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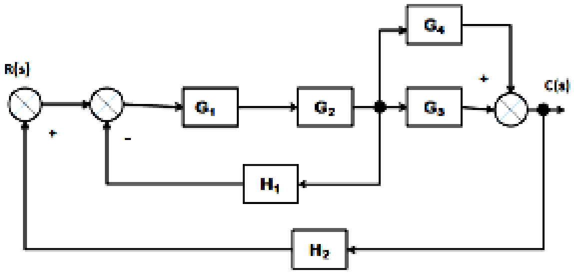
Internal Assessment Test 2 – Oct. 2018

Sub:	Automation & Robotics					Sub Code:	15ME563	Branch:	Mech
Date:	17.10.18	Duration:	90 min's	Max Marks:	50	Sem / Sec:	V/A&B		OBE

	Answer all the Questions	MARKS	CO	RBT
1	Derive the characteristic equation for a spring-mass and damper system subjected to a force "F" and find out the transfer function for the same.	[10]	CO3	L3
	(Or)			
2	Describe with a neat sketch open-loop and closed-loop systems and write the transfer function.	[10]	CO3	L2
3	Using a block diagram, explain the P-D and P-I-D controllers.	[10]	CO3	L2
	(Or)			
4	Using Block diagram algebra, reduce the following system and find out the transfer function.	[10]	CO3	L3



5	Write Short notes on Encoders and Resolvers.	[10]	CO3	L2
	(Or)			
6	Discuss briefly about various power transmission systems used in Robotics.	[10]	CO3	L2
7.	Explain the principle and working of Vidicon camera tube with a neat sketch.	[10]	CO4	L2
	(Or)			
8.	Briefly explain the application of Tactile sensors in robotics with an example.	[10]	CO4	L2
9.	Discuss briefly about Image processing and analysis in machine vision.	[10]	CO4	L2
	(Or)			
10.	Briefly explain the application of sensors in Robotics.	[10]	CO4	L2

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Solution Key

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Q.No	Solution

1.a)

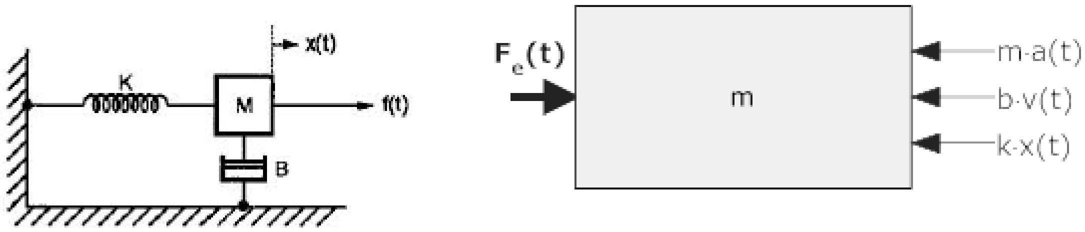


Fig a) Spring-mass damper system b) Free body diagram

Consider a simple system with a mass that is separated from a wall by a spring and a dashpot. An external force is also shown. Only horizontal motion and forces are considered.

Due to the applied force, mass (M) will be displaced by an amount x(t), in the direction of force f(t) as shown in fig.

There are four forces:

1. An external force - F(t)
2. A force from the spring. To determine the direction consider that the position "*x*" is defined positive to the right. If the mass moves in the positive "*x*" direction, the spring is compressed and exerts a force on the mass. So there will be a force from the spring, *k·x*, to the left.
3. A force from the dashpot. By an argument similar to that for the spring there will be a force from the dashpot, *b·v*, to the left. (The velocity, v, is the derivative of x with respect to time.)
4. Finally, there is the inertial force which is defined to be opposed to the defined direction of motion. This is represented by *m.a* to the left. (The acceleration, a, is the second derivative of x with respect to time.

According to Newton’s law of motion, sum of all these forces is equal to zero.

$$\sum_{\text{all}} F = 0$$

$$F_e(t) - ma(t) - bv(t) - kx(t) = 0$$

$$m\frac{d^2x(t)}{dt^2} + b\frac{dx(t)}{dt} + kx(t) = F_e(t)$$

Taking Laplace transformation of above equation,

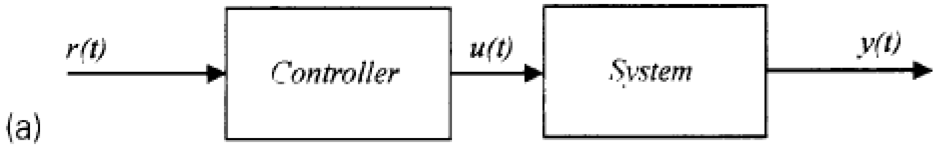
$$F(s) = Ms^2\,X(s) + Bs\,X(s) + K\,X(s)$$

$$= X(s)\,\{Ms^2 + Bs + K\}$$

$$\frac{F(s)}{X\,(s)} = Ms^2 + Bs + K$$

1.b)

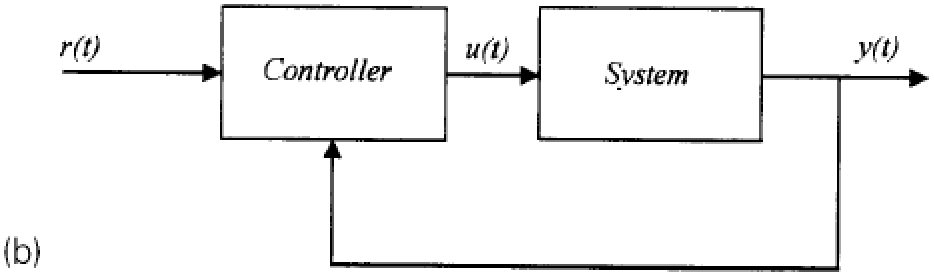
a) Open loop systems



An open-loop system (Figure 1.4a) is a system whose input *u(t)* does not depend on the output *y(t)* , i.e *u(t)* is not a function of *y(t)*.

b) Closed loop systems

A closed-loop system (Figure 1.4b) is a system whose input *u(t)* depends on the output *y(t)*.



In control systems, the control signal *u(t)* is not the output of a signal generator, but the output of another new additional component that we add to the system under control. This new component is called controller (and in special cases regulator or compensator).

In control systems, the controller is excited by an external signal *r(t)*, which is called the reference or command signal. This reference signal *r(t)* specifies the desired performance (i.e., the desired ouput *y(t)*) of the open- or closed-loop system. That is, in control systems, we aim to design an appropriate controller such that the output *y(t)* follows the command signal *r(t)* as close as possible.

In particular, in open-loop systems the controller is excited only by the reference signal *r(t)* and it is designed such that its output *u(t)* is the appropriate input signal to the system under control, which in turn will produce the desired output *y(t)*.

In closed-loop systems, the controller is excited not only by reference signal *r(t)* but also by the output *y(t)*. Therefore, in this case the control signal *u(t)* depends on both *r(t)* and *y(t)*.

Transfer function

The *transfer function* of a linear, time-invariant, differential equation system is defined as the ratio of the Laplace transform of the output (response function) to the Laplace transform of the input (driving function) under the assumption that all initial conditions are zero.

$$\text{Transfer function} = G(s) = \left.\frac{\mathcal{L}[\text{output}]}{\mathcal{L}[\text{input}]}\right|_{\text{zero initial conditions}}$$

2.a)

PROPORTIONAL PLUS DERIVATIVE CONTROLLER (PD-CONTROLLER)

The proportional plus derivative controller produces an output signal consisting of two terms : *one proportional to error signal and the other proportional to the derivative of error signal.*

$$\text{In PD - controller, } u(t) \; \alpha \; \left[e(t) + \frac{d}{dt} e(t) \right] ; \qquad \therefore u(t) = K_p \, e(t) + K_p T_d \frac{d}{dt} e(t) \qquad .(2.122)$$

where, K_p = Proportional gain

T_d = Derivative time

On taking Laplace transform of equation (2.123) with zero initial conditions we get,

$$U(s) = K_p \, E(s) + K_p \, T_d \, sE(s) \qquad .....(2.123)$$

$$\boxed{\therefore \text{ Transfer function of PD - controller, } \frac{U(s)}{E(s)} = K_p(1 + T_d s)} \qquad .....(2.124)$$

The equation (2.123) gives the output of the PD-controller for the input E(s) and equation (2.124) is the transfer function of PD-controller.

The block diagram of PD-controller is shown in fig 2.32.

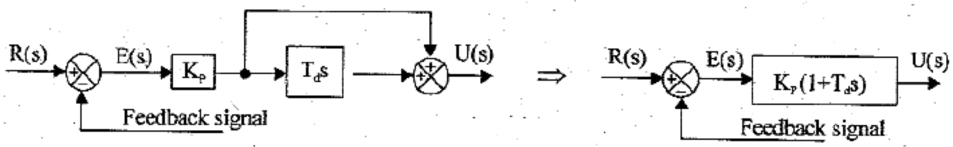


Fig 2.32 : Block diagram of PD- controller.

The derivative control acts on rate of change of error and not on the actual error signal. The derivative control action is effective only during transient periods and so it does not produce corrective measures for any constant error. Hence the derivative controller is never used alone, but it is employed in association with proportional and integral controllers. The derivative controller does not affect the steady-state error directly but anticipates the error, initiates an early corrective action and tends to increase the stability of the system. While derivative control action has an advantage of being anticipatory it has the disadvantage that it amplifies noise signals and may cause a saturation effect in the actuator.

The derivative control action is adjusted by varying the derivative time. The change in the value of K_p affects both the proportional and derivative parts of control action. The derivative control is also called ***rate control.***

PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROLLER (PID-CONTROLLER)

The PID-controller produces an output signal consisting of three terms : *one proportional to error signal, another one proportional to integral of error signal and the third one proportional to derivative of error signal.*

$$\text{In PID - controller, } u(t) \; \alpha \; \left[e(t) + \int e(t) \, dt + \frac{d}{dt} e(t) \right]$$

$$\therefore u(t) = K_p \, e(t) + \frac{K_p}{T_i} \int e(t) dt + K_p T_d \frac{d}{dt} e(t) \qquad .....(2.134)$$

where, K_p = Proportional gain

T_i = Integral time

T_d = Derivative time

On taking Laplace transform of equation (2.134) with zero initial conditions we get,

$$U(s) = K_p E(s) + \frac{K_p}{T_i} \frac{E(s)}{s} + K_p \, T_d \, s \, E(s) \qquad .....(2.135)$$

$$\boxed{\therefore \text{ Transfer function of PID - controller, } \frac{U(s)}{E(s)} = K_p \left(1 + \frac{1}{T_i s} + T_d s \right)} \qquad .....(2.136)$$

The equation (2.135) gives the output of the PID-controller for the input E(s) and equation (2.136) is the transfer function of the PID-controller. The block diagram of PID-contoller is shown in fig 2.36.

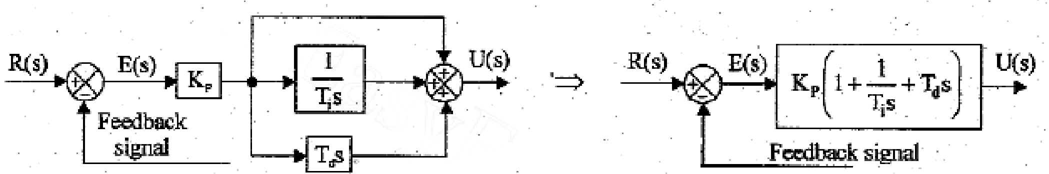
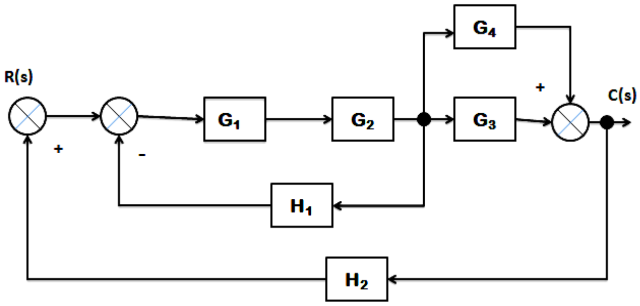


Fig 2.36: Block diagram of PID- controller.

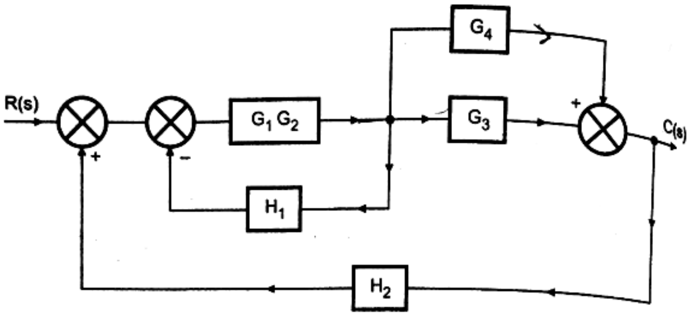
The combination of proportional control action, integral control action and derivative control action is called PID-control action. This combined action has the advantages of the each of the three individual control actions.

The proportional controller stabilizes the gain but produces a steady state error. The integral controller reduces or eliminates the steady state error. The derivative controller reduces the rate of change of error.

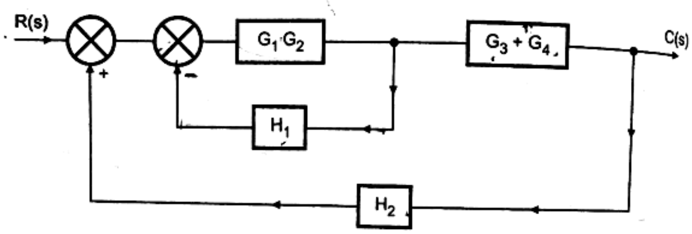
2.b)



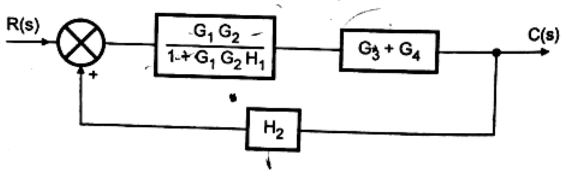
Sol. : Combine block G_1, G_2 which are in series.

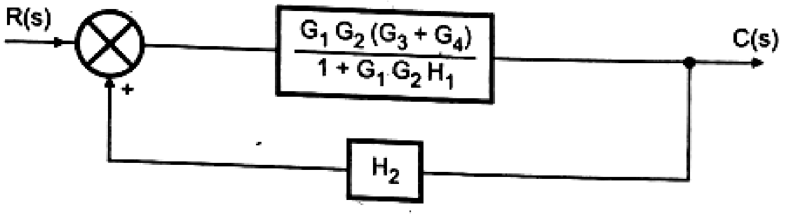


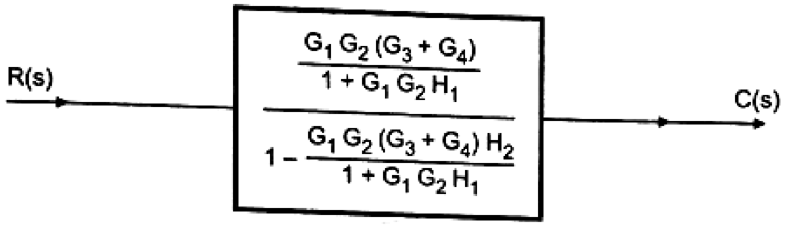
Combine blocks G_3, G_4 which are in parallel.



Reduce minor feedback loop of $G_1 G_2$ and H_1







$$\frac{C(s)}{R(s)} = \frac{G_1 \; G_2 (G_3 + G_4)}{1 + G_1 G_2 H_1 - G_1 G_2 (G_3 + G_4) H_2}$$

3.a) **Resolvers**

A resolver is another type of analog device whose output is proportional to the angle of a rotating element with respect to a fixed element. In its simplest form a resolver has a single winding on its rotor and a pair of windings on its stator. The stator windings are 90° apart as shown in Fig. If the rotor-is excited with a signal of the type *A sin (ωt),* voltage across two stator terminals are given by the expression,

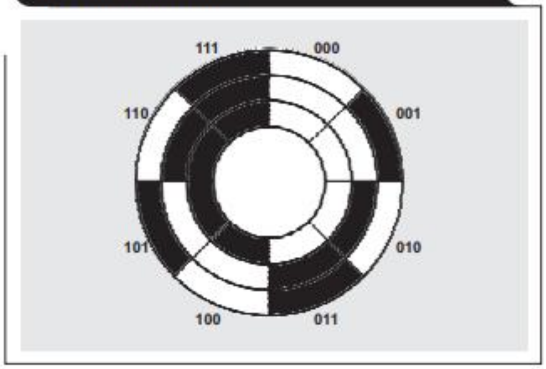
$$V_{s1}(t) = A \sin(\omega t) \sin \theta$$

$$V_{s_2}(t) = A \sin(\omega t) \cos \theta$$

Encoders

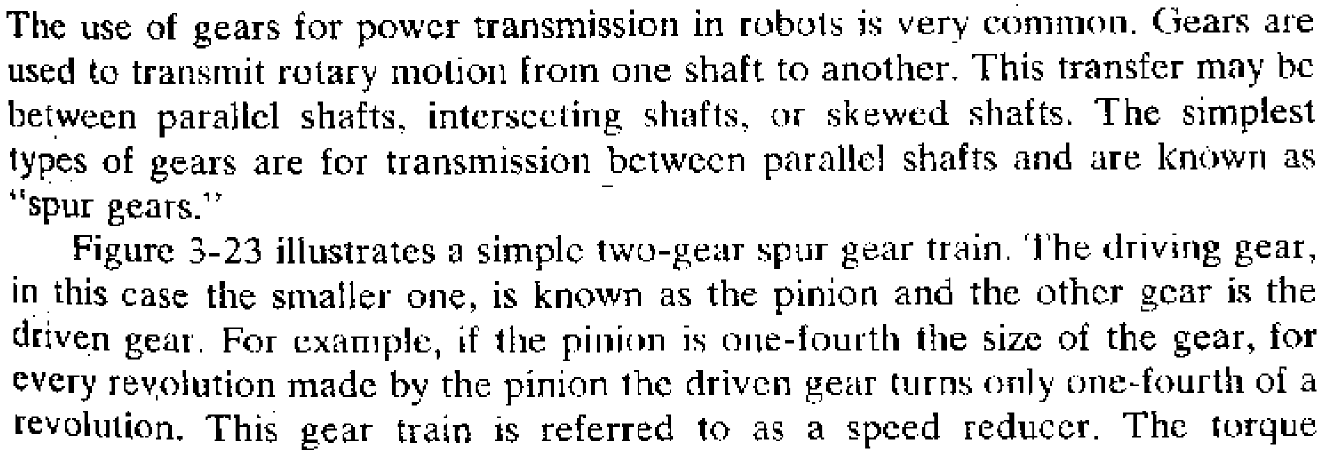
In a typical encoder, there are two sets of photo transmitters and receivers aligned 90º out of phase. This phasing provides direct information; i.e, if signal A leads signal B by 90º, the encoder disk is rotating in one direction; if B leads A, then it is going in other direction. By counting the pulses and by adding or subtracting based on sign, it is possible to use the encoder to provide the position information with respect to a known starting location.

Figure 4. Example of 3-bit absolute position value rotary encoder



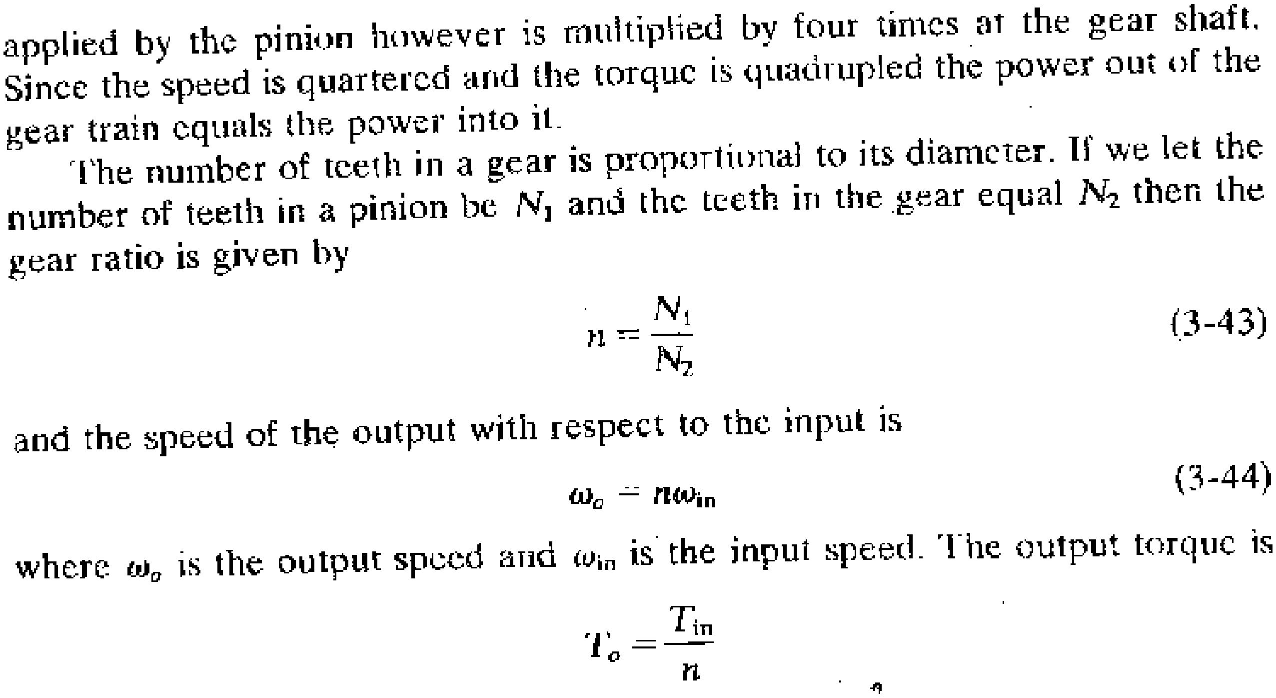
3.b)

Power Transmission systems
Gears:



The use of gears for power transmission in robots is very common. Gears are used to transmit rotary motion from one shaft to another. This transfer may be between parallel shafts, intersecting shafts, or skewed shafts. The simplest types of gears are for transmission between parallel shafts and are known as "spur gears."

Figure 3-23 illustrates a simple two-gear spur gear train. The driving gear, in this case the smaller one, is known as the pinion and the other gear is the driven gear. For example, if the pinion is one-fourth the size of the gear, for every revolution made by the pinion the driven gear turns only one-fourth of a revolution. This gear train is referred to as a speed reducer. The torque



applied by the pinion however is multiplied by four times at the gear shaft. Since the speed is quartered and the torque is quadrupled the power out of the gear train equals the power into it.

The number of teeth in a gear is proportional to its diameter. If we let the number of teeth in a pinion be N_1 and the teeth in the gear equal N_2 then the gear ratio is given by

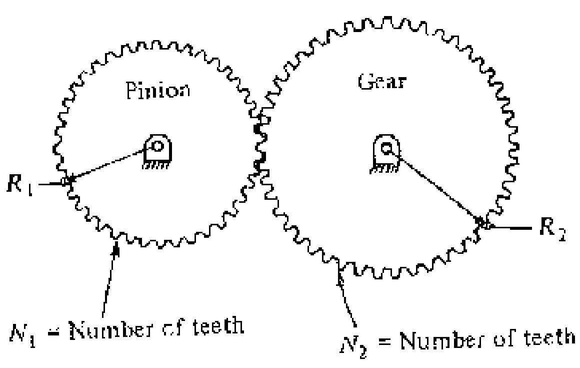
$$n = \frac{N_1}{N_2} \qquad (3\text{-}43)$$

and the speed of the output with respect to the input is

$$\omega_o = n\omega_{in} \qquad (3\text{-}44)$$

where ω_o is the output speed and ω_{in} is the input speed. The output torque is

$$T_o = \frac{T_{in}}{n}$$



$n = N_1/N_2$

4.a)

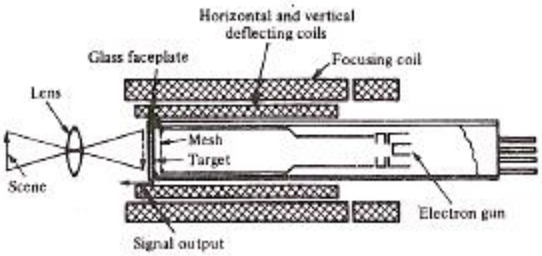


Figure 7-2 Cross section of a videcon tube and its associated deflection and focusing tube. (Rer with permission of McGraw-Hill, Inc. [10].)

device (CCD).

Figure 7-2 illustrates the vidicon camera. In the operation of this system, the lens forms an image on the glass faceplate of the camera. The faceplate has an inner surface which is coated with two layers of material. The first layer consists of a transparent signal electrode film deposited on the faceplate of the inner surface. The second layer is a thin photosensitive material deposited over the conducting film. The photosensitive layer consists of a high density of small areas. These areas are similar to the pixels mentioned previously. Each area generates a decreasing electrical resistance in response to increasing illumination. A charge is created in each small area upon illumination. An electrical charge pattern is thus generated corresponding to the image formed on the faceplate. The charge accumulated for an area is a function of the intensity of impinging light over a specified time.

Once a light sensitive charge is built up, this charge is read out to produce a video signal. This is accomplished by scanning the photosensitive layer by an electron beam. The scanning is controlled by a deflection coil mounted along the length of the tube. For an accumulated positive charge the electron beam deposits enough electrons to neutralize the charge. An equal number of electrons flow to cause a current at the video signal electrode. The magnitude of the signal is proportional to the light intensity and the amount of time with which an area is scanned. The current is then directed through a load resistor which develops a signal voltage which is further amplified and analyzed. Raster scanning eliminates the need to consider the time at each area by making the scan time the same for all areas. Only the intensity of the impinging light is considered. In the United States, the entire faceplate is scanned approximately 30 frames per second. The European standard is 25 frames per second. Raster scanning is typically done by scanning the electron beam from left to right and top to bottom. The process is such that the system is designed to start the integration with zero accumulated charge. For the fixed scan time the charge accumulated is proportional to the intensity of that portion of the image being considered. The output of the camera is a continuous voltage signal for each line scanned. The voltage signal for each scan line is subsequently sampled and quantized resulting in a series of sampled voltages being stored in digital memory. This analog-to-digital conversion process for the complete screen (horizontal and vertical) results in a two-dimensional array of picture elements (pixels). Typically, a single pixel is quantized to between 6 and 8 bits by the A/D converter.

4.b)

Tactile array sensors A tactile array sensor is a special type of force sensor composed of a matrix of force-sensing elements. The force data provided by this type of device may be combined with pattern recognition techniques to describe a number of characteristics about the impression contacting the array sensor surface. Among these characteristics are (1) the presence of an object, (2) the object's contact area, shape, location, and orientation, (3) the pressure and pressure distribution, and (4) force magnitude and location. Tactile array sensors can be mounted in the fingers of the robot gripper or attached to a work table as a flat touch surface. Figures 6-3 and 6-4 illustrate these two possible mountings for the sensor device.

The device is typically composed of an array of conductive elastomer pads. As each pad is squeezed its electrical resistance changes in response to the amount of deflection in the pad, which is proportional to the applied force. By measuring the resistance of each pad, information about the shape of the object against the array of sensing elements can be determined. The operation of a tactile array sensor (with an 8 × 8 matrix of pressure-sensitive pads) is pictured in Fig. 6-5. In the background is the CRT monitor display of the tactile impression made by the object placed on the surface of the sensor device. As the number of pads in the array is increased the resolution of the displayed information improves.

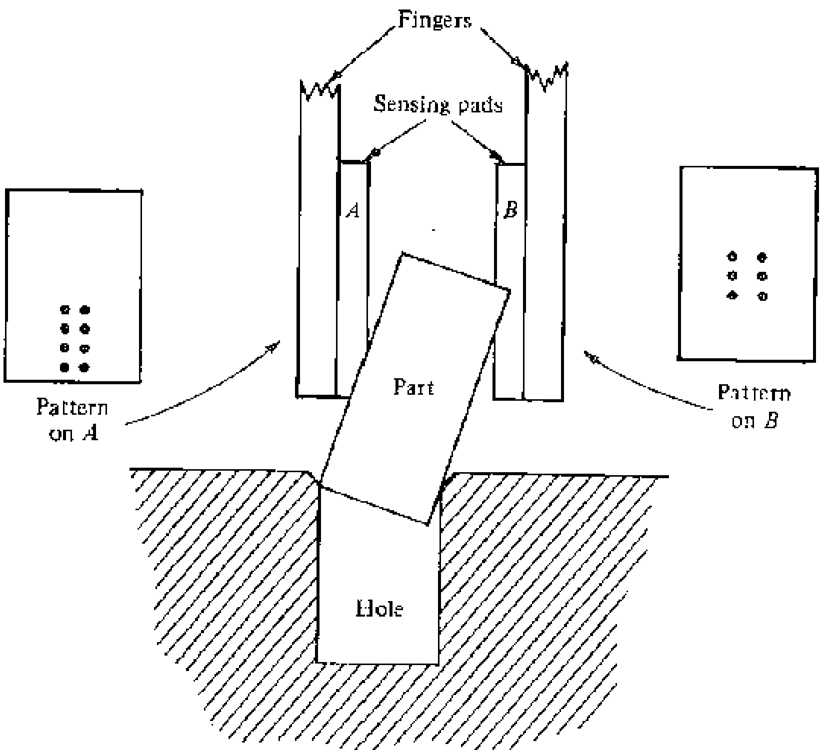


Figure 6-6 Possible binding action in an insertion task of Example 6-1 showing pattern of forces of the tactile array sensor surfaces.

an 80 by 80 pattern of sensor elements, making a total of 6400 sensitive sites. Each sensor has gray scale capability to allow force magnitude to be measured at each sensor location on the surface. The principal application foreseen for this product is for location and orientation of components in robotic assembly operations.

5.a)

1. Image data reduction
2. Segmentation
3. Feature extraction
4. Object recognition

Image Data Reduction

In image data reduction, the objective is to reduce the volume of data. As a preliminary step in the data analysis, the following two schemes have found common usage for data reduction:

1. Digital conversion
2. Windowing

The function of both schemes is to eliminate the bottleneck that can occur from the large volume of data in image processing.

Segmentation

Segmentation is a general term which applies to various methods of data reduction. In segmentation, the objective is to group areas of an image having similar characteristics or features into distinct entities representing parts of the image. For example, boundaries (edges) or regions (areas) represent two natural segments of an image. There are many ways to segment an image.

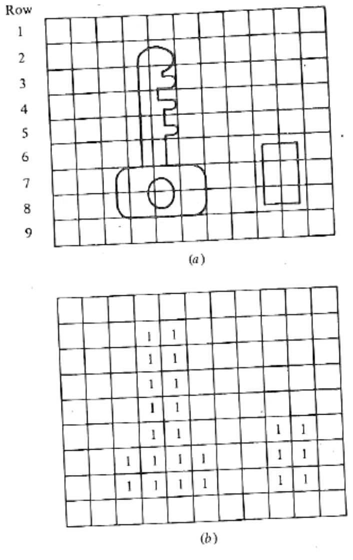


Figure 7-7 Image segmentation (a) image pattern with grid. (b) segmented image after runs test.

5.b)

Applications of sensors in Robotics

The major uses of sensors in industrial robotics and other automated manufacturing systems can be divided into four basic categories:

1. Safety monitoring
2. Interlocks in work cell control
3. Part inspection for quality control
4. Determining positions ‘and related information about objects in the robot cell

Safety Monitoring

Certain safety features can be designed into the robot work cell. These include physical barriers to limit intrusion into the cell, emergency stop buttons to halt the cell operation and laying out the equipment in the cell for maximum safety. The National Bureau of standards defines three levels of safety sensor systems in robotics.

Level- 1: Perimeter penetration detection
Level- 2: Intruder detection inside the work cell
Level- 3: Intruder detection in the immediate vicinity of the robot.

The first level systems are intended to detect that an intruder has crossed the perimeter boundary of the work cell without regard to the location of the intruder. Level-2 systems are designed to detect the presence of an intruder in the region between the work cell boundary and the limit of the robot work volume. Level-3 systems provide intruder detection inside the work volume of the robot.

Interlocks in work cell control

Interlocks are used to coordinate the sequence of activities of the different pieces of equipment in the work cell. In the execution of the robot program, there are certain elements of the work cycle whose completion must be verified before proceeding with the next element in the cycle.

Part inspection for quality control

Sensors can be used to determine a variety of part quality characteristics. Traditionally, quality control has been performed using manual inspection techniques on a statistical sampling basis. The use of sensors permits the inspection operation to be performed automatically on a 100 percent basis, in which every part is inspected. The limitation on the use of automatic inspection is that the sensor system can only inspect for a limited range of part characteristics and defects. For, example, a sensor probe designed to measure part length cannot detect flaws in the part surface.

Determining positions and related information about objects in the robot cell

The fourth major use of sensors in robotics is to determine the positions and other information about various objects in the work cell (e.g., work parts, fixtures, people, equipment, etc.). In addition to positional data about a particular object, other information required to properly execute the work cycle might include the object’s orientation, color, size, and other characteristics. Reasons why this kind of data would need to be determined during the program execution include:

Work part identification.

Random position and orientation of parts in the work cell.

Accuracy requirements in a given application exceed the inherent capabilities of the robot. Feedback information is required to improve the accuracy of the robot’s positioning.

An example of workpart identification would be in a work cell in which the robot processes several types of workparts, each requiring a different sequence of actions by the robot. Each part presented to the robot would have to be properly identified so that the correct subroutine could be called for execution. This type of identification problem arises in automobile body spot-welding lines where the line is designed to weld several different body styles (e.g., coupes, sedans, wagons). Each welding robot along the line must execute the welding cycle for the particular body style at that station. Simple optical sensors are typically used to indicate the presence or absence of specific body style features in order to make the proper identification.