7 Robot Sensors and Vision

7.1 INTRODUCTION

The interaction of the robot with the environment set-ups needs mechanisms known as sensors, that can perform the following functions :

- Motion control variables, detection.
- Robot guidance without obstruction.
- Object identification tasks.
- Handling the objects.

The sensors that provide the informations like joint position, velocity and acceleration are known as internal state sensors.

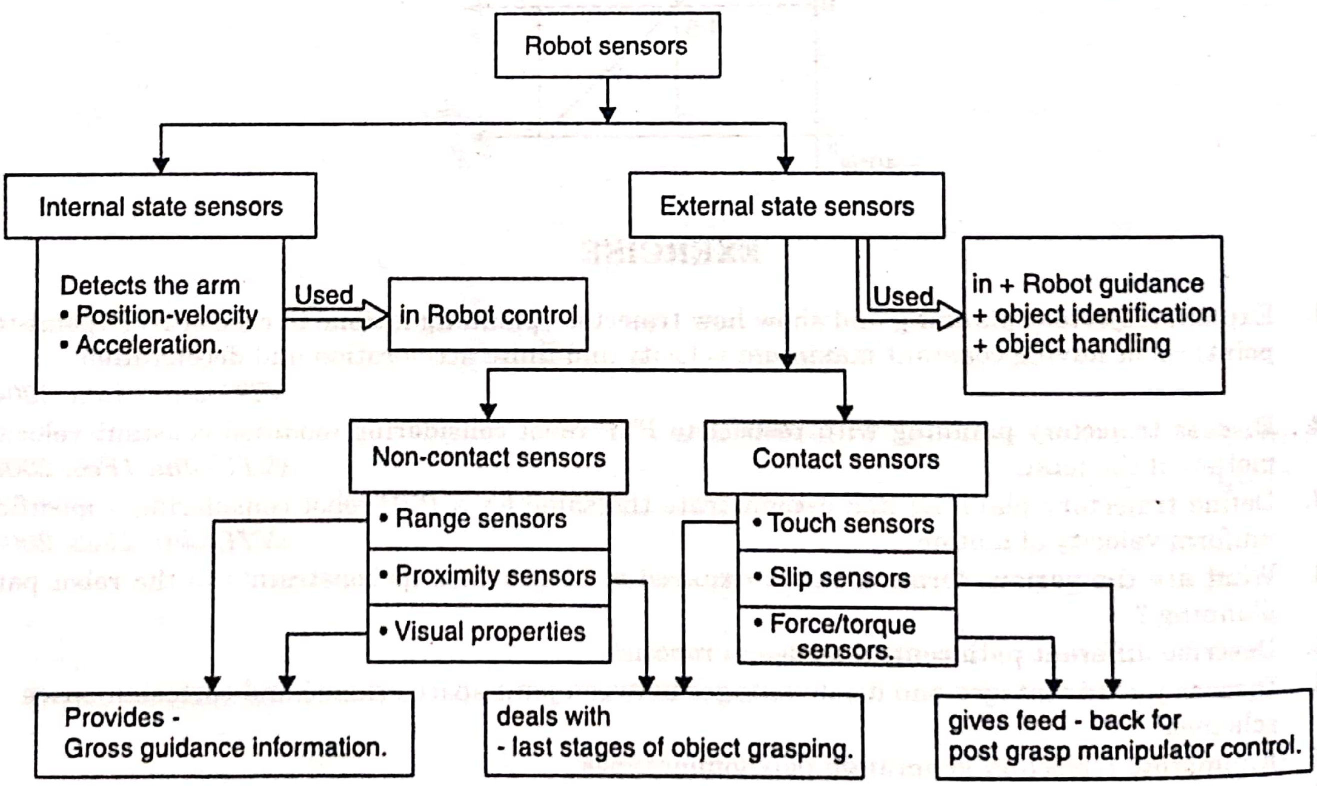
The robots are being guided by the help of vision and range sensors that are known as non-contact external state sensors.

The task of object identification is done by proximity and touch sensors known as contact type external state sensors.

The informations of object handling are supplied as a feedback from force and torque sensors termed as contact type internal state sensors.

The brief classification of sensors based on functions is given in section 7.2.

7.2 CLASSIFICATION OF SENSORS AND THEIR FUNCTIONS



7.3 TOUCH SENSORS

The touch sensors gather the informations established by the contact between the parts to be handled and the fingers in the manipulator end effectors. The signals of touch informations are useful in

- locating the objects.
- recognising the object type.
- Force and torque control needed for task manipulation.

The Types of Touch Sensors are :

1. *Binary sensors* detect the existence of the object to be handled. For example, micro-switches and limit switches.
2. *Analog sensors* produce proportional output signal for the force exerted locally. For example, a code wheel with a plunger.

A useful application of binary sensors is to use it on a robot engaged in contact inspection of the parts. A robot with six degree of freedom can provide higher manuarability compared to three axis co-ordinate measuring machine.

7.4 BINARY SENSORS

The devices that deliver sensing signal by contact at two gripping points are termed the binary sensors. The fingers as shown in Fig. 7.1. accommodate the binary sensors. The contact with the parts results in deflection and this information is sufficient to determine the presence of the object between the fingers. The proper grasping and manipulation of the object in the work envelope can be easily achieved through centering of the fingers assisted by the information given by binary sensors.

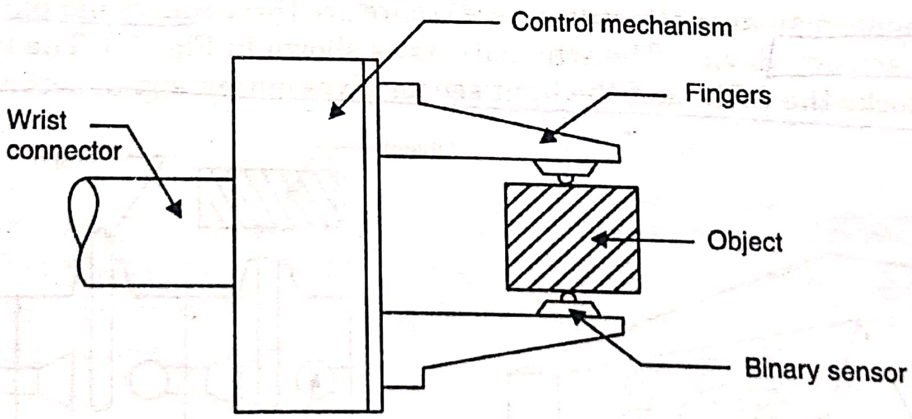


Fig. 7.1. Hand with Binary Sensors.

7.5 ANALOG SENSORS

This type of sensors are featured by spring actuated plunger connected to a code wheel. The deflection of the plunger rod by the action of contact force, results in rotation of the wheel which gives an output proportional to the sensors force. The schematic arrangement of the analog sensor is as shown in Fig. 7.2.

If k is the spring rate and δ is the deflection of the plunger recorded, the force of contact is given by

$$F = k\,\delta. \qquad ...(7.1)$$

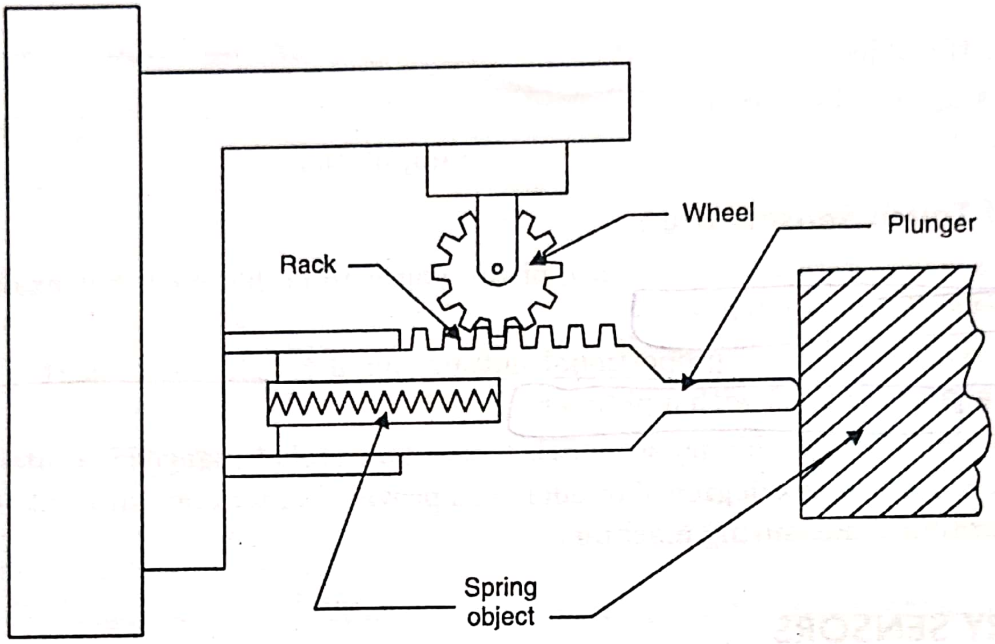


Fig. 7.2. Analog Sensor.

7.6 TACTILE SENSORS

An array of touch sensors arranged systematically to provide information about the contact of the fingers with the object is called the tactile sensors. The special tactile sensors also provide additional informations like shape, size and the type of material of the objects.

Each element in an array (tactile sensor) there are three functional parts : A plunger, a LED and a light sensing device. The schematic is as shown in Fig. 7.3. The movement of the plunger opens/blocks the LED, and the light sensor gives output signal accordingly.

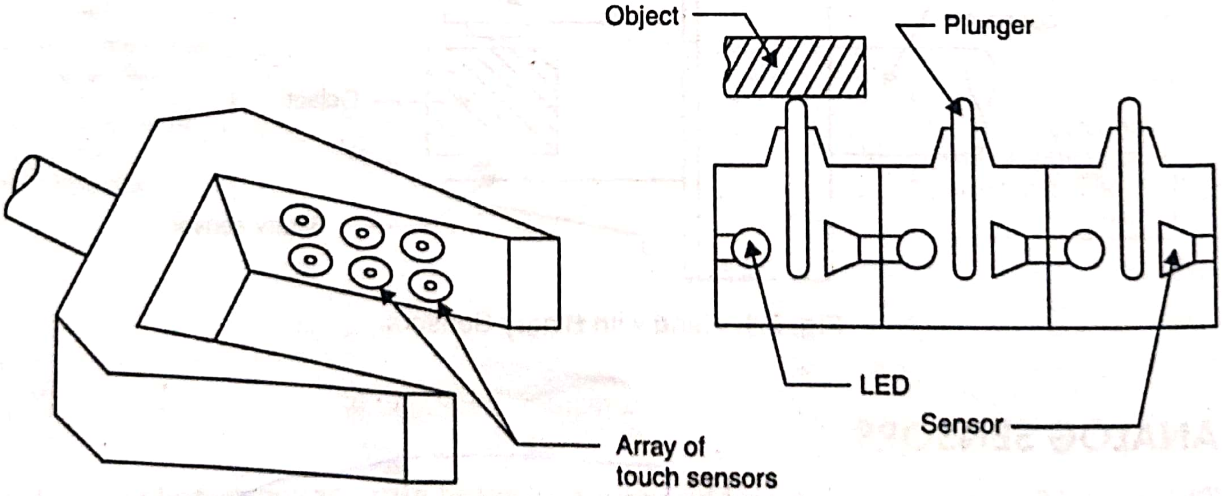


Fig. 7.3. Tactile Sensors.

7.7 DESIRABLE FEATURES FOR SENSORS AND TRANSDUCERS

Features	*Functions*
• Precision	→ Should be as high as possible. → Deviation in measurement reading should be minimum.
• Accuracy	→ Should be as high as possible. → Error between sensed value and actual value should approach zero.
• Speed of response	→ Time taken to respond to variation should be minimum. → Response to be instaneous.
• Operating range	→ Range operating to be wide. → Accuracy over the range to be acceptable.
• Reliability	→ The life to be high. → Frequent failures are not acceptable.
• Calibration	→ Should be easy to calibrate. → Drift to be minimum. → Should take less time to calibrate without much trouble.
• Cost and ease	→ The cost of purchase should be low. → The installation and operation should be easy and less costly.

7.8 PROXIMITY SENSORS

Imp *

The output of the proximity sensors gives an indication of the presence of an object with in the vicinity job operation. In robotics these sensors are used to generate information of object grasping and obstacle avoidance. This section deals with some of the important proximity sensors used in robotics.

• Inductive Sensors

** Principle*

The ferromagnetic material brought close to this type of sensor results in change in position of the flux lines of the permanent magnet leading to change in inductance of the coil. The induced current pulse in the coil with change in amplitude and shape is proportional to rate of change of flux line in magnet.

** Construction*

The proximity inductive sensor basically consists of a wound coil located infront of a permanent magnet encased inside a rugged housing. The leads from the coil, embedded in resin is connected to the display through a connector. The schematic is as shown in Fig. 7.4.

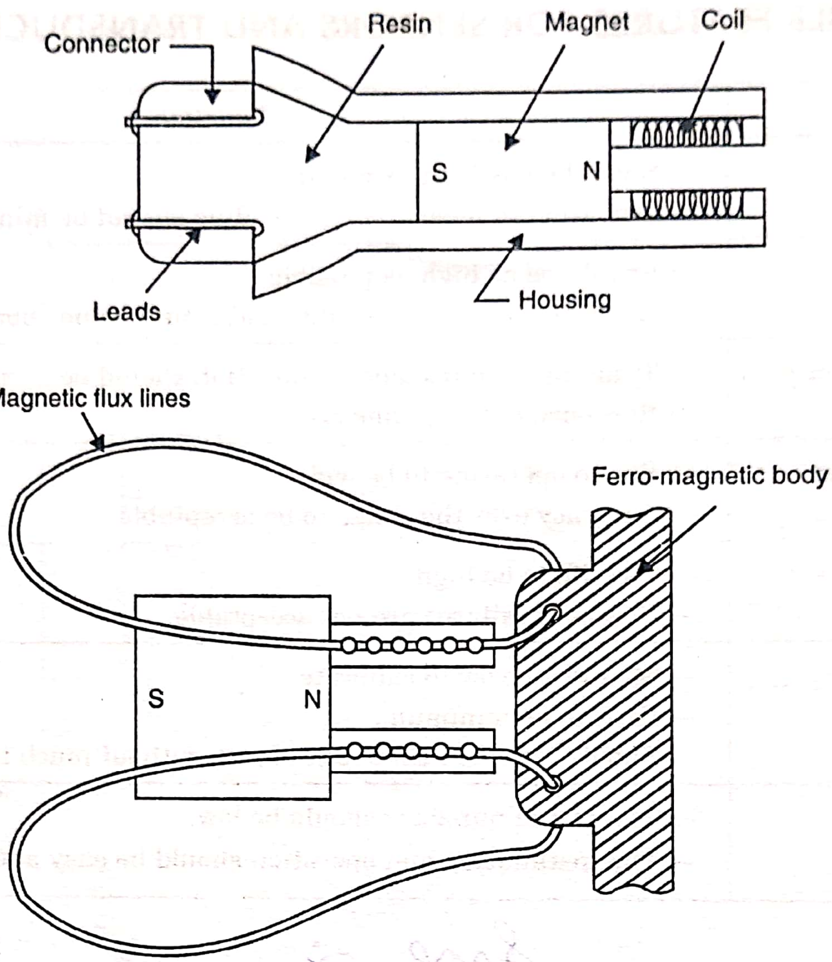


Fig. 7.4. Inductive Sensor.

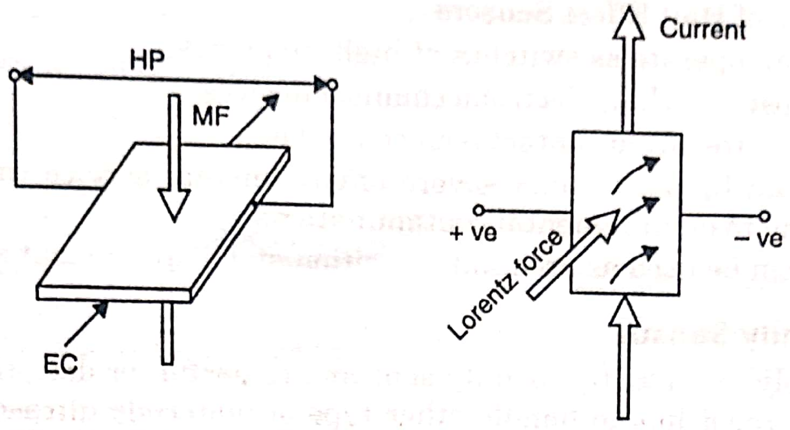
• Hall-Effect Sensors

** Principle*

Hall-Effect deals with the voltage between the two points in a conductor which changes by the near field of the magnetised or ferromagnetic material. The sensor experiences a weakened magnetic field in the close proximity of a ferromagnetic materials, due to the bending of the flux lines of the magnet through approaching object.

E.R. Hall in 1879 discovered Hall Effect, which states that "A beam of charged particles passing through a magnetic field experiences a force that deflect the beam from the straight line path".

Electrons (negative charged particles) are made to pass through a plate rectangular in shape and a magnetic field is applied at right angle to the plane of plate as shown in Fig. 7.5(*a*). The electrons are deflected towards one side of the plate making that side negatively charged and other side positively charged. The force due to applied magnetic field is known as Lorentz force. The mechanism of deflection is governed by the balance of Lorentz force and force on the beam of electrons.



HP = Hall Potential ; MF = Magnetic Field ; EC = Electric Current

Fig. 7.5 (*a*) Hall Effect Principle.

* ***Construction***

A sensor element is stationed between the poles of a horse shoe magnet constructed inside a container. The principle of operation is as depicted in Fig. 7.5 (*b*).

The decrease in the strength of the magnetic field resulting due to the proximity of the object field reduces the voltage across the sensor. The sensor gives binary output for the decision making devices of control for further actions. The silicon makes the ideal selection for a semiconductor interms of size, strength and capacity to electrical interference prevention.

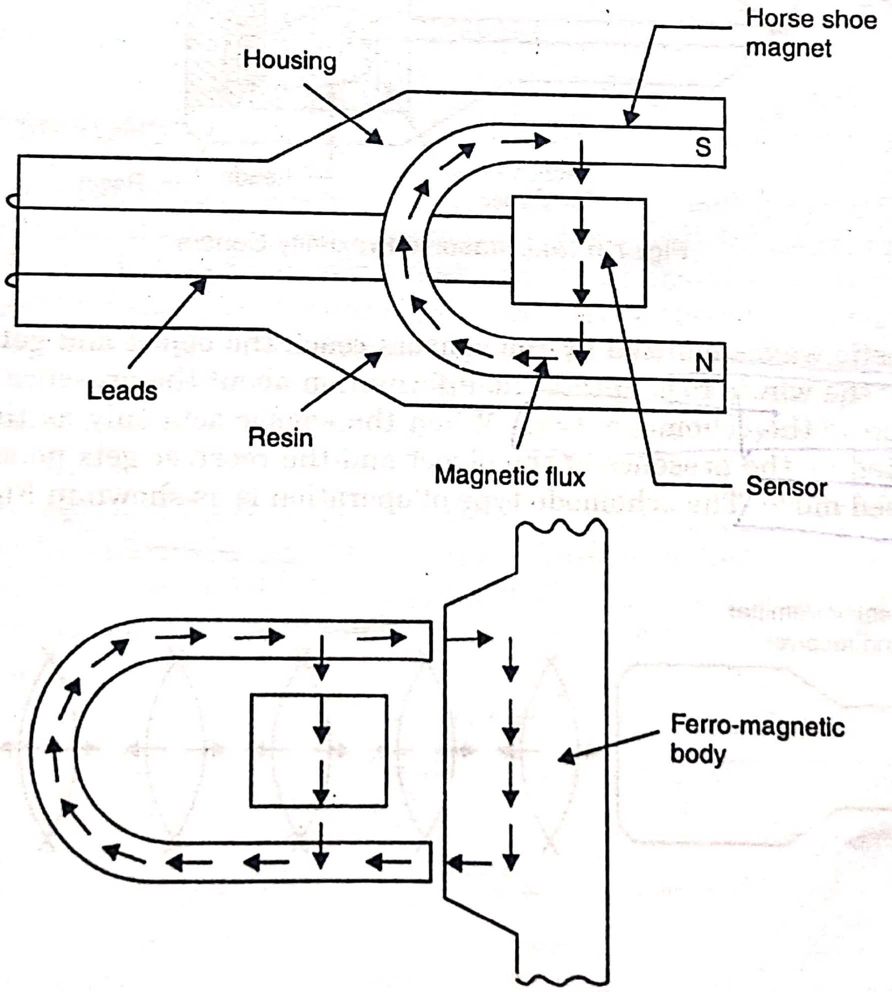


Fig. 7.5 (*b*) Hall-Effect Sensor.

- Advantages of Hall Effect Sensors :
  - ✓ They can operate as switches at high frequency.
  - ✓ They cost less than electromechanical devices.
  - ✓ They are free from contact bounce problem.
  - ✓ They can be used under severe environmental service conditions as they are immune to environmental contaminations.
  - ✓ They can be used as proximity, position and displacement sensors.

Ultrasonic Proximity Sensor

The previously discussed proximity sensors are useful for detection of ferro-magnetic matter only. If the robot has to handle other type of materials ultrasonic sensors find the application.

* *Construction*

The main part in this type of sensor is the transducer which can act both as transmitter ~~and receiver.~~ The sensor is covered by a resin block which protects from dust and humidity. For the acoustic damping, absorber material is provide as shown in Fig. 7.6 (*a*). Finally a metallic housing gives general protection.

opposed mode

echo mode

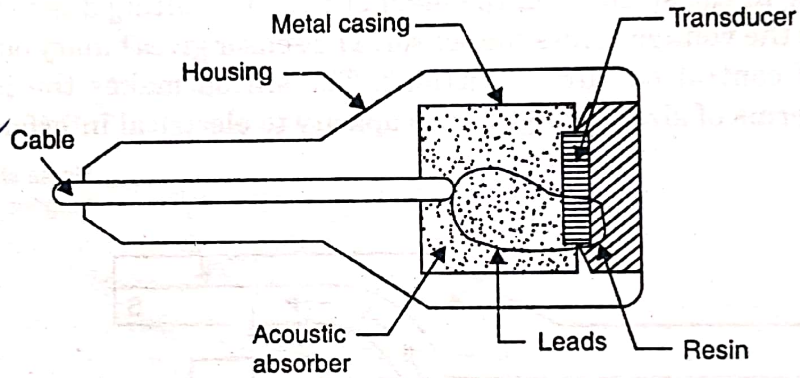


Fig. 7.6 (*a*) Ultrasonic Proximity Sensor.

* *Operation*

The acoustic waves emitted by the sensors reach the object and get reflected and the receiver sensors the waves to generate the information about the presence of the object. This type of operation is the echomode, type. When the sensor acts only as the transmitter the waves get blocked by the presence of the object and the receiver gets no signal. This type is known as opposed mode. The echomode type of operation is as shown in Fig. 7.6 (*b*).

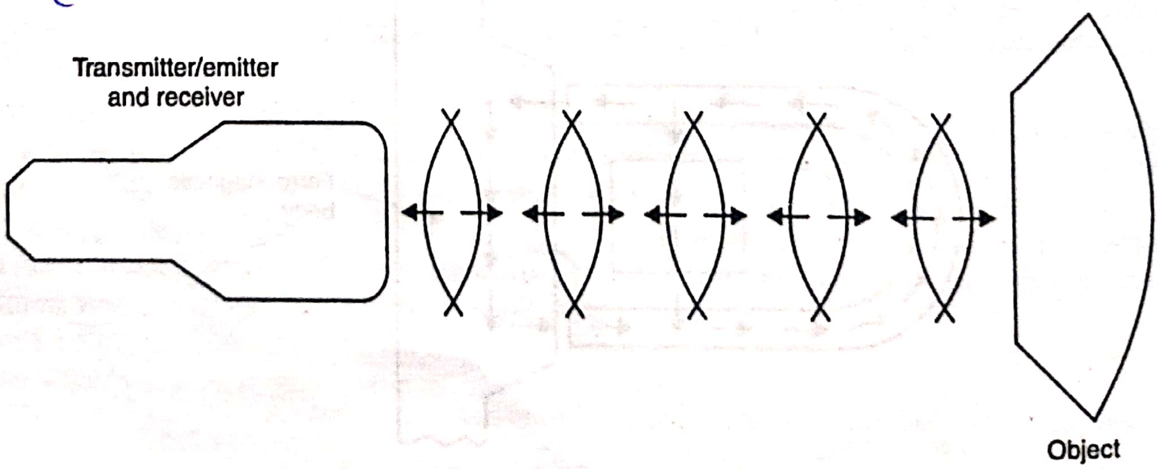


Fig. 7.6 (*b*) Echomode Operation.

Optical Sensors

Optical Sensors are similar to ultrasonic sensors. The proximity of the object is detected by the action of the travelling light wave as it propogates from the transmitter and reflected by the object towards the receiver.

The Fig. 7.7 shows the constructional details of the optical sensor. The light emitted by a diode is focussed by the transmitter lens, on to the object surface. The reflected light waves travel back and received by the solid-state photo diode, through a receiver lens. When the object is within the range of the sensor it is possible to detect the presense of the receiver. The range is defined by the position and orientation of the object and the focal length of the sensor lenses.

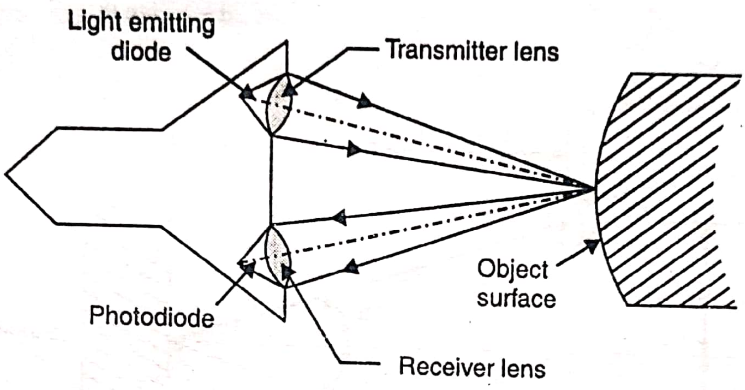


Fig. 7.7. Optical Proximity Sensor.

7.9 RANGE SENSORS

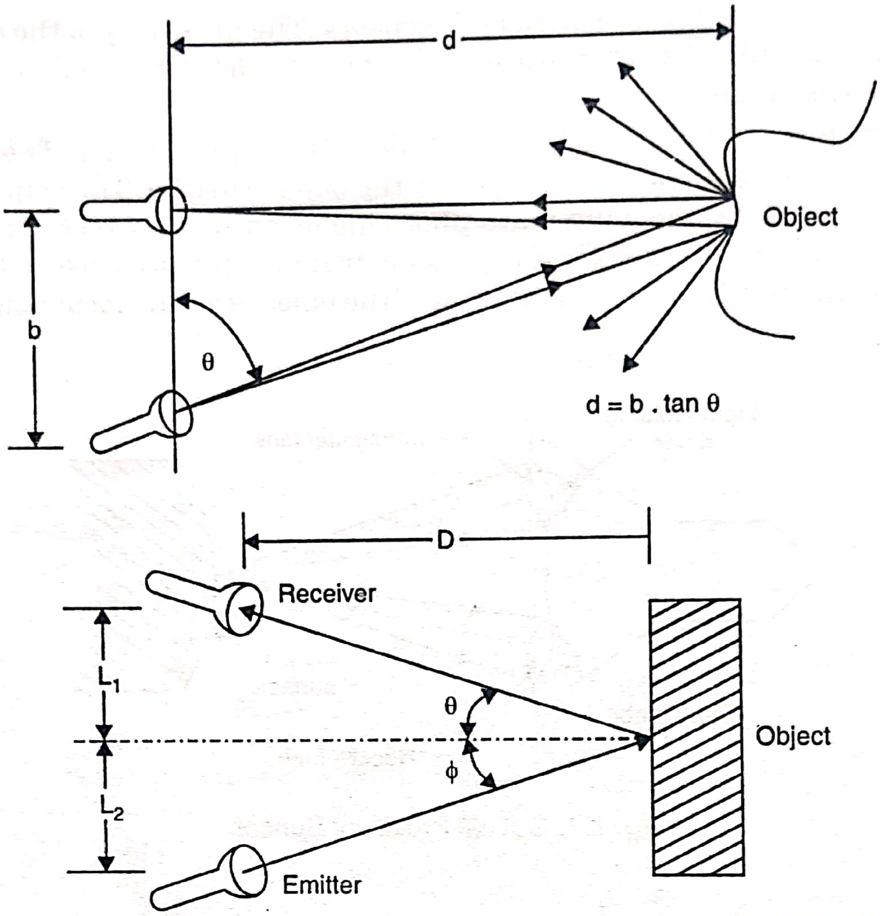
The distance between the object and the robot hand is measured using the range sensors within it is range of operation. The calculation of the distance is by visual processing. Range sensors find use in robot navigation and avoidance of the obstacles in the path. The exact location and the general shape characteristics of the part in the work evelope of the robot is done by special applications for the range sensors. There are several approaches like, triangulation method, structured lighting approach and time-of-flight range finders etc. In these cases the source of illumination can be light-source, laser beam or based on ultrasonics.

* *Triangulation Method*

This is the simplest of the techniques, which is easily demonstrated in the Fig. 7.8. The object is swept over by a narrow beam of sharp light. The sensor focussed on a small spot of the object surface detects the reflected beam of light. If 'θ' is the angle made by the illuminating source and 'b' is the distance between source and the sensor, the distance 'd' of the sensor on the robot is given as

$$d = b \cdot \tan \theta \qquad ...(7.2)$$

The distance '*d*' can be easily transformed into 3D-co-ordinates



$$D = \frac{(L_1 + L_2)\tan\theta \cdot \tan\phi}{\tan\theta + \tan\phi}$$

Fig. 7.8. Triangulation Method of Range Sensing.

7.10 FORCE AND TORQUE SENSORS

The wrist force sensor shown in Fig. 7.9 is used to measure the force and torque induced on the wrist of the robotic manipulator. They can also be used to measure the joint forces. Typical force/torque sensor work on the strain gauge principle. The change in the resistance of the electrical strain gauges effected by the strain due to change in force induced is a measure of force and torque.

The construction of the sensor has got a disc housing support and a deflection bar. The strain gauges are mounted on the six faces of the deflection bar. The force on the wrist is transformed into measurable deflections or displacements at the wrist.

A balanced wheatstone bridge is used to arrange the four resistance. The galvanometer connected between X and Y with equal potential shows zero deflection when there is no force exerted. The force on the wrist changes the resistance in any one arm, which results in current flow and leads to the movement of the galvanometer needle. The change in resistance is given by

$$\frac{R_1}{R_4} = \frac{R_2}{R_3} \qquad ...(7.3)$$

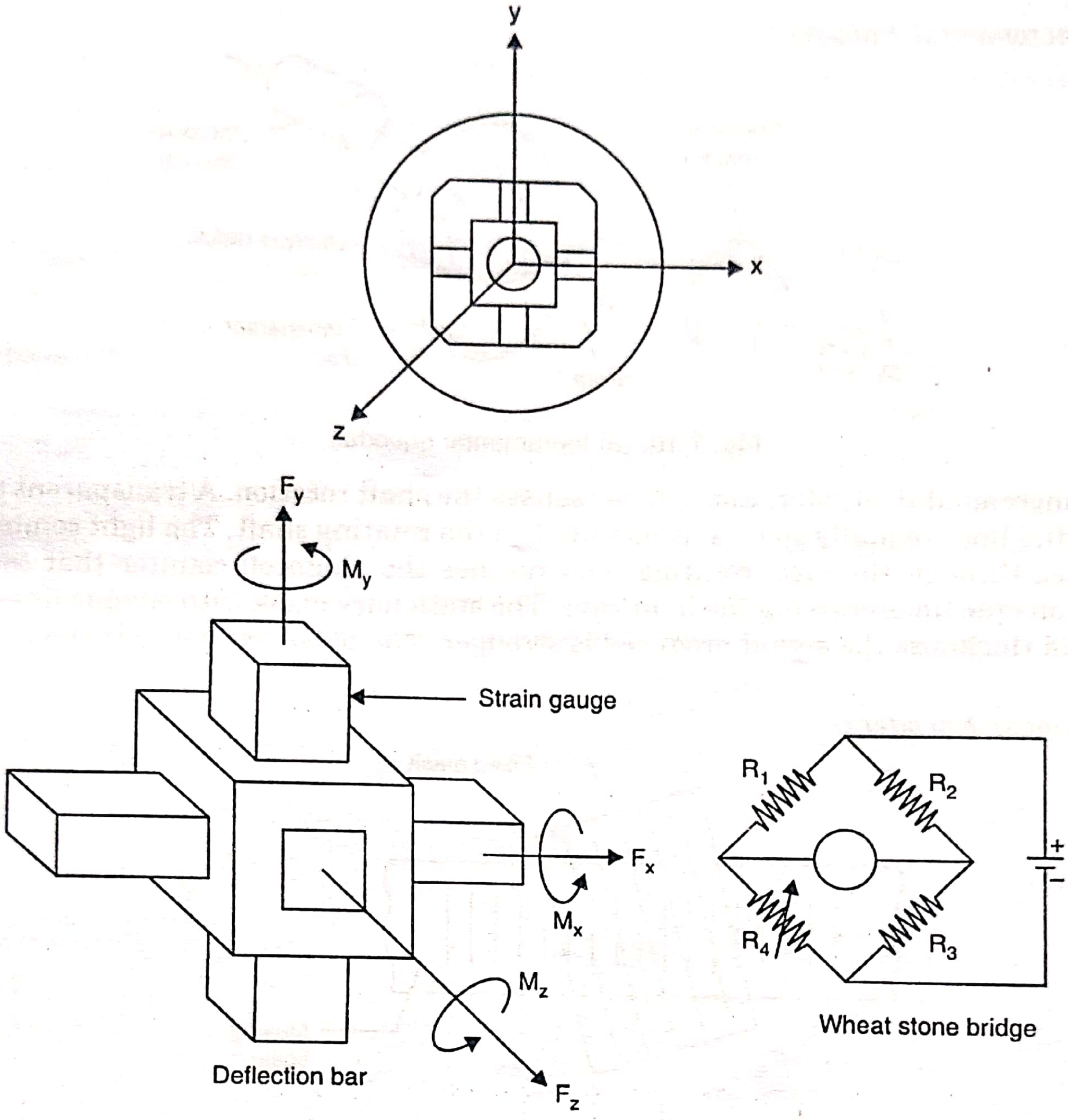


Fig. 7.9. Wrist Force/Torque Sensor.

To accommodate for the temperature changes one of the resistances in the Wheatstone bridge is made dummy. The needed performance specifications for the force sensors are

+ Linearity between response and applied force.
+ Low hysterisis and internal friction for restoring the original position, and to enhance the sensitivity.
+ Compact design to avoid the collision with other objects in the work space.
+ High stiffness to ensure the damping of the disturbing forces by higher natural frequency.

Encoders

There are two types encoders in use :

1. Incremental encoder that measures rotational speed and
2. The Linear encoders that measures linear speed.

- *Incremental Encoder :*

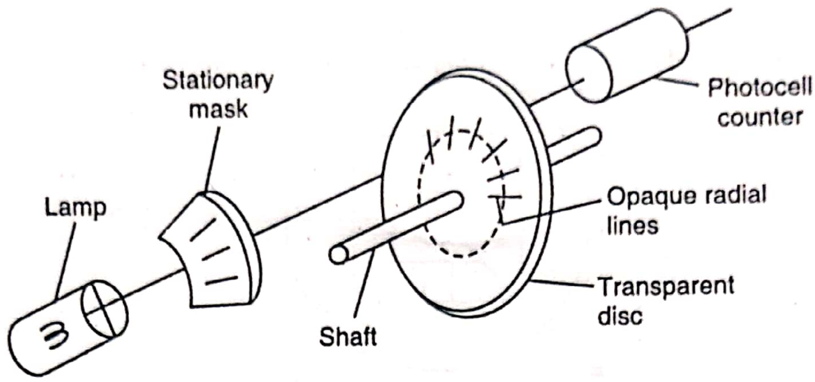


Fig. 7.10. (*a*) Incremental encoder.

An incremental encoder, Fig. 7.10 (*a*) senses the shaft rotation. A transparent disc with opaque radial lines (equally spaced) is mounted on the rotating shaft. The light coming from a lamp passes through the disc (rotating) and reaches the photocell counter that counts the passing of opaque lines crossing the light rays. The stationary mask with opaque lines of same spacing and thickness the signal produced is stronger. The pulse frequency is the measure of speed.

- *Linear Encoder :*

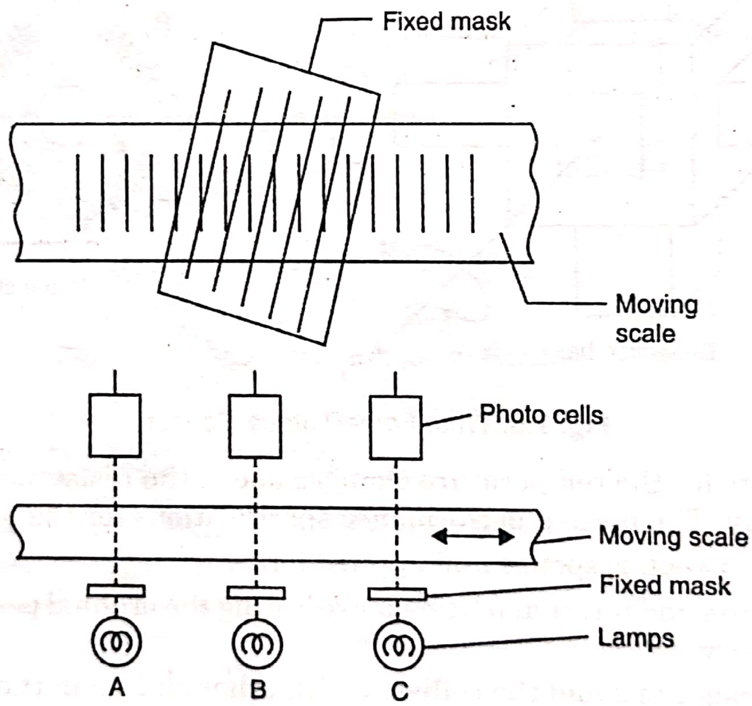


Fig. 7.10. (*b*) Linear encoder.

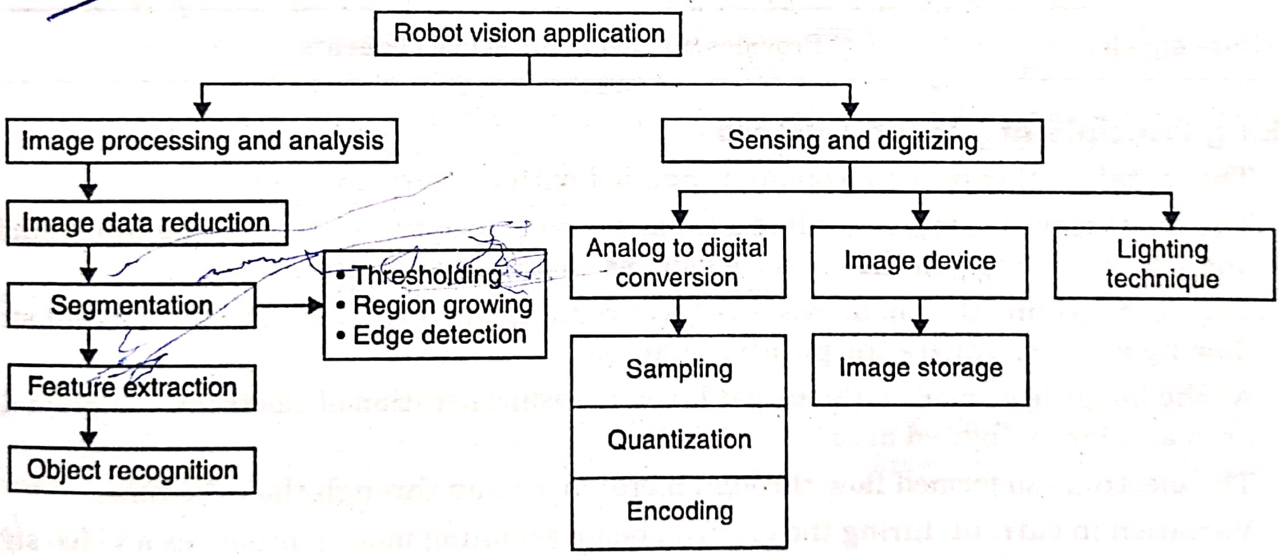
The moving scale with parallel opaque lines is mounted on the machine slide. A skewed fixed mask is kept in between the moving scale and the lamp. The light from the lamp passing through the moving opaque lines produces pulses sensed by photocells. The pulses are the measure of linear speed of the machine slide.

7.11 ROBOT VISION

The process of deriving, featurizing and analizing the details from the three dimensional object in the form of a picture is known as Robot vision or machine vision. As the application utilizes the computer for processing it is also known as computer vision. The areas of processing and analysis of the images are categorized as follows :

Principal functions	*Functional Description*
• Sensing	+ The process that describes and gives out visual image.
• Preprocessting	+ Deals with the process of disturbance reduction and image development.
• Segmentation	+ Is associated with the technique of dividing the image into parts of need.
• Description	+ Distinguishes the parts of focus from other object for computation of the image feature.
• Recognition	+ Is the identifying stage where in parts like spanner, bolts and nuts are recognized.
• Interpretation	+ In this process the recognized objects are given useful meaning for task operation.

7.12 BLOCK DIAGRAM OF VISION SYSTEM



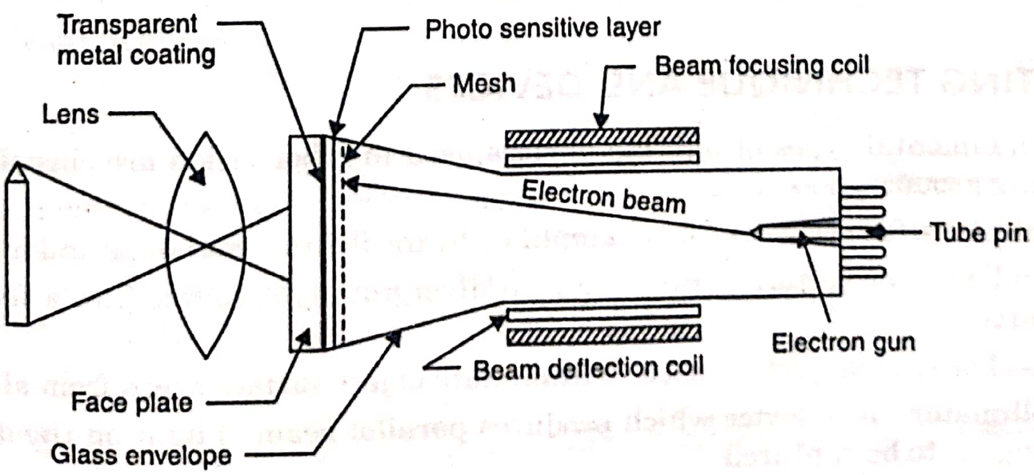


Fig. 7.11. Vidicon Camera.

7.13 CONSTRUCTIONAL FEATURES OF VIDICON CAMERA

Parts of Construction	*Relative Functions*
1. Lens	* Focuses the image of the object on to the camera.
2. Face plate	* Glass cover at front end of camera.
3. Transparent metal coating	* Acts as electrode which derives electrical video signal.
4. Photo sensitive layer	* Is a layer of resistive particles whose resistance is inversely proportional to light intensity.
5. Wire Mesh	* Decelerates the beam of electrons so that they reach photo sensitive layer with zero velocity.
6. Electron gun	* Generates beam of electrons that scans the photo sensitive layer.
7. Beam deflection coil	* Deflects the beam of electrons vertically and horizontally for scanning.
8. Beam focusing coil	* The electron beam is focused by this coil.
9. Tube pins	* Acts as connector to the electric supply source.
10. Glass envelope	* Provides a housing for above elements.

Working Principle of Vidicon Camera

- The metal coating of the faceplate is applied with a positive voltage.
- The photosensitive layer acts like a capacitor with negative charge on the inner surface and positive charge on the opposite side, as electron beam strikes.
- The light striking the photosensitive layer reduces the resistance and the current starts flowing and neutralizes the positive charge.
- As the image is formed on the target layer, the concentration of electrons is high in dark area and low in lighted area.
- The electrons so formed flow through metal layer and through the tube pins.
- Variation in current during the electron beam scanning motion produces a video signal proportional to the intensity of input image.

7.14 LIGHTING TECHNIQUE AND DEVICES

- The fundamental types of lighting devices used in robot vision are classified into the following groups :
  (*a*) Diffuse surface Devices : are examplified by the flourescent lamps and lighted tables.
  (*b*) Condensor projectors : transforms an diverging light source into a focusing light source.
  (*c*) Flood or spot projector : used to illuminate object surface areas from all angles.
  (*d*) Collimator : is a device which produces parallel beam of light on the object whose image is to be captured.

(e) Imagers : example slide projectors and optical enlargers produce at the object plane real form of an image.

The illumination techniques are many. Some such special cases are listed in table 7.1. along with the application. The objective of illumination is to provide a suitable environment for the camera to provide the realistic images of the object in the work-space.

There are basically two major type of illumination techniques : Front lighting and rear lighting. In the front lighting, source of light is on the same side of the camera and in rear lighting technique, the source of light is on the opposite side of the camera.

Table 7.1

Illumination Techniques

Front Light Source	
(a) Front illumination	* The feature of the image is defined by the surface flooded by light.
(b) Light field specular illumination	* Used for recognition of surface defects with light background.
(c) Dark field specular illumination	* Useful in recognition of surface defects in dark background.
(d) Front imager	* Super imposition of imaged light on object surface.

Back Light Source	
(a) Light field rear illumin-ation	* Used in simple measurements and inspection of the parts.
(b) Condensed rear illumination	* High contrast of images produced is useful in high magnification.
(c) Rear illumination collimator	* Parallel light ray source produced so that same plane objects are featured.
(d) Offset rear illumination.	* Highlights the object feature in transparent medium.

7.15 ANALOG TO DIGITAL CONVERSION

The imaging device like video camera gives analog signal voltage denoting the two dimensional images of the object. This information about the image has to be stored in the bit memory of the computer only on conversion to digital signal. The digital conversion of the analog signal is an approximation of reality with minimum error, done using a analog to digital (A/D) converter. This process has three staged phases :

(1) Sampling

(2) Quantization

(3) Encoding.

• Sampling

Let the function $f(x, y)$ denote the two-dimensional image pattern on the image device. The geometric co-ordinates x and y of the image plane are digitized to get information by the process known as 'image sampling'. After sampling the digitised function $f(x, y)$ in the spatial co-ordinates is generated which can be easily stored in the computer memory.

Assume

N = number of lines in the face plate of the image device like vidicon camera.

S = sampling capability of A/D converter in sec. (sampling capability is the cycle time or frequency needed to convert the analog signal of a pixel by the A/D converter)

R = scanning rate in second, for complete face plate.

R_d = line change over delay for the electron beam.

Hence the scanning rate per line,

$$R_L = \left(\frac{R}{N} + R_d\right) \quad ...(7.4)$$

Number of pixels that can be processed/line,

$$P_n = \left(\frac{R + NR_d}{N.S}\right) \quad ...(7.5)$$

Generally the scan line change over is given in the percentage of the scan rate for a line.

- **Quantization**

The digitization of the amplitude of the image function $f(x, y)$ depending on the intensity of the pixel is known as Quantization.

The number of quantization level,

$$Q = 2^n \quad ...(7.6)$$

where the, n is number of memory bits in the A/D converter.

The quantization level spacing is given as

$$L = \frac{F_r}{Q} \quad ...(7.7)$$

where F_r = full scale range of the camera in volts.

From equations (7.6) and (7.7)

$$L = \frac{F_r}{2^n} \quad ...(7.8)$$

The digital approximation of the analog signal gives the error in quantization as

Quantization error, $e_q = \pm\frac{1}{2}(L)$

or $$e_q = \pm\frac{1}{2}\left(\frac{F_r}{2^n}\right) \quad ...(7.9)$$

- **Encoding**

Depending on the image created on the faceplate of the camera, the intensity of the different pixel would be different. The conversion into the digital code of the amplitude levels follows the process of quantization. The digitized amplitude code is represented by the binary sequence of digits, which is known as encoding. The spaced quantization levels show the difference in intensities and the amplitude levels. All zeros in the binary sequence of digits represent dark (black) intensity level. All ones in the bit memory is the representative bright (white) intensity pixel. In between the two with combination of zeros and ones shows the gray color.

7.16 IMAGE STORAGE

The storage of image (digitized) in the computer memory is done by the frame buffer which can be made a part of the computer or frame grabber. The more popular frame grabber technique can be explained as follows.

The access and acquisition of the image is done in $\frac{1}{30}$ second by the frame grabber of a video camera. An average camera can produce a disturbance free data with a 6-bit buffer where as the quantization of the frame has a specification of 8 bits. The lower level bits are rejected in the operation of noise cleaning. As the resolution of the general human eye = $2^6(64)$, the image grabbed by the video camera would be sufficiently good.

The row and column counters of the frame grabber are synchronized by the electron beam of the camera. The signal sent by the computer to the position address (x, y) of the face-plate reads the information stored in the frame buffer, uniquely addressed by sampling and quantization.

7.17 IMAGE PROCESSING AND ANALYSIS

In the industrial applications the algorithms and programs are developed to process the images captured, digitized and stored in the computer memory. The size of data to be processed is huge, of the order of 10^6 which is to be substantially executed in $\frac{1}{30}$ seconds. The difficult and time consuming task of processing is handled effectively by the following techniques :

(1) Image data reduction

(2) Segmentation

(3) Feature extraction

(4) Object recognition.

• Image Data Reduction

The purpose of image data reduction is to reduce the volume of data either by ellimination of some or part processing, leading to the following sub-techniques.

(*a*) Digital conversion

(*b*) Windowing.

* *Digital conversion* is characterized by reduction in number of gray levels. For a 8-bit register each pixel would have 2^8 =256 gray levels. When fewer bits are used to represent pixel intensity the digital conversion is reduced, to suit the requirements.

The data reduction is effected in the following manner generalized as

Total number of bits on the face plate,

$$T_1 = N_r . N_c (2)^n \quad \text{...(7.10)}$$

where N_r = number of lines or rows

N_c = number of points per line

2^n = total gray levels.

Binary bit conversion for totally black and white intensities,

$$T_2 = N_c.N_r.(2)$$

Reduction in data volume $= (T_1 - T_2)$

$$= 2N_cN_r(2^{n-1} - 1) \quad ...(7.11)$$

* *Windowing* is processing a portion of the stored digital image. The portion of focus extracted for image processing is the window. A rectangular window is selected as to highlight the component of interest on the screen. The pixels of the faceplate within the window are processed and analized by the computer.

PROBLEMS

Example 7.1. *A rastor scan system of vision has a frame of face-plate with 256 lines, having $\frac{1}{3}$ sec. as the scanning rate. It may be assumed that the electron beam takes 10% of the scan time to move from one line to other line. If there are 256 pixels per line, determine the sampling rate.*

Sol. It is given in equation (7.5) as

$$P_n = \left(\frac{R + NR_d}{N.S}\right)$$

where $R = \frac{1}{3}$ sec.

$N = 256$ lines

$P_n = 256$ pixels

$$R_d = 10\% \text{ of } \frac{R}{N} = \frac{0.1R}{N}$$

Hence S = sampling rate in seconds/ pixel.

$$= \frac{R + 0.1R}{P_n.N} = \frac{1.1 \times \frac{1}{3}}{256 \times 256} = 5.6 \times 10^{-6} \text{ s/pixel.}$$

Example 7.2. *The maximum voltage range for a 8 bit capacity A/D converter is 18 V. Calculate the quantization levels, quantization level spacing, and the quantization error.*

Sol. From equation (7.6)

The number of quantization level,

$$Q = 2^n = 2^8 = 256$$

The quantization level spacing,

$$L = \frac{F_r}{Q}$$

where $F_r = 18$ volts

So

$$L = \frac{18}{256} = 0.0703 \text{ V}$$

The quantization error,

$$e_q = \pm\frac{1}{2}L = \pm\frac{1}{2}\left(\frac{18}{256}\right) = 0.03515\text{ V}.$$

Segmentation

The representation different, distinct parts of the entire image data are grouped into area of similar characteristics is known as 'Segmentation'. The major segments of the images are regions and edges that differentiate them from the background. The image processing and analysis are explained by the following segmentation techniques.

(1) Edge detection

(2) Region growing

(3) Thresholding.

• *Edge detection*

At boundary the pixels on the faceplate different intensity levels which are stored in the computer in the binary form. This is the distinguishing feature of the object images. The features of similar region, at the edges show demarcation representing change over of the attributes. The edge detection is based on follow-the-edge procedure as shown in the Fig. 7.12. The procedure is to scan the pixel within the region, for which turn left and step or otherwise turnright and step from a starting point outside the boundary. This is continued till the end point meets the starting point.

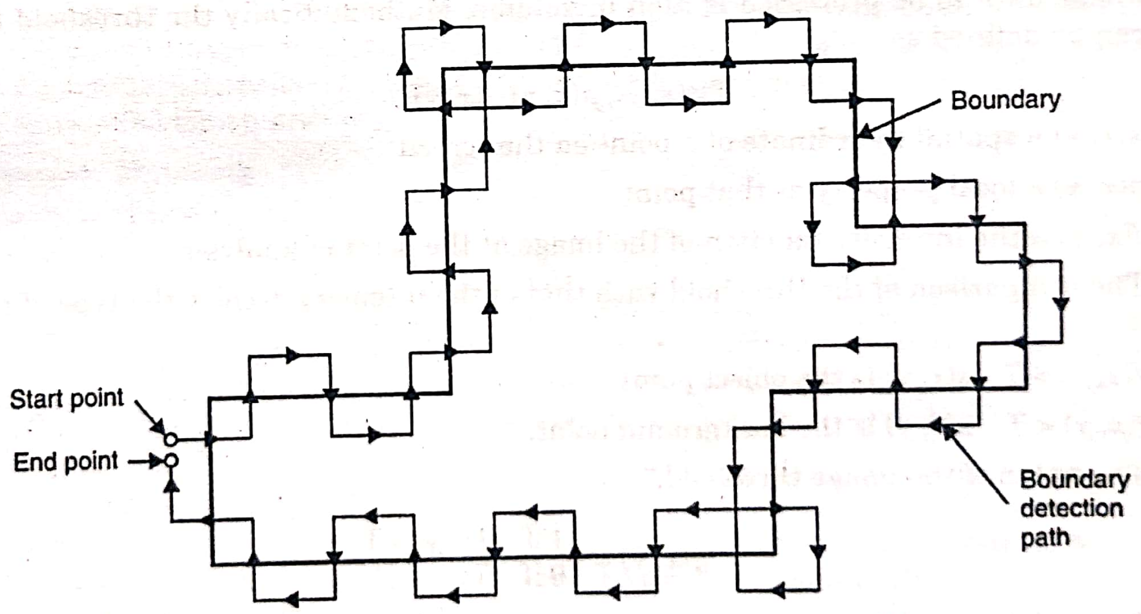
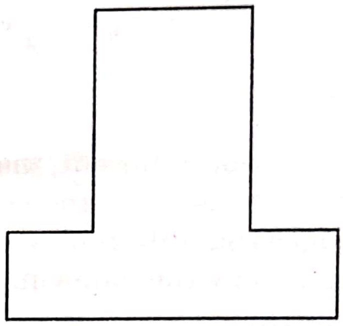


Fig. 7.12. Edge Detection.

• *Region growing* is the processing technique where grid elements processing similar attributes are grouped to form a region. The grid elements are collection of pixels which discretize the object image and the background formed on the faceplate. The properties and the spatial geometric co-ordinates of a region decide, on the process of merging or if to be left independent as a separate entity. The region growing procedure can be better understood by assigning 0s for the background and 1s for the object regions. This is depicted in the Fig. 7.13.

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	1	0	0
0	0	1	1	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0



Object image

Fig. 7.13. Region Growing Technique.

The region growing procedure can be briefed as follows :

- A pixel on the object is identified and assigned the value 1.
- The adjacent pixel are tracked for match in the attributes. The matching pixel is assigned 1 and non-matching pixel with 0.
- The terms are repeated till the complete screen is covered resulting in growth and identification of region.
- *Thresholding of image* is one of the principal object detection techniques when the binary image data to be processed is high in volume. Mathematically the threshold function can be defined as

$$T = T[s(x, y), p(x, y), f(x, y)]$$

where $s(x, y)$ = spatial co-ordinate of a point on the screen

$p(x, y)$ = local property at that point.

$f(x, y)$ = the intensity function of the image at the point of analysis.

The comparison of the threshold with that of the intensity decides the type of point on the plate.

when $f(x, y) > T$ $s(x, y)$ is the object point

$f(x, y) < T$ $s(x, y)$ is the background point.

The value of the image threshold,

$$g(x, y) = \begin{cases} 1 \text{ if } & f(x, y) > T \\ 0 \text{ if } & f(x, y) \leq T \end{cases}$$

Dependability of T	Threshold type
on $f(x, y)$	global threshold
on $f(x, y)$ and $p(x, y)$	local threshold
on $s(x, y)$	dynamic threshold

7.18 FEATURE EXTRACTION

The images formed on the screen can have multiple objects which are to be distinguished from one another for processing and anylysis. The features that characterize uniquely, the objects provide means to extract the identification and comparison. This is accomplished by the features like area, diameter and perimeter, also minimum enclosing rectangle, and gray levels are considered in the feature extraction.

The area of the object is described by the region growing procedure as explained before. The area is given by

$$\text{Area} = \frac{(\text{perimeter})^2}{\text{thickness}},$$

where thickness = compactness of the object.

Diameter = (Thickness × Area).

The enclosing boundary that covers the specific area can be established by the pixel intensity difference, at the boundary.

The diameter of an object image is the maximum distance obtainable on two different points on the perimeter of an object.

An important observation is that the selected feature does not depend upon position and orientation of the boundary.

7.19 OBJECT RECOGNITION

One of the major approaches in image processing is the technique of matching the captured image with object to be recognized. The technique of object recognition is based on the feature extraction described previously. The powerful algorithms are used for this purpose, the techniques used which are

- Template Matching
- Structural Technique.
  - *Template matching* is a part of a general statistical pattern recognition technique. The object to be recognized is stored in computer memory in advance. The properties like area, perimeter etc., are calculated for the prototype pattern. Then the objects are matched and compared with the stored information, which is known as template matching. The success of this technique is dependent on less number of stored pattern.
  - *Structural technique* is technique deals with relation between features or the boundaries of an object which is sub-divided into primitive or the elements with defined inter-relations. This is a separate topic is known as syntactic pattern recognition, the explanation of which is beyond the scope of this book.

7.20 COMPONENTS OF DIGITAL IMAGE PROCESSING

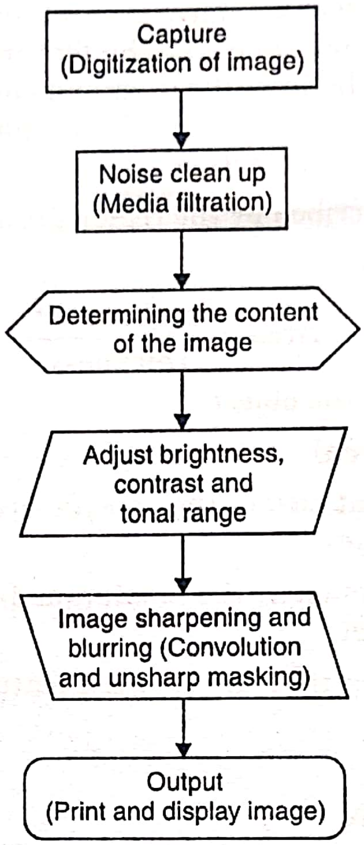


Fig. 7.14. Image Processing Block Diagram.

EXERCISE

7.1. With the help of a block diagram, explain the functions of a robotic vision system and devices used in the same. *(VTU–Jan./Feb. 2003)*

7.2. Write a short notes on object recognition technique. *(VTU–May/June 2004)*

7.3. Enlist the desirable sensor and transducer features. *(VTU–Jan./Feb. 2004)*

7.4. Give the classification of sensors with example. *(VTU–Jan./Feb. 2004)*

7.5. List the various sensors used in the robotic systems. *(VTU–May/June 2004)*

7.6. With a neat sketch explain the tactile sensors and the range sensors. *(VTU–May/June 2004)*

7.7. Sketch and explain a six component wrist sensors based on strain gauge element for force/torque sensing. *(VTU–May/June 2004)*

7.8. Discuss the desirable engineering features of sensors and transducers. *(VTU–Jan./Feb. 2003)*

7.9. Explain the types of touch sensors with neat sketches.

7.10. Explain principle and construction of Inductive type proximity sensors.

7.11. Explain the construction and operation of ultrasonic proximity sensors.

7.12. Explain with a neat sketch the optical proximity sensors.

7.13. Give the performance specifications for the force sensors.

7.14. Describe the principal functions of robot vision system.

7.15. Explain the construction and principle of operation of Vidicon camera.

7.16. What are the image devices used in robot lighting Technique ?

7.17. Explain the illumination technique used in robot vision system.

7.18. Explain sampling function of A/D conversion.
7.19. Write short notes on quantization and encoding.
7.20. Explain image storage.
7.21. Discuss digital conversion and windowing.
7.22. What is edge detection ? Explain the procedure.
7.23. Discuss region growing technique with example.
7.24. What is thresholding ? Explain threshold types.
7.25. Discuss feature extraction technique.
7.26. What is object recognition ? Explain template matching.
7.27. Explain with block diagram component of digital image processing.
7.28. State and explain the principle of Hall effect.
7.29. What are the advantages of Hall effect sensors ?
7.30. What is the function of encoder ? What are the types of encoders ?
7.31. Explain the principle of operation of incremental encoder.
7.32. Explain the working linear encoder.