspection

In some respects, assembly and inspection are hybrids of the previous two categories: material handling and processing. Assembly and inspection can involve either the handling of materials or the manipulation of a tool.

Assembly

Assembly involves the combining of two or more parts to form a new entity, called a subassembly or assembly. The new entity is made secure by fastening the parts together using mechanical fastening techniques (e.g., screws, bolts and nuts, rivets) or joining processes (e.g., welding, brazing, soldering, or adhesive bonding). Industrial robots used for the types of assembly operations described here are typically small, with light load capacities. The most common configurations are jointed arm, SCARA, and Cartesian coordinate.

Inspection.

There is often a need in automated production to inspect the work that is done. Inspections accomplish the following functions: (1) making sure that a given process has been completed, (2) ensuring that parts have been assembled as specified, and (3) identifying flaws in raw materials and finished parts.

6. Continuous Control systems

In continuous control, the usual objective is to maintain the value of an output variable at a desired level, similar to the operation of a feedback control system.

Regulatory Control: In regulatory control, the objective is to maintain process performance at a certain level or within a given tolerance band of that level. This is appropriate, for example, when the performance attribute is some measure of product quality, and it is important to keep the quality at the specified level or within a specified range. In many applications, the performance measure of the process, sometimes called the *index of performance*, must be calculated based on several output variables of the process. Except for this feature, regulatory control is to the overall process what feedback control is to an individual control loop in the process, as suggested by Figure 5.2.

The trouble with regulatory control (and also with a simple feedback control loop) is that compensating action is taken only after a disturbance has affected the process output. An error must be present for any control action to be taken. The presence of an error means that the output of the process is different from the desired value.

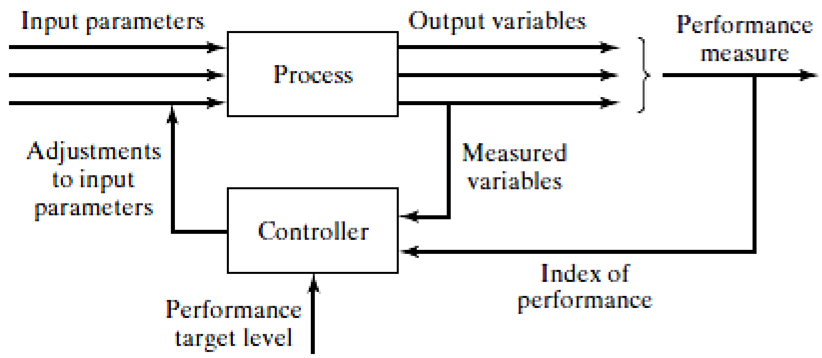


Figure 5.2 Regulatory control.

Feed forward Control. The strategy in feed forward control is to anticipate the effect of disturbances that will upset the process by sensing them and compensating for them before they affect the process. As shown in Figure 5.3, the feed forward control elements sense the presence of a disturbance and take corrective action by adjusting a process parameter that compensates for any effect the disturbance will have on the process. In the ideal case, the compensation is completely effective. However, complete compensation is unlikely because of delays and/or imperfections in the feedback measurements, actuator operations, and control algorithms, so feed forward control is usually combined with feedback control, as shown in the figure. Regulatory and feed forward control are more closely associated with the process industries than with discrete product manufacturing.

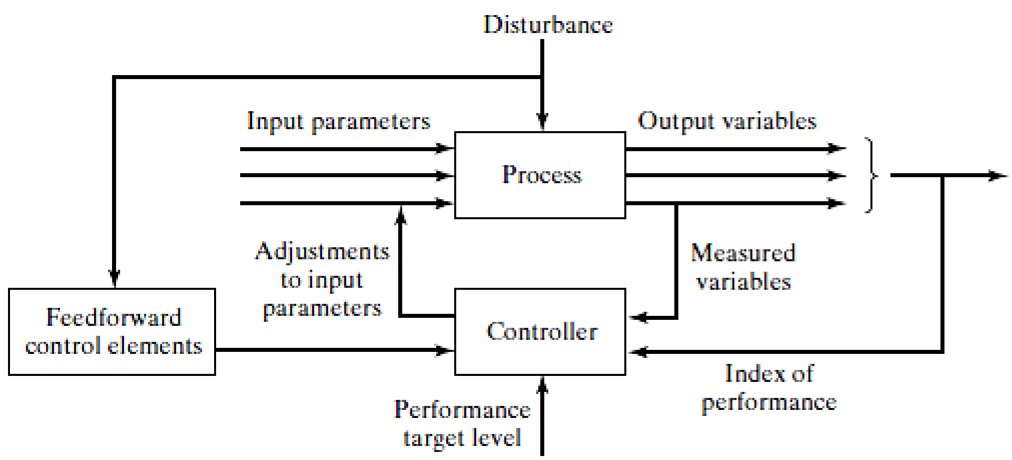


Figure 5.3 Feedforward control, combined with feedback control.

Steady-State Optimization: This term refers to a class of optimization techniques in which the process exhibits the following characteristics: (1) there is a well-defined index of performance, such as product cost, production rate, or process yield; (2) the relationship between the process variables and the index of performance is known; and (3) the values of the system parameters that optimize the index of performance can be determined mathematically. When these characteristics apply, the control algorithm is designed to make adjustments in the process parameters to drive the process toward the optimal state. The control system is open loop, as seen in Figure 5.4. Several mathematical techniques are available for solving steady-state optimal control problems, including differential calculus, calculus of variations, and various mathematical programming methods.

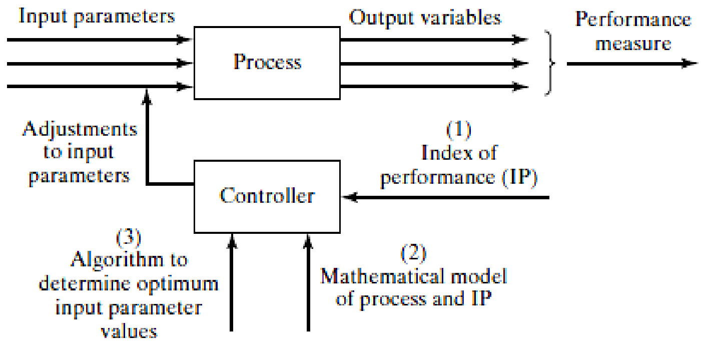


Figure 5.4 Steady-state (open loop) optimal control.

Adaptive Control: Steady-state optimal control operates as an open-loop system. It works successfully when there are no disturbances that invalidate the known relationship between process parameters and process performance. When such disturbances are present in the application, a self-correcting form of optimal control can be used, called *adaptive control*. Adaptive control combines feedback control and optimal control by measuring the relevant process variables during operation (as in feedback control) and using a control algorithm that attempts to optimize some index of performance (as in optimal control).

The general configuration of an adaptive control system is illustrated in Figure 5.5.

To evaluate its performance and respond accordingly, an adaptive control system performs three functions, as shown in the figure:

1. Identification. In this function, the current value of the index of performance of the system is determined, based on measurements collected from the process. Because the environment changes over time, system performance also changes. Accordingly, the identification function must be accomplished more or less continuously over time during system operation.

2. Decision. Once system performance is determined, the next function decides what changes should be made to improve performance. The decision function is implemented by means of the adaptive system's programmed algorithm. Depending on this algorithm, the decision may be to change one or more input parameters, alter some of the internal parameters of the controller, or make other changes.

3. Modification. The third function is to implement the decision. Whereas decision is a logic function, modification is concerned with physical changes in the system. It involves hardware rather than software. In modification, the system parameters or process inputs are altered using available actuators to drive the system toward a more optimal state.

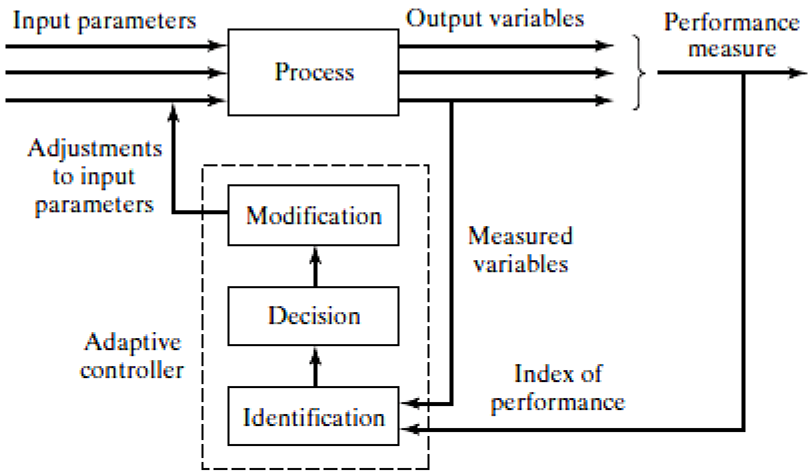


Figure 5.5 Configuration of an adaptive control system.

Discrete Control Systems

In discrete control, the parameters and variables of the system are changed at discrete moments in time, and the changes involve variables and parameters that are also discrete, typically binary (ON/OFF). The changes are defined in advance by means of a program of instructions.