Robot sensors

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- A transducer is a device that converts one type of physical variable (e.g. force, pressure, temperature, velocity,flow rate) into another form.
- A common conversion is to electrical voltage as it is more convenient to use and evaluate.
- A sensor is a transducer that is used to make a measurement of physical variable of interest.
- Two types: Analog transducers & Digital Transducers

2

Desirable features of sensors

- Accuracy
- Precision
- Operating Range
- Speed of response
- Calibration
- Reliability
- Cost and ease of operation

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Sensor classification

- Tactile
- Proximity & Range sensors
- Miscellaneous
- Machine Vision System

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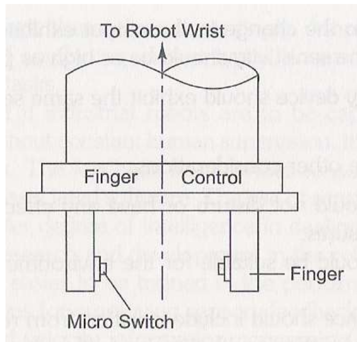
Touch Sensor



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Position & Displacement sensor

Position and Displacement Sensors

Position and displacement sensors are used as components of the robot contro system. The control structure of a robot needs to know the position of each joint in order to calculate the position of the end-effector thus enabling the successfu completion of the programmed task. The movements of the joints can be eithe linear or angular (rotary) depending on the type of robot.

Future developments in the robotics field may allow the use of external sensor to actually measure the end-effector position in relation to its surroundings, thereb dispensing with the need to calculate it from the joint positions. But, for the present, internal position sensors remain the most accurate and reliable way o determining the end-effector position within a robot control structure. There ar two main types of position sensors: absolute and incremental, the latter bein also called displacement sensors. Some common devices which are used as positio sensors are discussed below.

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Potentiometers

Potentiometers Potentiometers are analog devices whose output voltage is proportional to the position (linear or angular) of a wiper. Potentiometers may be either linear or angular. Figure 5.3 illustrates a typical angular potentiometer, which has a resistive element and a rotating wiper. When voltage is applied across the resistive element, the output voltage between the wiper and the ground is proportional to the ratio of the resistance on one side of the wiper to the total resistance of the resistive element, which essentially gives the position of the wiper. The function of a potentiometer can be represented by the function,

$$V_o = K \cdot \theta$$

where V_o = output voltage

K = voltage constant of the potentiometer in volts per radian (for angular pot) or volts per mm (for linear pot)

θ = position of the pot in radian or mm

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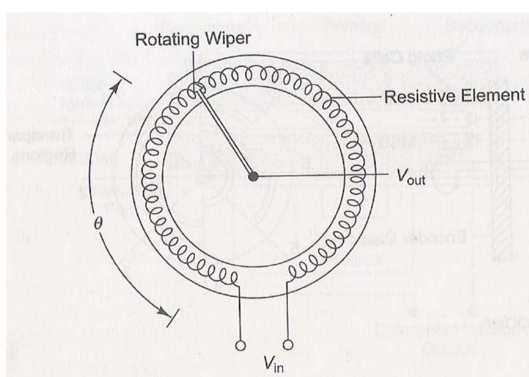
Potentiometer



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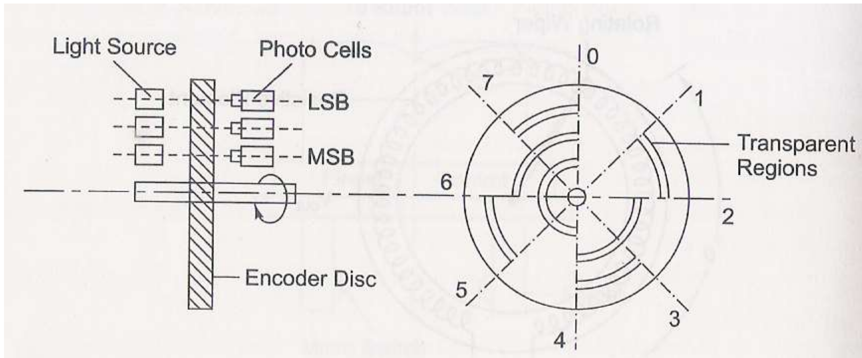
Encoders



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Binary & Gray Encoder

Decimal number	Natural binary code	Gray code
0	000	000
1	001	001
2	010	011
3	011	010
4	100	110
5	101	111
6	110	101
7	111	100

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LVDT

LVDT The linear variable differential transformer (LVDT) is another type of position sensor, whose construction is shown in Fig. 5.5. It consists of a primary, two secondaries, and a movable core. The primary is excited with an a.c. source.

When the core is in its exact central location, the amplitude of the voltage induced in secondary-1 will be the same as that in secondary-2. The secondaries are connected to cancel phase, and the output voltage will be zero at this point. Figure 5.6 illustrates the nature of output voltage as the core is moved to the left or to the right. The magnitude of the output voltage is shown to be a linear function of core position, and the phase is determined by the side of the null position on which the core is located. Finally, the a.c. output of LVDT can be converted to d.c. using rectifiers.

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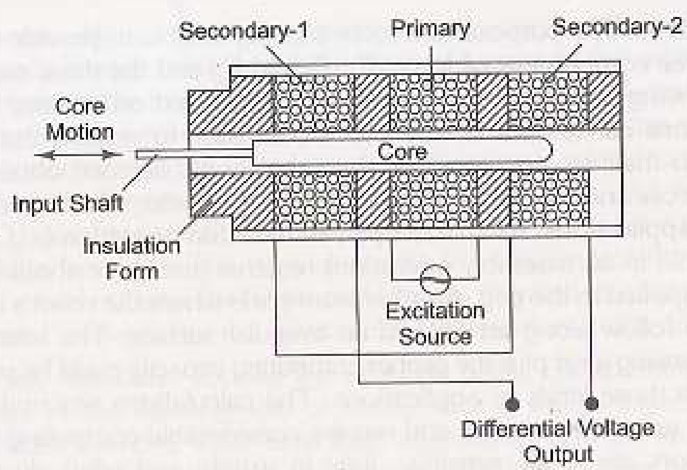
LVDT



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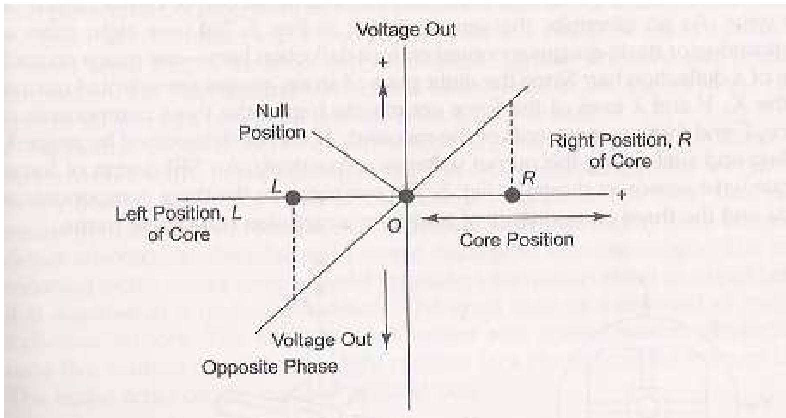
LVDT



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Force & Torque Sensors

Force and Torque Sensors

The capacity to measure forces permits the robot to perform a number of tasks like grasping parts of different sizes in material handling, machine loading and assembly work applying the appropriate level of force for the given part. Force being a vector quantity must be specified both in magnitude and direction.

Force sensing in robotics can be accomplished in several ways. A commonly used technique is wrist sensing, in which the sensors (like strain gauges) are mounted between the tip of a robot arm and the end-effector. Another technique is joint sensing, in which the sensors measure the cartesian components of force and torque acting on a robot joint and adds them vectorially. For joints driven by d.c. motor, sensing is done simply by measuring the armature current for each of the joint motors. Finally, a third technique is to form an array of force sensing elements so that the shape and other information about the contact surface can be determined.

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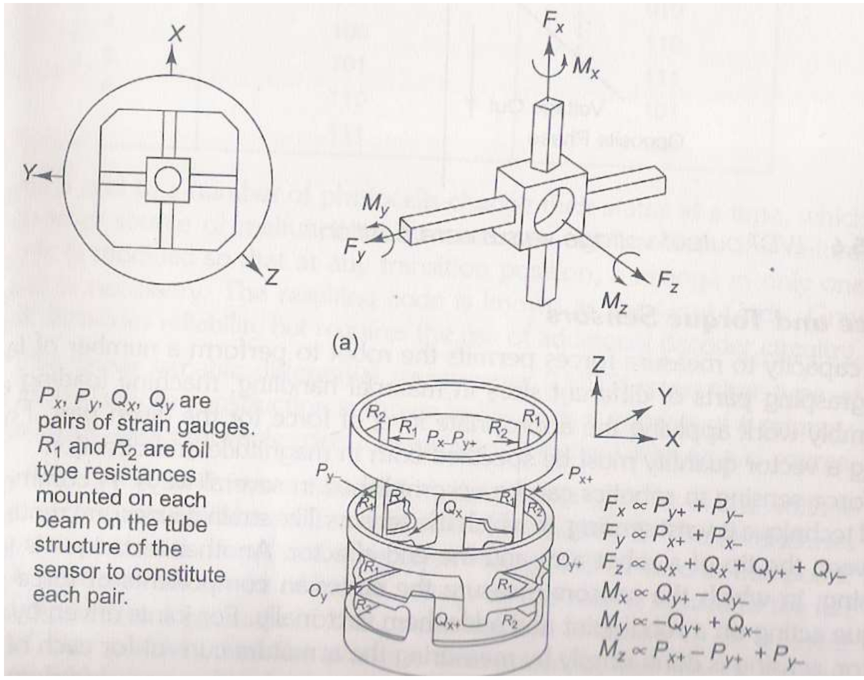

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Joint Sensor

Joint Sensors Many robots are powered by d.c. servo motors, for which the output torque is linearly related to the armature current in the motor. Thus, it is possible to measure the torque of each robot joint (indirectly) by inserting a suitable series resistor in one lead of each servo motor and measuring the voltage across it which is proportional to the motor current and, hence is related to motor torque.

Motor current measurement is simple and inexpensive, but is not without drawbacks. The accuracy is affected by any friction in the motor bearings, associated gears and joint bearings. The measurements not only reflect the forces being applied at the tool but also the forces and torques required to accelerate the links of the arm and to overcome the friction and transmission losses of the joints

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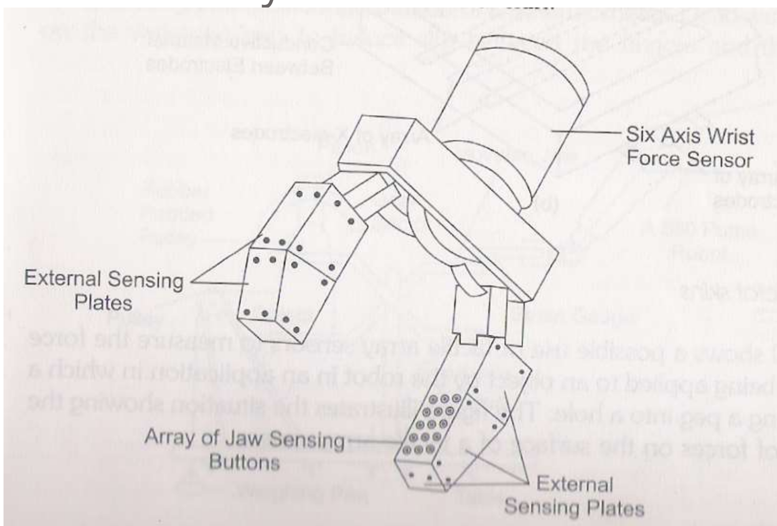
Tactile Array Sensor



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Tactile Array Sensors During the past few years, considerable efforts have been devoted to the development of tactile sensing arrays capable of yielding touch information over a wider area than afforded by a single sensor. 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 in contact with the array sensor surface, like (i) the object's presence, contact area, shape, location and orientation, (ii) the pressure and pressure distribution, etc. Tactile array sensors can be mounted in the fingers of the robot gripper or attached to a work table as a flat touch surface.

Figure 5.8 shows a robot hand in which the inner surface of each finger has been covered with a tactile sensing array. The external sensing plates are typically binary devices, which are fitted to the outer jaw surfaces. The inner face has a matrix of touch buttons to sense the workpiece. The outer sensors may be used to detect unavoidable obstacles and prevent damage to the manipulator. The inner mounted tactile sensor array is useful in getting information about an object before it is acquired at a particular location. The array may be composed of multiple individual sensors. The force on each sensor acts against washer displacing a vane that controls the amount of light received by a phototransistor from an LED. The tactile array can be made of artificial skin.

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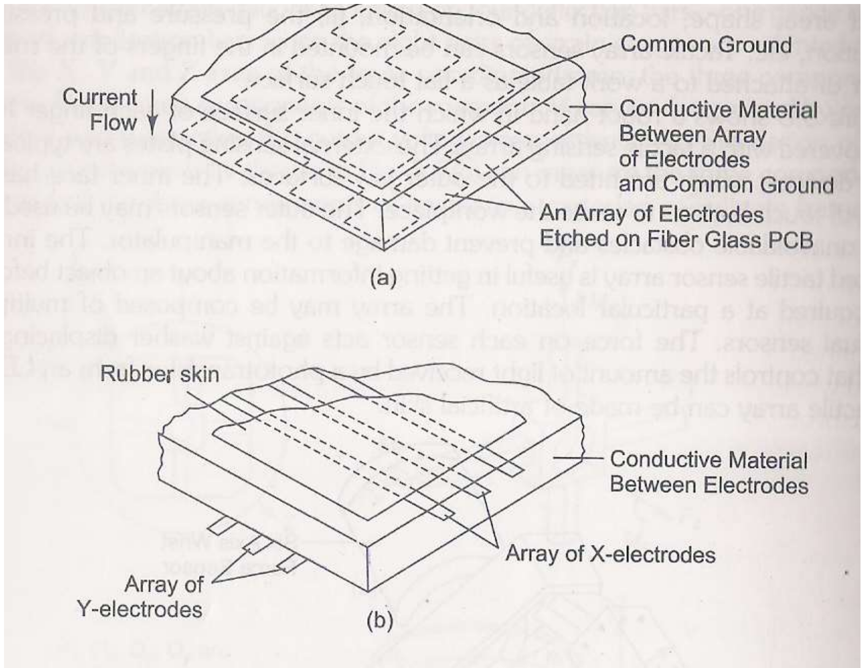

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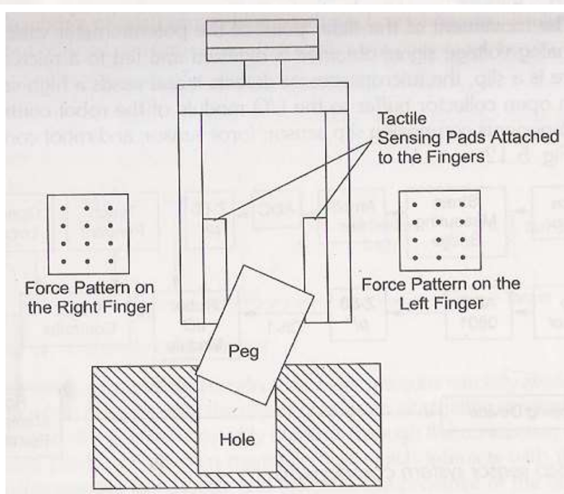
Figure 5.10 shows a possible use of tactile array sensors to measure the force and moments being applied to an object by the robot in an application in which a robot is inserting a peg into a hole. The figure illustrates the situation showing the likely pattern of forces on the surface of a tactile array sensor.



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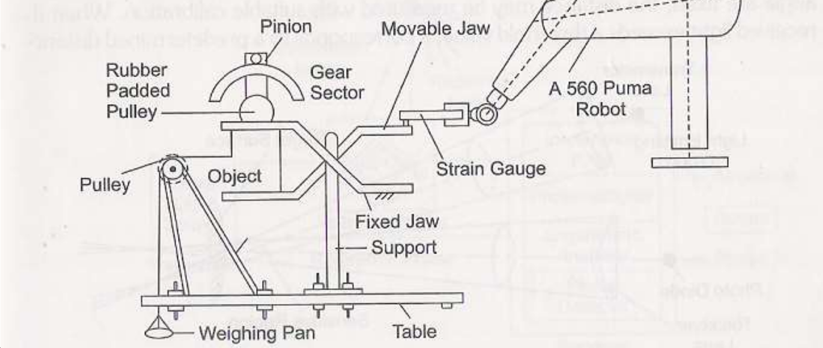
Slip Sensor

Figure 5.11 indicates a scheme of a sensor based robot gripper. The fingers are closed on the object to secure gripping by means of a lever actuated with the wrist of a robot. A full bridge with electrical strain gauges on the lever measures strain due to the effort required to close the finger and the gripping force can be determined with proper calibration. A specially mounted, rubber padded and spring loaded wheel in contact with the upper surface of the object measures the degree of slip through the positional rotation of a potentiometer. Dead weights are placed on the weighing pan to induce slip between the fingers and the object being



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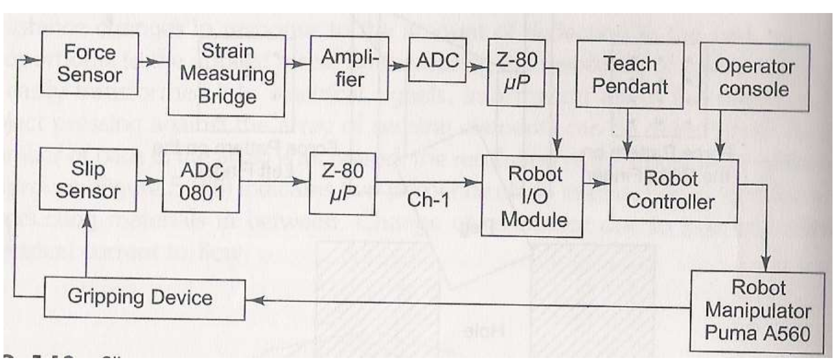
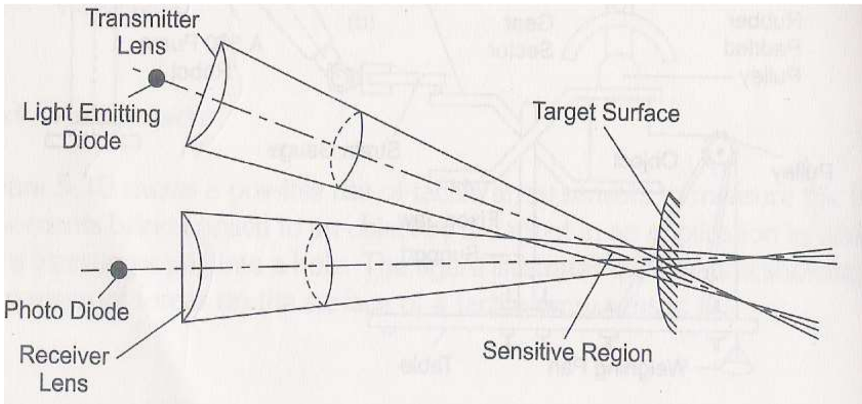
Slip Sensor



Proximity Sensor



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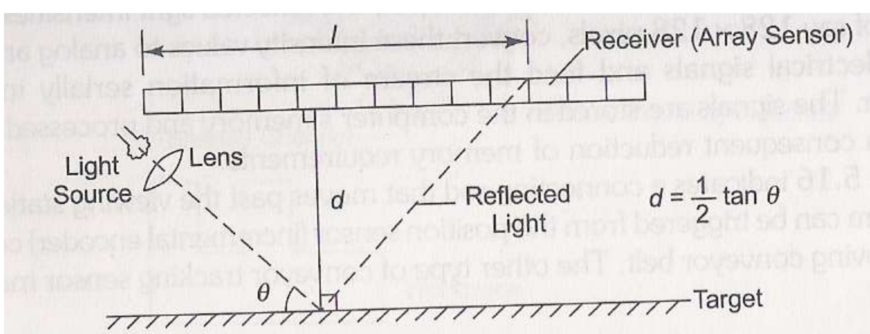
Proximity Array Sensor



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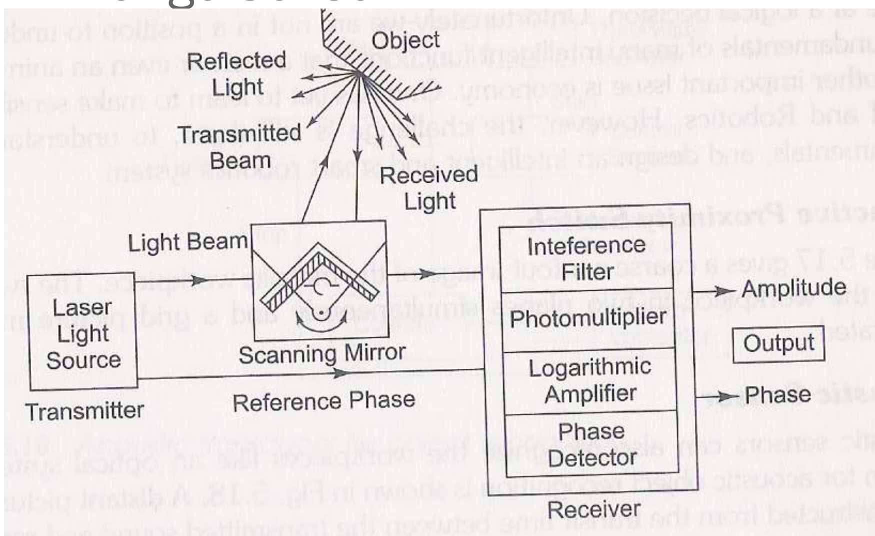
Range Sensor



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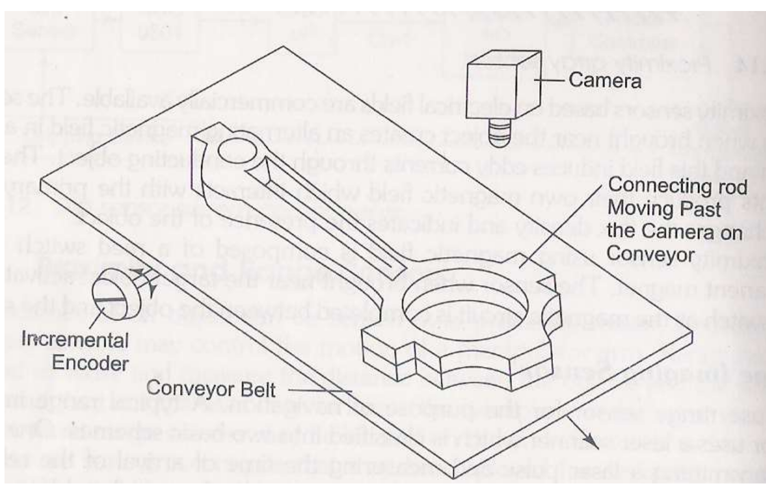
Electro Optical Imaging Sensor



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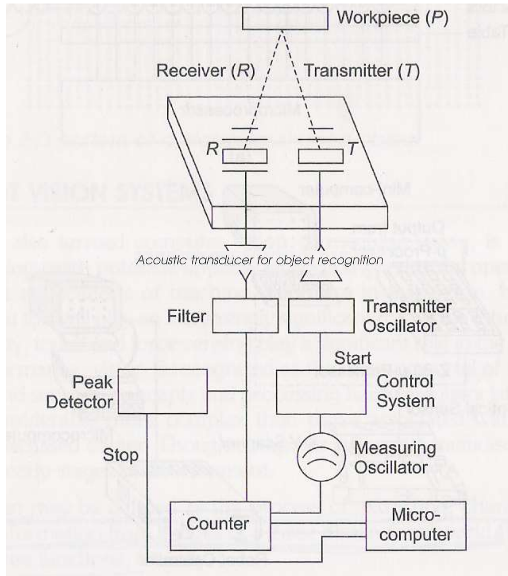
Acoustic transducer for object recognition



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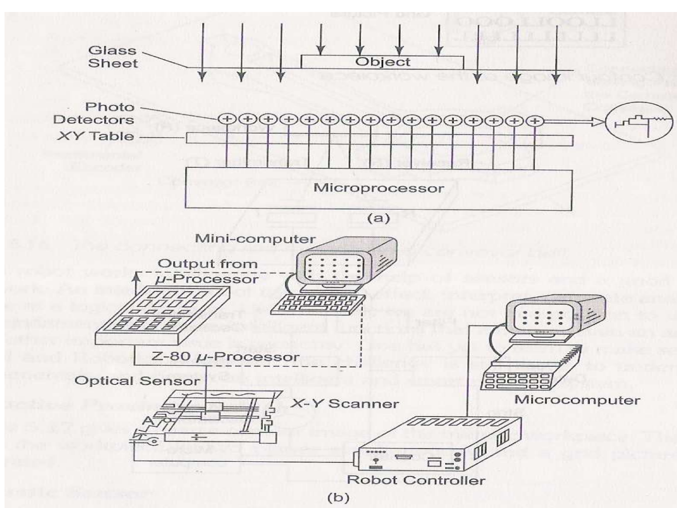
Opto-electronic sensor (a) Schematic diagrams of sensor systems hardware for contouring (b) Network of entire sensor systems for contouring



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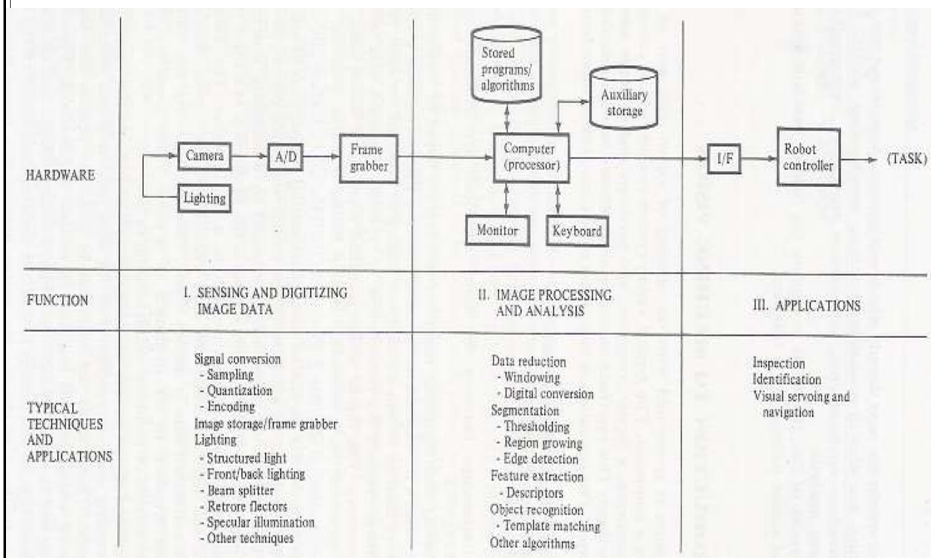
Machine Vision System



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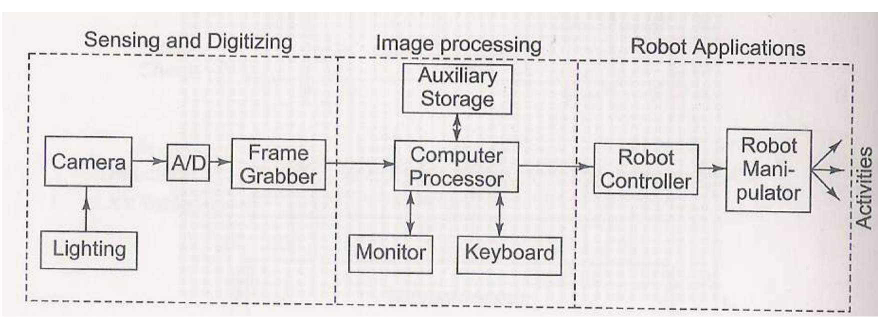
Machine Vision System Elements



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Vidicon Camera

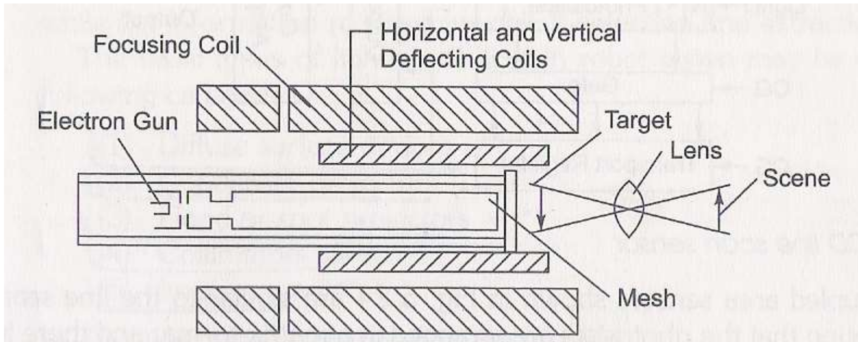

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Figure 5.22 shows the scheme of a vidicon camera. An image is formed on the glass faceplate that has its inner surface coated with two layers of materials. The first layer is a transparent signal electrode film deposited on the faceplate of the inner surface. The second is a thin layer of photosensitive material deposited over the conducting film which consists of small areas of high density. Each area produces a decreasing electrical resistance in response to increasing illumination. A charge is created in each small area upon illumination. Thus an electrical charge pattern is generated corresponding to the image formed on the faceplate, which is a function of light intensity over a specified time.

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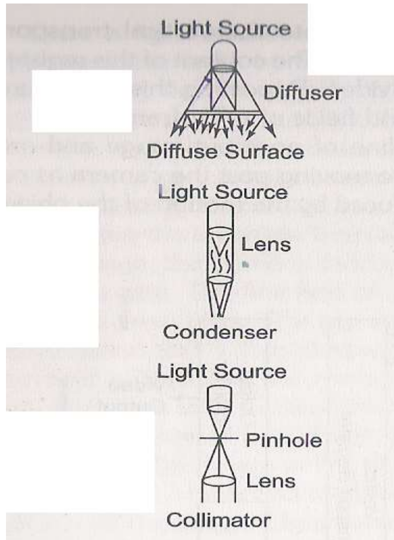
Illumination Techniques



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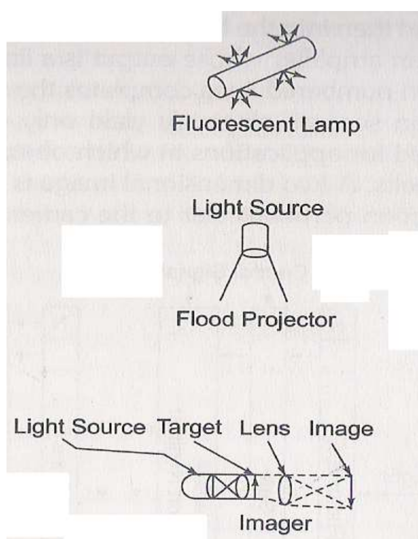
Illumination Techniques



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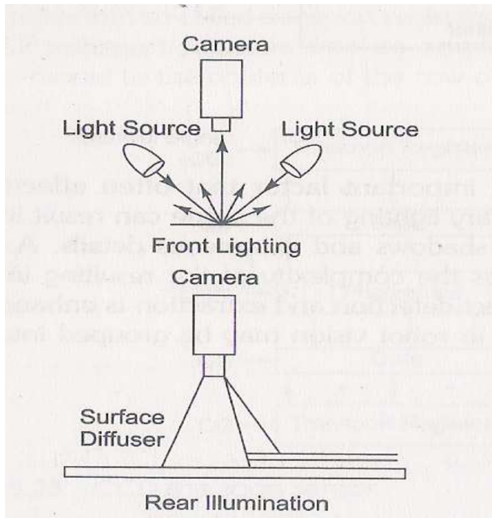
Front & Rear illumination



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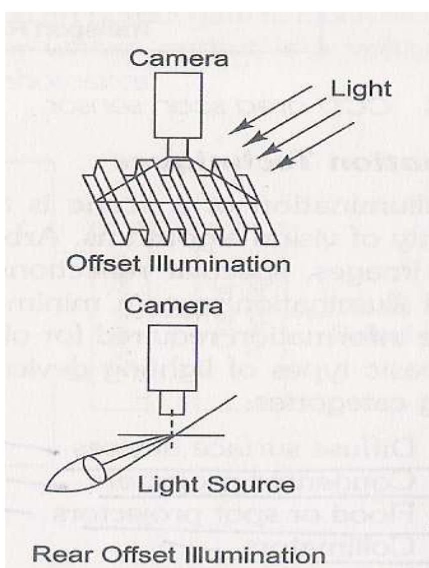
Front & Rear Offset illumination



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Analog to Digital Conversion

Analog-to-Digital (A/D) Signal Conversion

For vidicon tube camera, it is necessary to convert the analog signal for each pixel into digital form. Analog-to-digital (A/D) conversion process consists of three phases: sampling, quantization and encoding.

A given analog signal is approximated by the sampled digital outputs after a series of discrete-time analog signals are obtained. This is done by sampling the analog signal periodically at a proper sampling rate. Each sampled voltage level is quantized into a finite number of defined amplitude levels which correspond to the gray scale used in the system. The number of quantization levels is equal to 2^n, where n is the number of digits (bits) of the A/D converter.

The amplitude levels that are quantized must be changed into digital code, the process being termed encoding. This involves representing an amplitude level by a binary digit sequence.

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Preprocessing

Preprocessing deals with techniques like noise reduction and enhancement details. There are several approaches of preprocessing used in robot vision systems. The preprocessing approaches typical of the methods satisfying the requirements of computational speed and low implementation cost are discussed in this section.

Noise Reduction or Smoothing

Smoothing operations are used for reducing noise and other spurious effects that are introduced in an image as a result of sampling, quantization, transmission or disturbances in the environment during image acquisition and digitizing.

One straightforward technique for image smoothing is neighbourhood averaging in which a smoothed image is generated whose intensity at every point is obtained by averaging the intensity values of the pixels of the given image contained in a predefined neighbourhood of that point. One of the principal difficulties in this technique is that it blurs edges and other sharp details. This blurring can be reduced by the use of so called median filters in which the intensity of each pixel is replaced by the median of the intensities in a predefined neighbourhood of that pixel, instead of by the average.

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Image Storage

Image Storage

The image following A/D converter is stored in the computer memory, typically called a frame buffer, which may be a part of the frame grabber, or, in the computer itself. Various techniques have been developed to acquire and access digital images. Frame grabber is an example of a video data acquisition device. A combination of row and column counters are used in the frame grabber which are synchronized with the electron beam scanning in the camera, so that each position of the screen may be uniquely addressed and the data is 'grabbed' via a signal sent from the computer to the address corresponding to a row-column combination. Such frame grabber techniques have become extremely popular and are used frequently in vision systems.

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Chain Code

Chain Codes These are used to represent a boundary as a set of straight line segments of specified length and direction, typically established on a rectangular grid using 4- or 8-connectivity, as shown in Fig. 5.28 where directions are given by the code chosen. Figure 5.29 shows a result using the 4-connectivity direction code, where the coding was started at the dot and proceeded in a clockwise direction. It is important to note that the chain code of a given boundary depends upon the starting point. However it is possible to normalize the code by a straightforward procedure.

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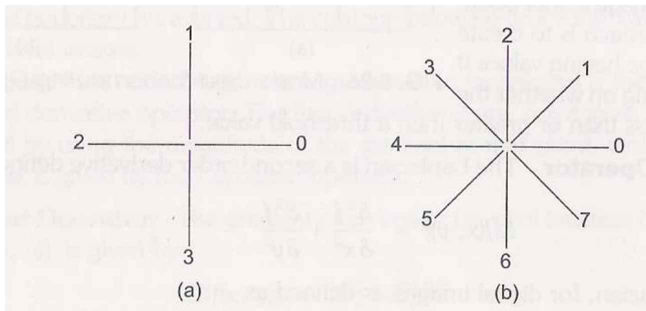
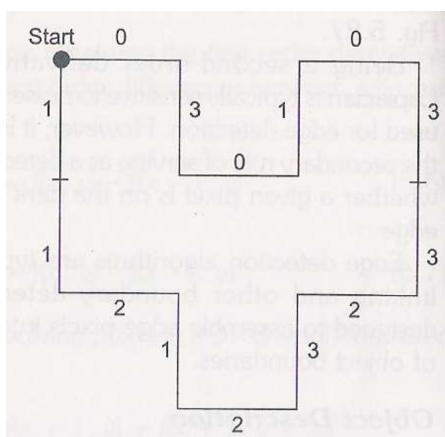
Chain Code



Chain Code



Chain code: 03010332321211
The dot (•) indicates the starting point

The major axis of a boundary is the straight line segment joining the two points farthest from each other. The minor axis is perpendicular to the major axis and of such a length that a box can be formed to just enclose the boundary. The ratio of the major to minor axis is called the eccentricity of the boundary, and the rectangle just described is called the basic rectangle. The major and minor axes are useful for establishing the orientation of an object. The eccentricity is also an important description of its shape.

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Object Recognition

The next step in image data processing is to identify or recognize the object that the image represents, which is accomplished using the extracted feature information. The function of recognition algorithms is to identify each segmented object in a scene and to assign a label to that object, which must be powerful enough to uniquely identify the object. Object recognition techniques may be classified into two major categories:

- Template-matching techniques
- Structural techniques

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Template Matching

In template-matching, the object is matched with a stored pattern feature-set defined as a model template that is obtained during the training procedure in which the vision system is programmed for known prototype objects. Training of the vision system should be carried out under conditions as close to operating conditions as possible. The system stores these model objects in the form of extracted feature values which can be subsequently compared against the corresponding feature values from images of unknown objects. These techniques are applicable if there is not a requirement for a large number of model templates. This procedure is based on the use of a sufficient number of features to minimize errors in the classification process.

In structural technique, relationships between features of an object are considered. Structural technique differs from decision-theoretic technique in that the latter deals with pattern on a quantitative basis, and mostly ignores interrelationships among object primitives. Structural methods, on the other hand, attempt to achieve object discrimination by capitalizing on these relationships; central to the structural recognition approach is the decomposition of an object into pattern primitives.

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Interpretation

Interpretation process endorses a vision system with a higher level of cognition about its environment than that offered by any of the concepts previously discussed and encompasses all these methods as an integral part of understanding a visual scene. This is one of the most active research topics in robot vision. The power of a robot vision system is determined by its ability to extract meaningful information from a scene under a broad range of viewing conditions. Processing scenes requires the capability to obtain description and procedures for establishing relationships between these descriptors, even when they are incomplete.

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Uses of Sensors in Robotics

- Safety Monitoring/Navigation
- Interlocks in workcell control
- Part inspection for quality control
- Determining positions and related information about objects in the robot cell

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