

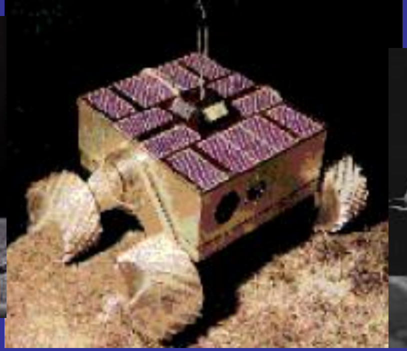
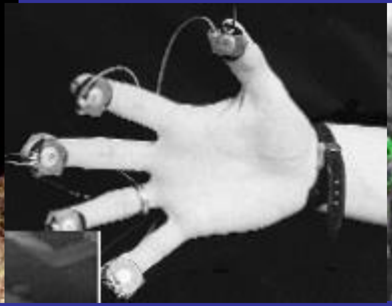


ROBOT SENSORS

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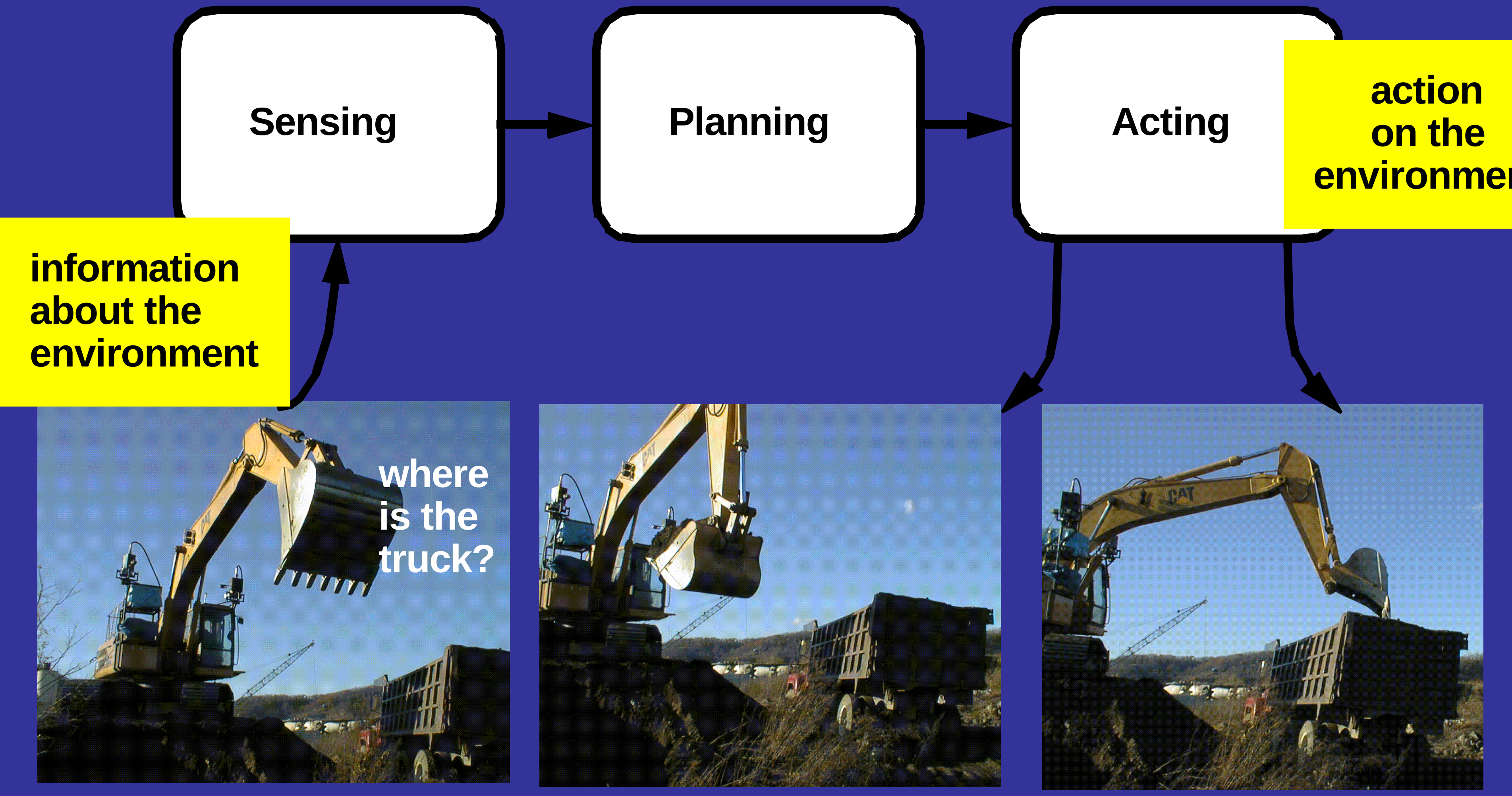
NAGAPATTINAM.

What makes a machine a robot?



What is sensing?

Sensing is converting a quantity that you want to measure into a useable signal (usually electronic).

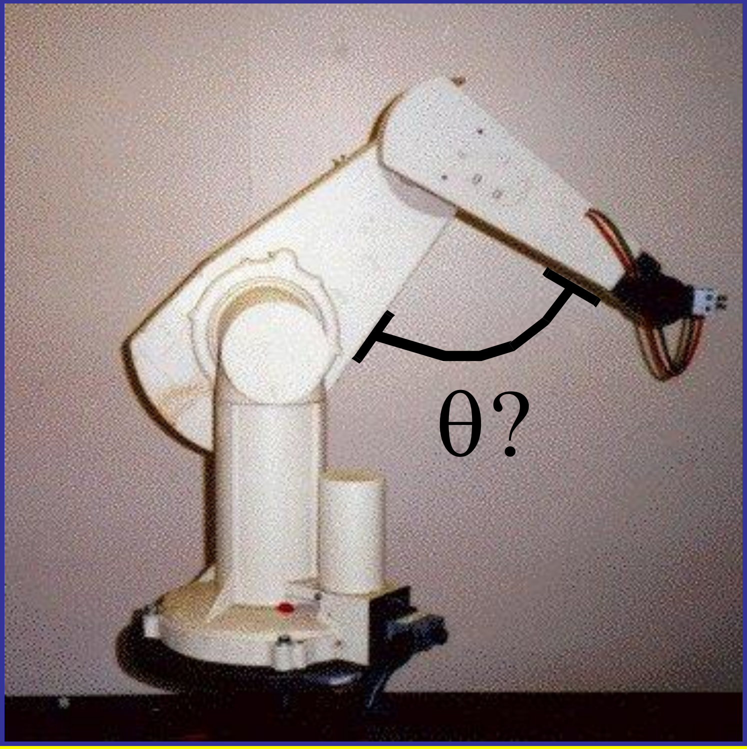
Perception is the interpretation or under-standing of these signals.

Example:

Sensing: Sound waves -> vibrating eardrums -> signals to brain
Perception: Understanding that I am talking to you about sensors.

Why do robots need sensors?

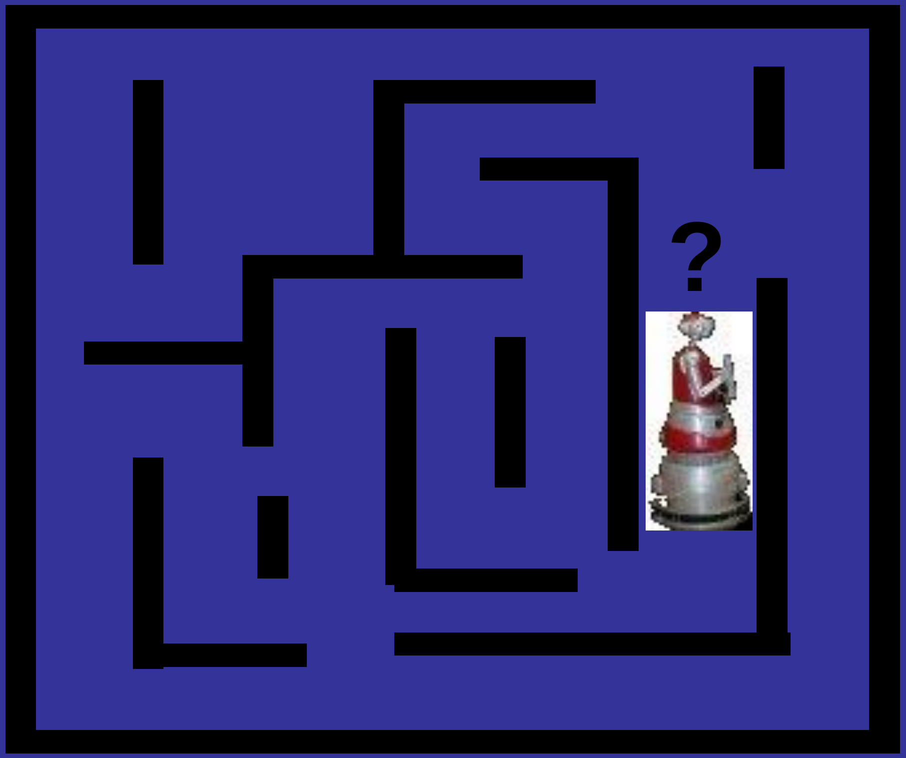
What is the angle of my arm?



internal information

Why do robots need sensors?

Where am I?



localization

Why do robots need sensors?

Will I hit anything?

obstacle detection

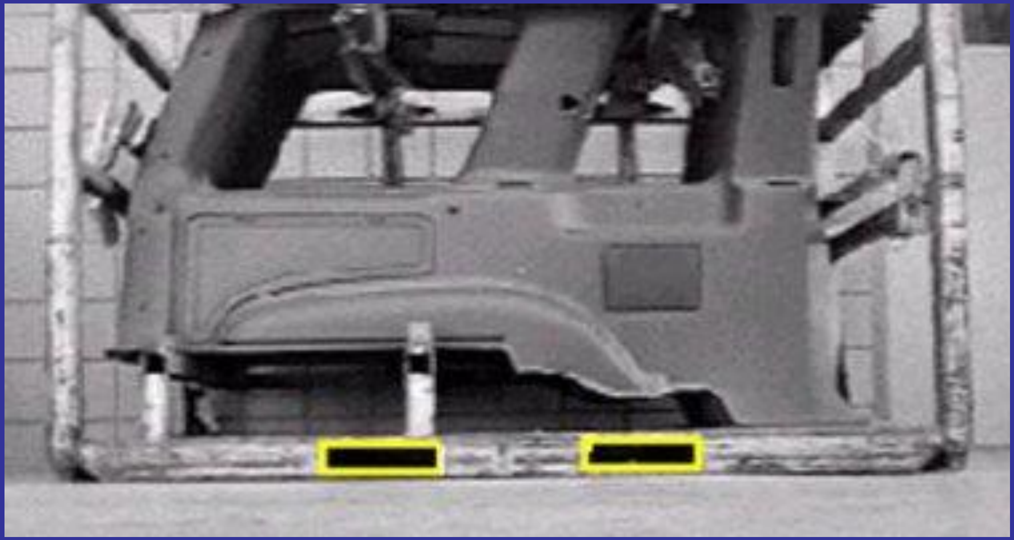
Sensing for specific tasks

Where is the cropline?

Autonomous harvesting

Sensing for specific tasks

Where are the forkholes?



Autonomous material handling

Sensing for specific tasks

Where is the face?

Face detection & tracking

INTRODUCTION

- To be useful, systems must interact with their environment. To do this they use sensors and actuators
- Sensors and actuators are examples of **transducers**

  A transducer is a device that converts one physical quantity into another

  – examples include:
    - a mercury-in-glass thermometer (converts temperature into displacement of a column of mercury)
    - a microphone (converts sound into an electrical signal).

SENSORS

Sensors are electrical/electronic devices used to detect physical stimuli like:

- Light
- Temperature
- Angular speed
- Pressure

Sensors: I

•Human senses: sight, sound, touch, taste, and smell provide us vital information to function and survive

•Robot sensors: measure robot configuration/condition and its environment and send such information to robot controller as electronic signals (e.g., arm position, presence of toxic gas)

•Robots often need information that is beyond 5 human senses (e.g., ability to: see in the dark, detect tiny amounts of invisible radiation, measure movement that is too small or fast for the human eye to see)

Accelerometer
Using Piezoelectric Effect

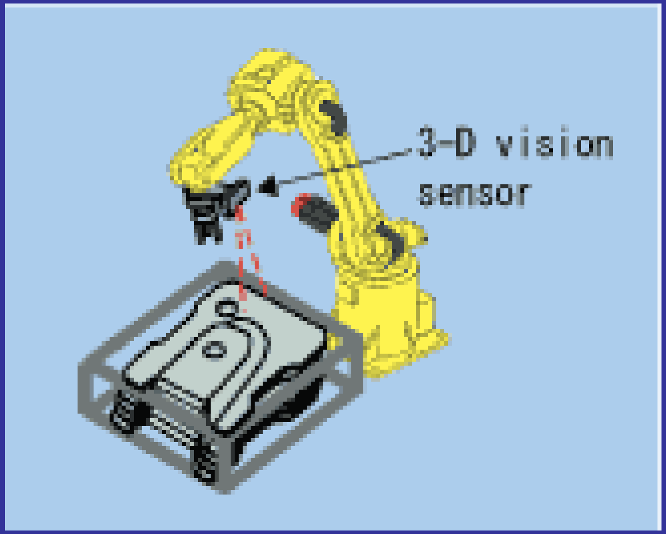
Flexiforce Sensor

Sensors: II

Vision Sensor: e.g., to pick bins, perform inspection, etc.

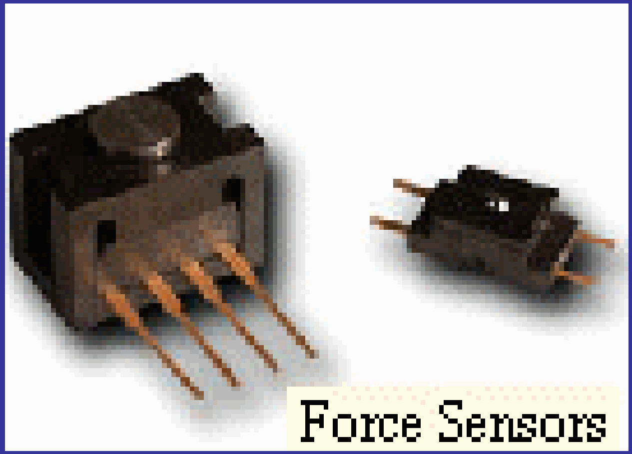
In-Sight Vision

Part-Picking: Robot can handle work pieces that are randomly piled by using 3-D vision sensor. Since alignment operation, a special parts feeder, and an alignment pallete are not required, an automatic system can be constructed at low cost.

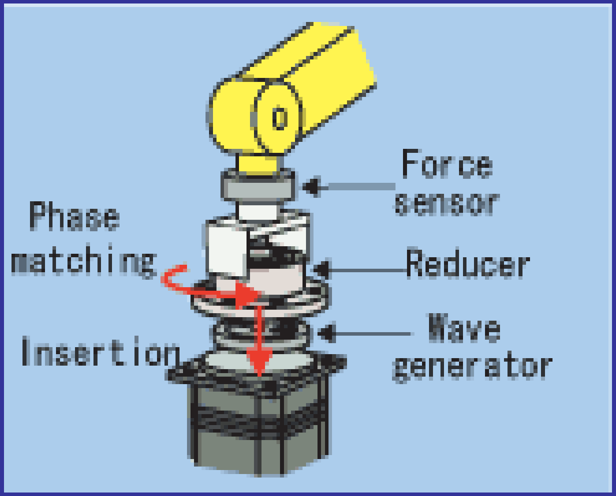


Sensors: III

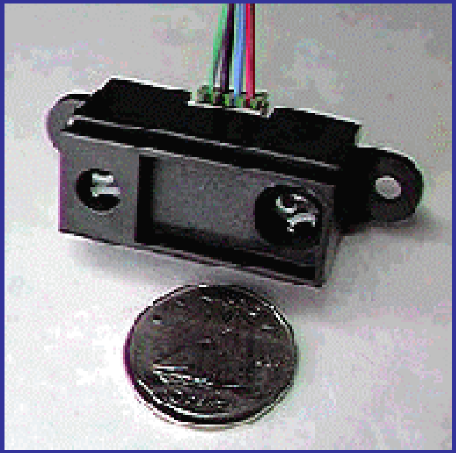
Force Sensor: e.g., parts fitting and insertion, force feedback in robotic surgery



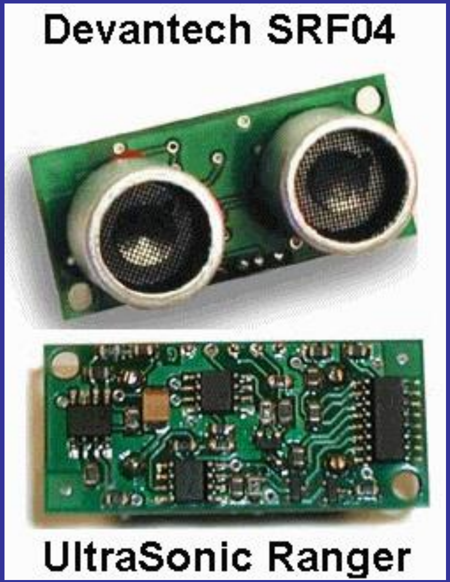
Parts fitting and insertion: Robots can do precise fitting and insertion of machine parts by using force sensor. A robot can insert parts that have the phases after matching their phases in addition to simply inserting them. It can automate high-skill jobs.



Sensors: IV



Infrared Ranging Sensor



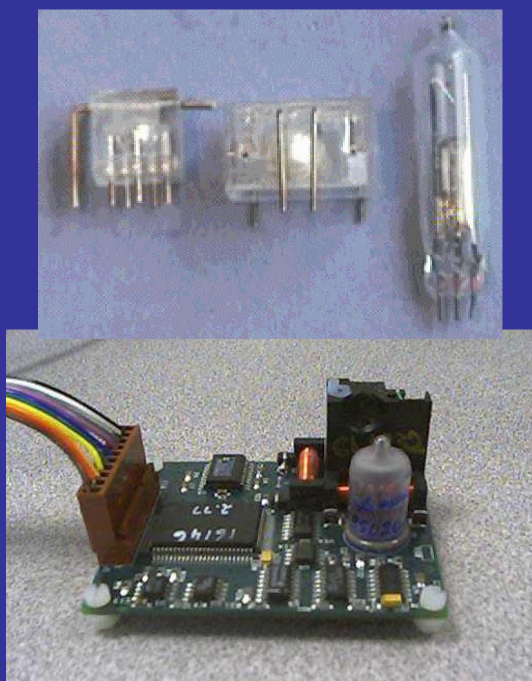
Example

KOALA ROBOT

- 6 ultrasonic sonar transducers to explore wide, open areas
- Obstacle detection over a wide range from 15cm to 3m
- 16 built-in infrared proximity sensors (range 5-20cm)
- Infrared sensors act as a “virtual bumper” and allow for negotiating tight spaces

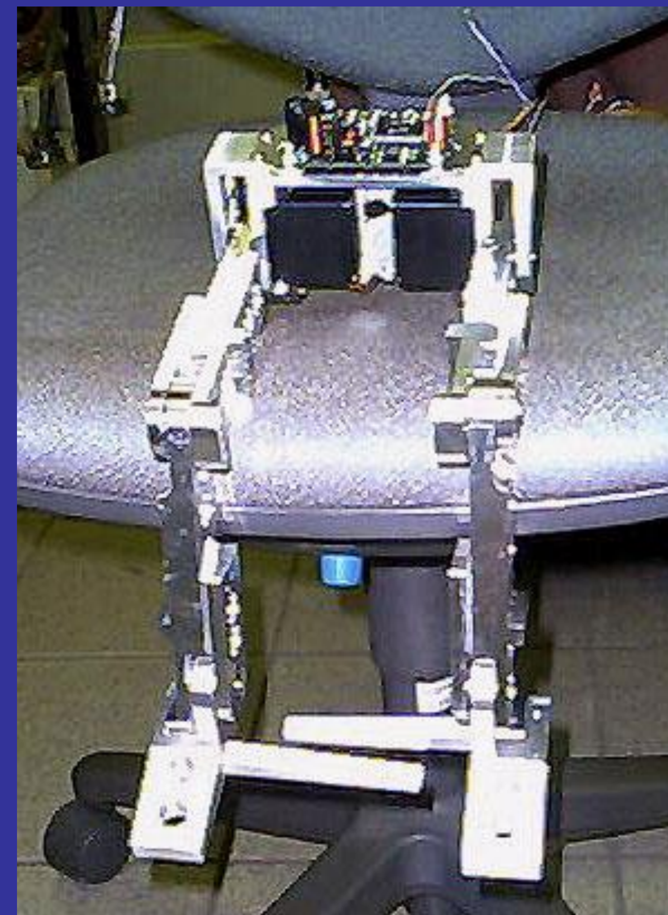
Sensors: V

Tilt sensors: e.g., to balance a robot



Tilt Sensor

Example



Planar Bipedal Robot

Sensors

- Contact sensors: Bumpers
- Internal sensors
  - Accelerometers (spring-mounted masses)
  - Gyroscopes (spinning mass, laser light)
  - Compasses, inclinometers (earth magnetic field, gravity)
- Proximity sensors
  - Sonar (time of flight)
  - Radar (phase and frequency)
  - Laser range-finders (triangulation, tof, phase)
  - Infrared (intensity)
- Visual sensors: Cameras
- Satellite-based sensors: GPS

Sensors: Types

- Electromagnetic
  - Photosensors, RF
  - Current, voltage – EKG, EMG, EEG, …
- Mechanical
  - Physical pressure/force
  - accelerometer
  - Sound
  - Heat
- Chemical
  - Smell
  - Taste
  - pH
  - glucometer
- Biological
  - DNA
  - T cell count
- Nuclear

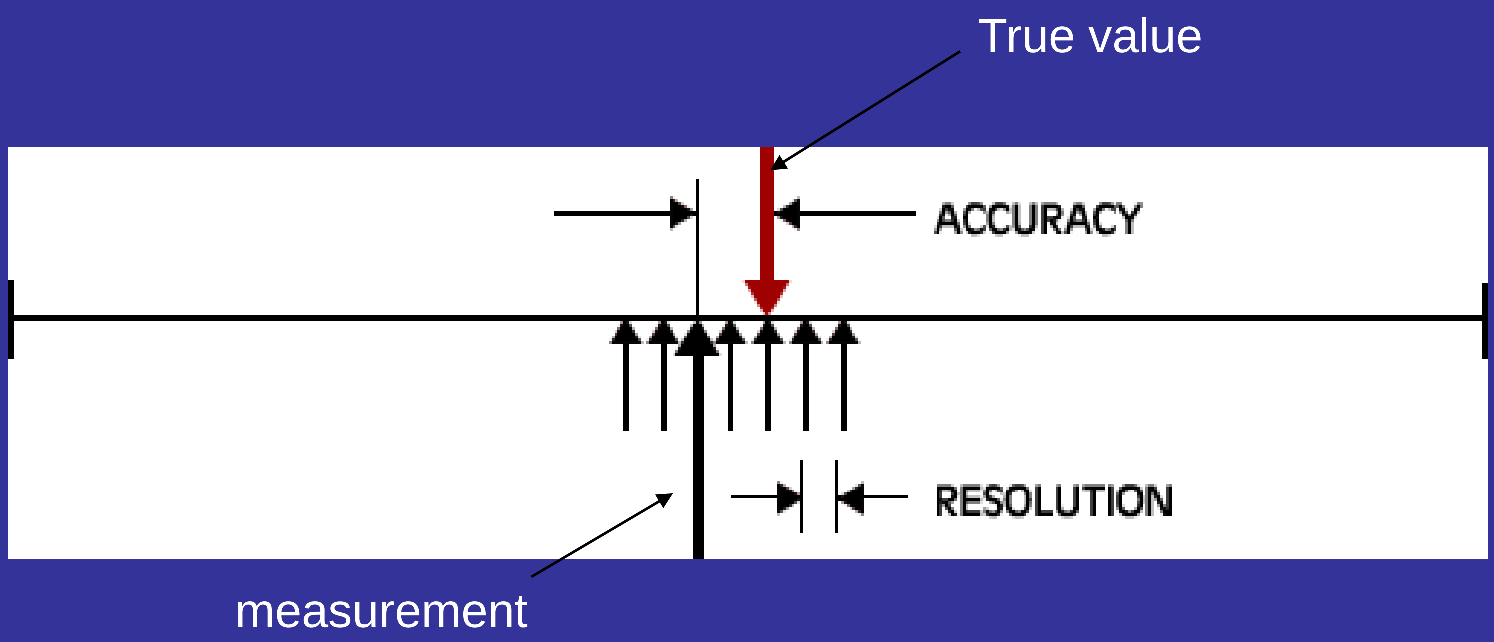
Specifications of Sensor

- **Accuracy:** error between the result of a measurement and the true value being measured.
- **Resolution:** the smallest increment of measure that a device can make.
- **Sensitivity**: the ratio between the change in the output signal to a small change in input physical signal. Slope of the input-output fit line.
- **Repeatability/Precision**: the ability of the sensor to output the same value for the same input over a number of trials

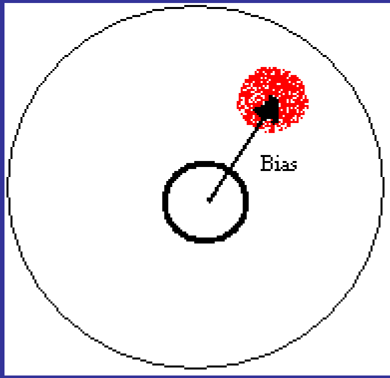
Specifications of Sensor

- **Dynamic Range**: the ratio of maximum recordable input amplitude to minimum input amplitude, i.e. D.R. = 20 log (Max. Input Ampl./Min. Input Ampl.) dB
- **Linearity**: the deviation of the output from a best-fit straight line for a given range of the sensor
- **Transfer Function** (Frequency Response): The relationship between physical input signal and electrical output signal, which may constitute a complete description of the sensor characteristics.
- **Bandwidth**: the frequency range between the lower and upper cutoff frequencies, within which the sensor transfer function is constant gain or linear.
- **Noise**: random fluctuation in the value of input that causes random fluctuation in the output value

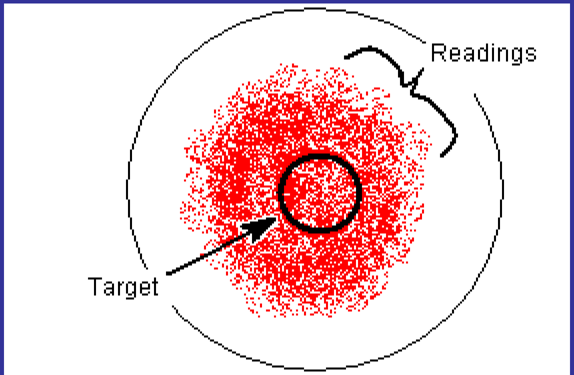
Accuracy vs. Resolution



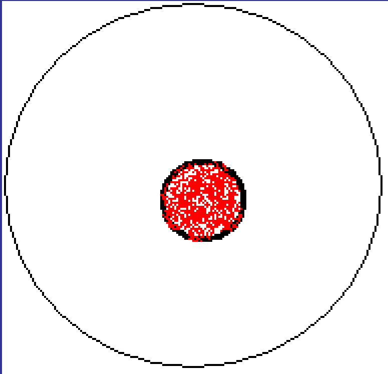
Accuracy vs. Precision



Precision without accuracy



Accuracy without precision



Precision and accuracy

Attributes of Sensors

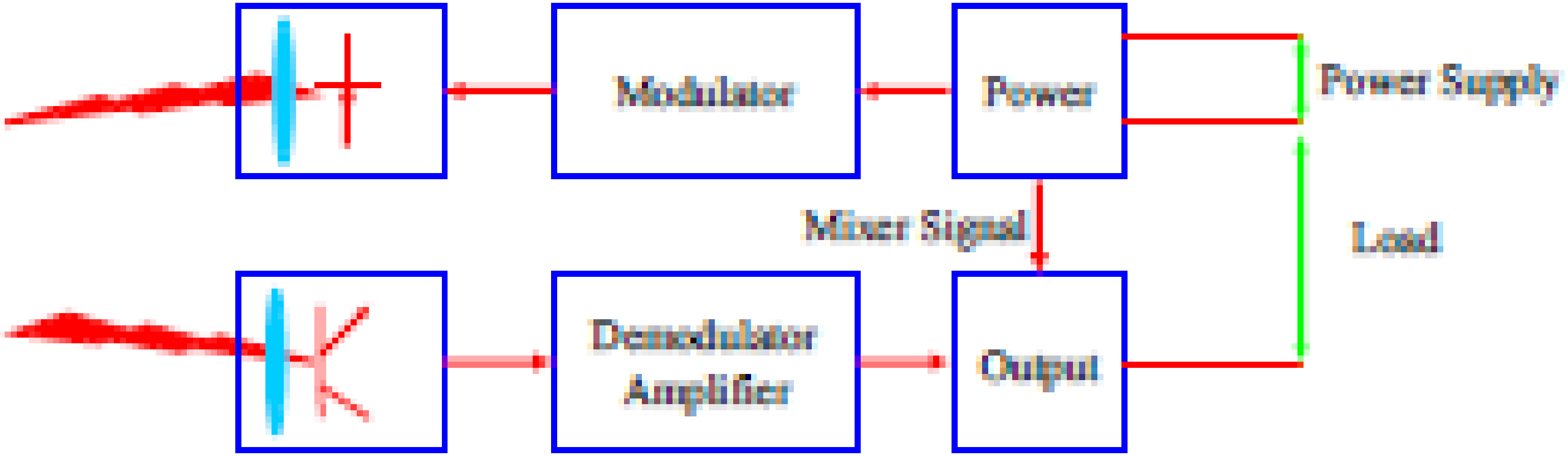
- **Operating Principle**: Embedded technologies that make sensors function, such as electro-optics, electromagnetic, piezoelectricity, active and passive ultraviolet.
- **Dimension of Variables**: The number of dimensions of physical variables.
- **Size**: The physical volume of sensors.
- **Data Format**: The measuring feature of data in time; continuous or discrete/analog or digital.
- **Intelligence**: Capabilities of on-board data processing and decision-making.
- **Active versus Passive Sensors**: Capability of generating vs. just receiving signals.
- **Physical Contact**: The way sensors observe the disturbance in environment.
- **Environmental durability**: will the sensor robust enough for its operation conditions

Proximity Measurement

- Measurement can be caused by …
  - a known obstacle.
  - cross-talk.
  - an unexpected obstacle (people, furniture, …).
  - missing all obstacles (total reflection, glass, …).
- Noise is due to uncertainty …
  - in measuring distance to known obstacle.
  - in position of known obstacles.
  - in position of additional obstacles.
  - whether obstacle is missed.

Optical Proximity Sensors

- Consist of a light source (LED) and light detector (phototransistor)
- Modulation of signal to minimize ambient lighting conditions
- Various models: 12-30V DC, 24-240V AC, power
- Output: TTL 5V, Solid-state relay, etc.

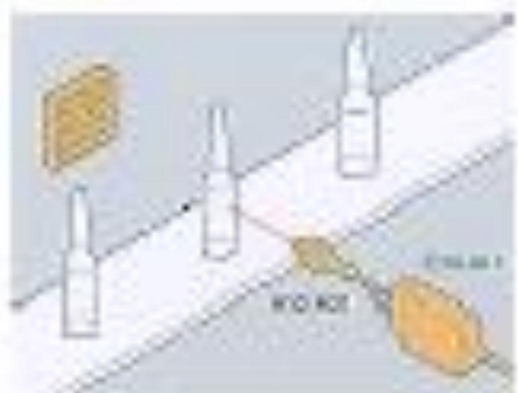


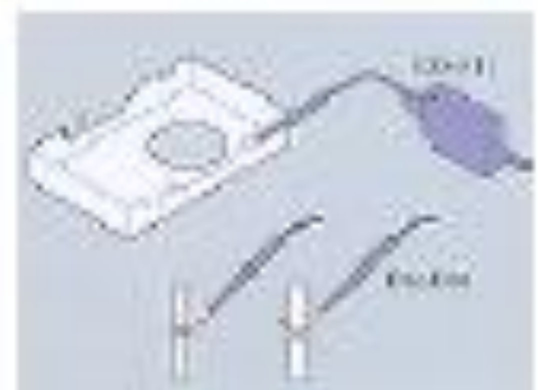
Operational Modes

- Through Beam:
  - Long range (20m)
  - Alignment is critical !
- Retro-reflective
  - Range 1-3m
  - Popular and cheap
- Diffuse-reflective
  - Range 12-300mm
  - Cheap and easy to use

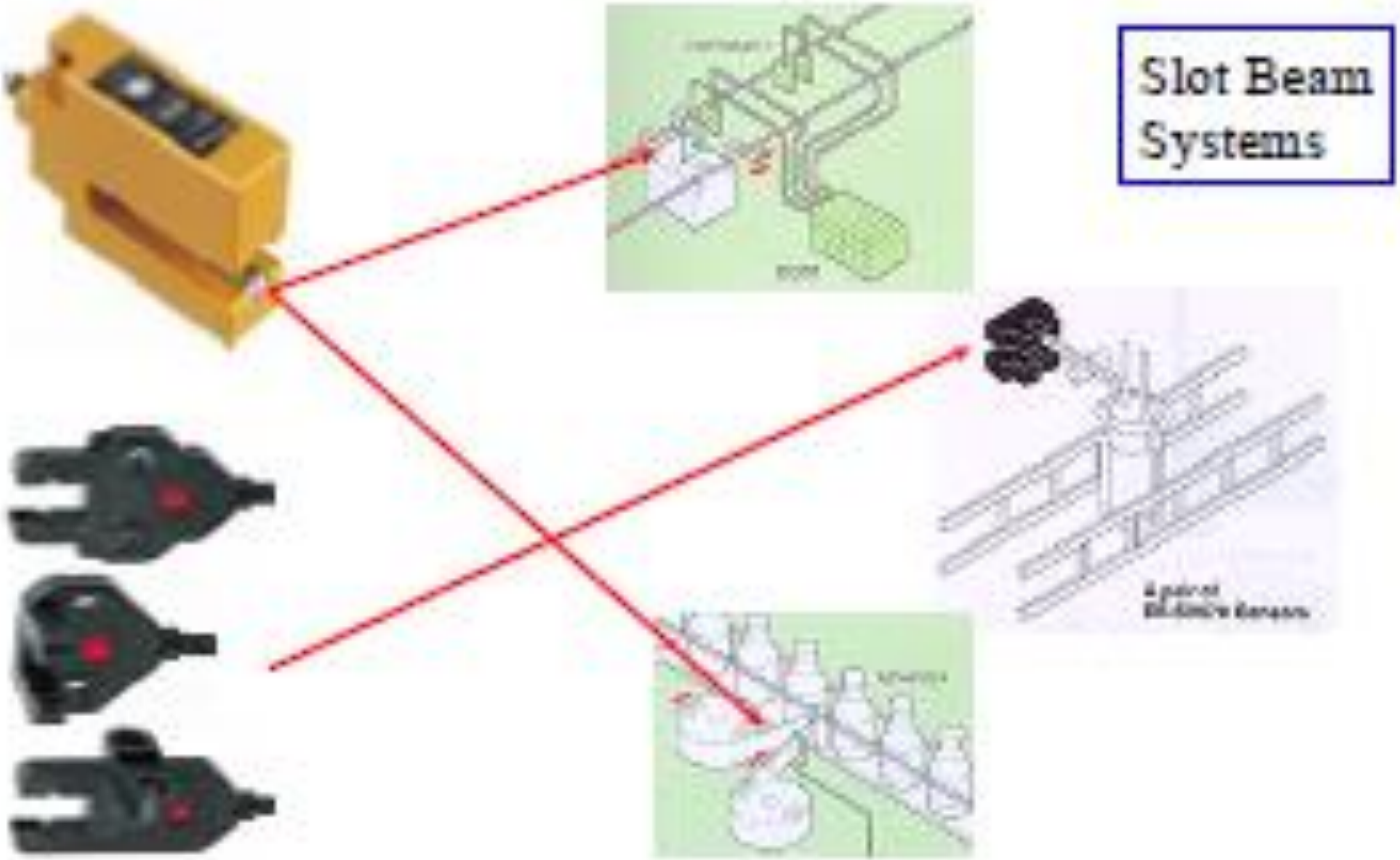
Example Optical Proximity I

Optical Fibre
Delivery System





Example Optical Proximity II



When to use an Optical Proximity Sensor

- Pros
  - Non-contact, no moving parts, small.
  - Fast switching, no switch bounce.
  - Insensitive to vibration and shock
  - Many configurations available
- Cons
  - Alignment always required
  - Can be blinded by ambient light conditions (welding for example)
  - Requires clean, dust and water free, environment

Applications of Optical Proximity Sensors

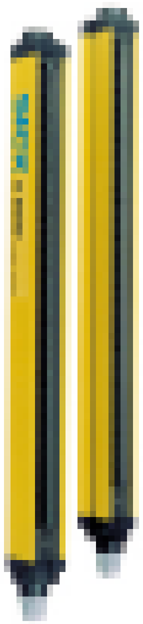
- Stack height control/box counting
- Fluid level control (filling and clarity)
- Breakage and jam detection
- And many others…

http://www.omron-ap.com/application_ex/index.htm

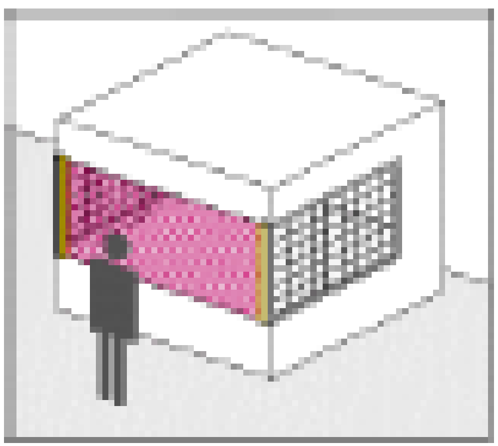
http://www.sick.de/english/products/products.htm

http://content.honeywell.com/sensing/prodinfo/

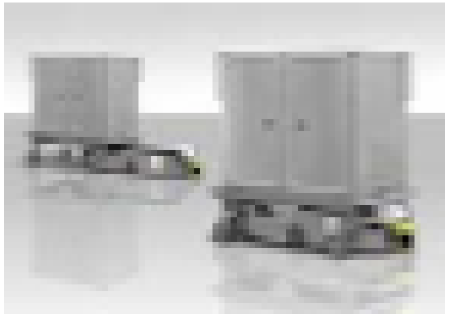
Other Optical Devices



Light Curtain

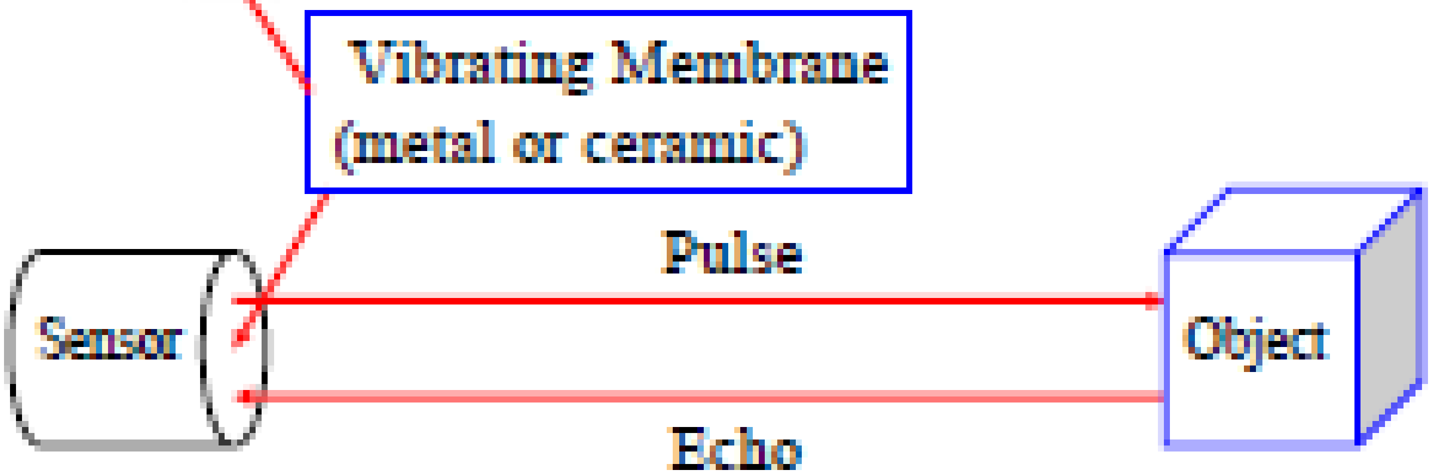


Collision Detection



Ultrasonic Proximity Sensors

- Use sound pulses
- Measures amplitude and time of flight
- Range provides more than on/off information
- Frequencies 40KHz-2MHz



When to use Ultrasonic Sensors

- Provide range data directly:
- Level monitoring of solid and liquids
- Approach warning (collisions)
- Can (usually) work in heavy dust and water
- Ambient noise is potentially an issue

http://www.automationsensors.com/

Example Applications

Car Wash
Application

Paper roll
Thickness Monitor

Waste water
flow volume

Inductive and Capacitive Proximity Sensors

- Inductive sensors use change in local magnetic field to detect presence of metal target
- Capacitive Sensors use change in local capacitance caused by non-metallic objects
- Generally short ranges only
- Regarded as very robust and reliable

Example Inductive Sensors I

Detection of open/close functions

Detection of rotation

Example Inductive Sensors II

Bulk mounted inductive sensors. Detect presence of object without contact. Range 3mm +/- 10%

- **Inductive proximity sensors**
  - coil inductance is greatly affected by the presence of ferromagnetic materials
  - here the proximity of a ferromagnetic plate is determined by measuring the inductance of a coil

Inductive proximity sensors

Example Capacitive Sensors

Panel Mounted Capacitive Sensor. Can detect wood, plastic and metal.
Range 3mm-25mm

Flat mounted Capacitive Sensor. Used for detecting panels of glass.
Range=10mm +/- 10%

RANGE SENSORS

1. Triangulation principle
2. Structured Lighting Approach
3. Time of flight range finders
4. Laser range finders

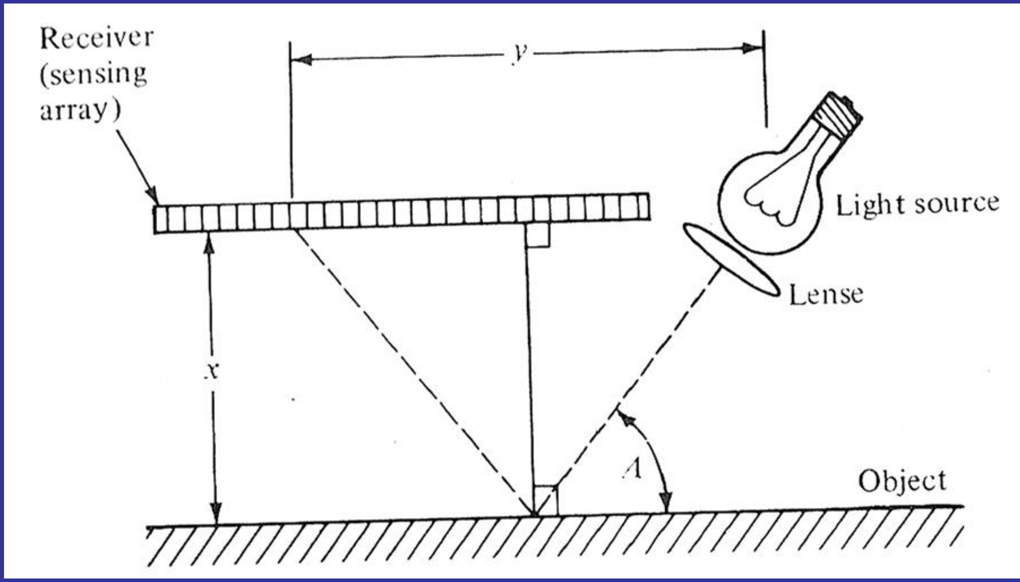


Figure 6-7 Scheme for a proximity sensor using reflected light against a sensor array.

X=0.5ytan(A)

Laser range finder

• A **laser rangefinder** is a device which uses a laser beam to determine the distance to an object.
• The most common form of laser rangefinder operates on the time of flight principle by sending a laser pulse in a narrow beam towards the object and measuring the time taken by the pulse to be reflected off the target and returned to the sender.
• Due to the high speed of light, this technique is not appropriate for high precision sub-millimeter measurements, where triangulation and other techniques are often used.

A long range laser rangefinder is capable of measuring distance up to 20 km; mounted on a tripod with an angular mount. The resulting system also provides azimuth and elevation measurements.

Technologies

Time of flight - this measures the time taken for a light pulse to travel to the target and back. With the speed of light known, and an accurate measurement of the time taken, the distance can be calculated. Many pulses are fired sequentially and the average response is most commonly used. This technique requires very accurate sub-nanosecond timing circuitry.

Multiple frequency phase-shift - this measures the phase shift of multiple frequencies on reflection then solves some simultaneous equations to give a final measure.

Interferometry - the most accurate and most useful technique for measuring changes in distance rather than absolute distances.

Applications

1. **Military -** laser-guided weapons
2. **3-D Modeling**
3. **Forestry -** Laser rangefinders with anti-leaf filter are used for example for forest inventories
4. **Sports -** golf, hunting, and archery
5. **Industry production processes -** during the automation of stock management systems and production processes in steel industry
6. **Laser measuring tools -** area or volume of a room, as well as switch between English and metric units

Velocity Sensors

A **velocity receiver** (**velocity sensor**) is a sensor that responds to velocity rather than absolute position.

Speed measurement can be obtained by taking consecutive position measurements at known time intervals and computing the derivative of the position values.

A tachometer is an example of a velocity sensor that does this for a rotating shaft.

Some types

Encoders

Tachometers

Differentiation of position signal

ENCODERS

- If an encoder is used for displacement measurement, there is no need to use a velocity sensor.

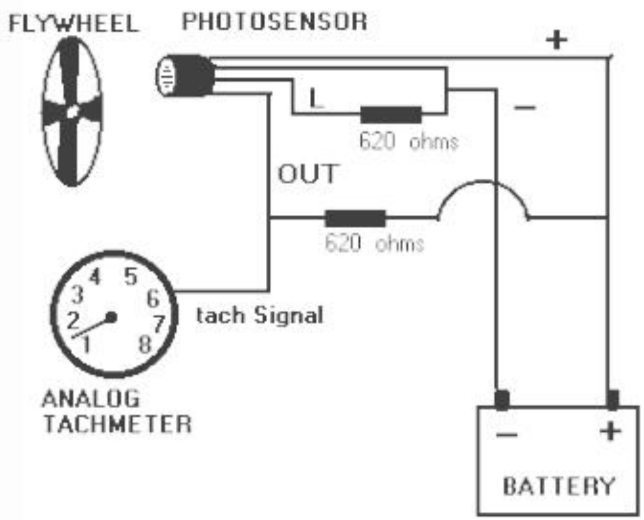
- Since encoders send a known number of signals for any given angular displacement, by counting the number of signals received in a given length of time *(dt),we can calculate velocity.*

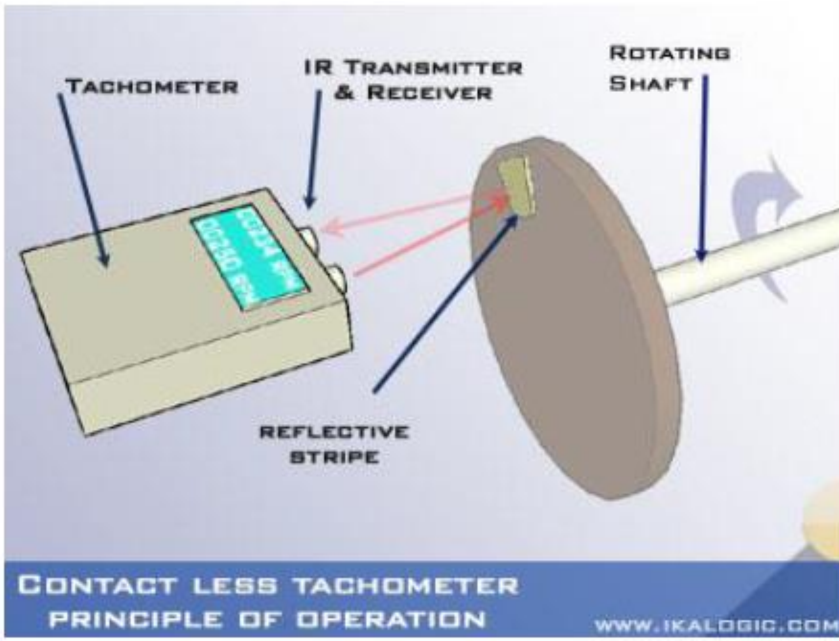
- *A smaller length of time (dt) yields a more accurate calculated velocity, once that is closer to the true instantaneous velocity.*

- *This velocity calculation is accomplished by programming the controller to convert number of signals in a given length of time into velocity information.*

TACHOMETERS

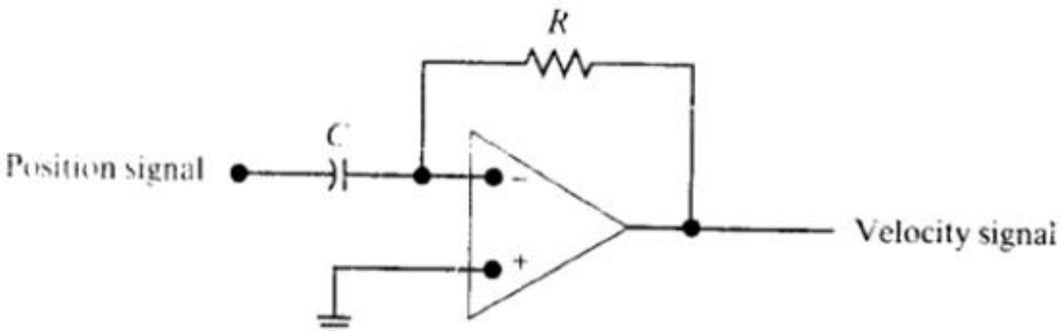
- A tachometer is a generator that converts mechanical energy into electrical energy.
- Its output is an analog voltage proportional to the input angular speed.
- It may be used along with potentiometers to estimate velocities.





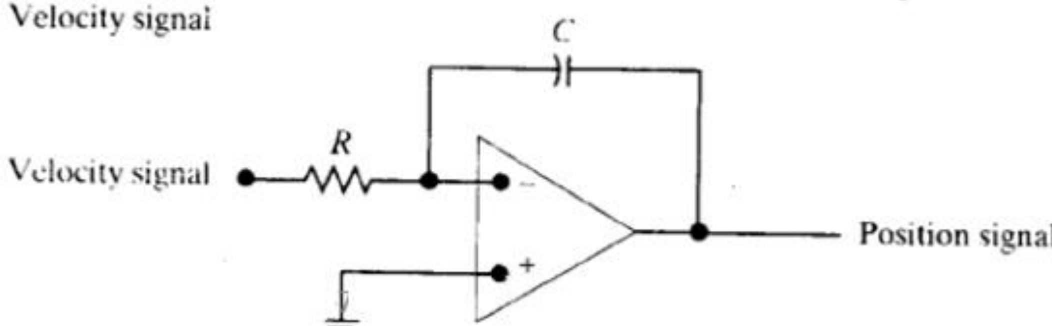
Differentiation of Position Signal

- If the position signal is clean, it is actually possible, and even simple, to differentiate the position signal and to convert it to velocity signal.
- To do this, it is necessary that the signal be as continuous as possible in order to prevent creation of large impulses in velocity signal.
- However, differentiation of a signal is always noisy and should be done very carefully.
- Figure shows a simple R-C circuit with an op-amp that can be used for differentiation, where the velocity signal is $V_{out} = -RC\frac{dV_{in}}{dt}$.
- Similarly, the velocity (or acceleration) signal can be integrated to yield position (or velocity) signals: $V_{out} = -\frac{1}{RC}\int V_{in}dt$.



$$V_{out} = -RC\frac{dV_{in}}{dt}.$$

$$V_{out} = -\frac{1}{RC}\int V_{in}dt.$$



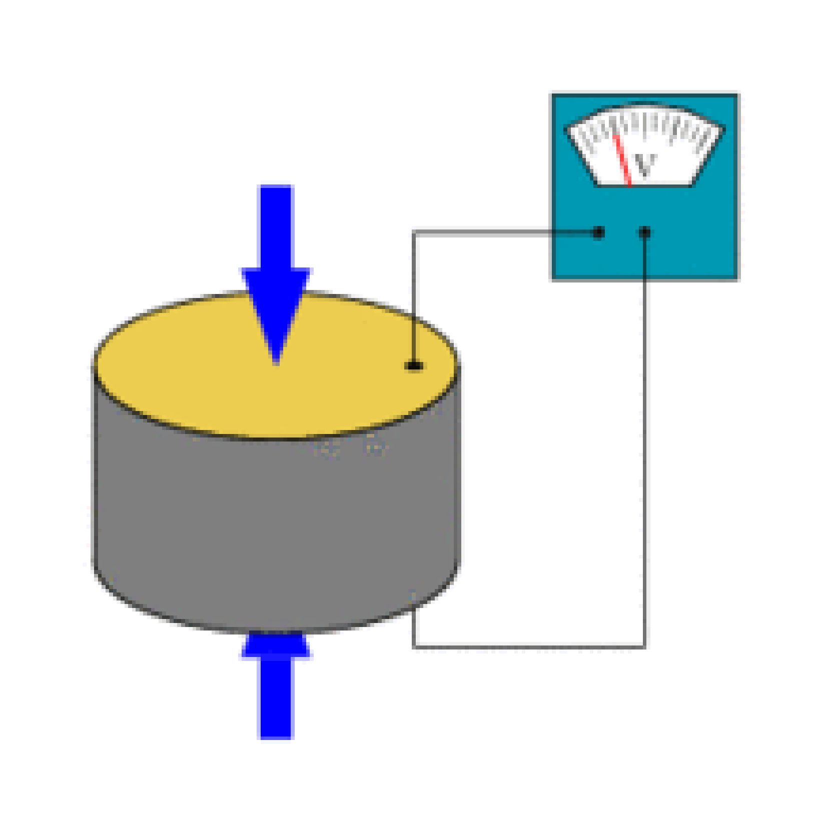
Piezoelectric sensor

* A **piezoelectric sensor** is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them to an electrical charge.

* The word Piezoelectric is derived from the Greek piezein, which means to squeeze or press, and piezo, which is Greek for "push".

* Some naturally piezoelectric occurring materials include Berlinite (structurally identical to quartz), cane sugar, quartz, Rochelle salt, topaz, tourmaline, and bone.

* An example of man-made piezoelectric materials includes barium titanate and lead zirconate titanate.



Contact sensor

•Contact sensor uses transducer for the sensing operation. Some mostly used sensors are potentiometer, strain gauge etc. Contact or touch sensors are one of the most common sensors in robotics.

•These are generally used to detect a change in position, velocity, acceleration, force, or torque at the manipulator joints and the end-effecter.

•There are two main types, bumper and tactile.

•Bumper type detect whether they are touching anything, the information is either Yes or No. They cannot give information about how hard is the contact or what they are touching.

•Tactile sensor are more complex and provide information on how hard the sensor is touched, or what is the direction and rate of relative movement.

NON-CONTACTING SENSOR

- Non-contacting sensors detect parametric information about the environment of the object.
- It is used to detect the existence, distance and features of the object without having contact.
- There are mainly five types of non-contacting sensor are as:

(1). Visual and optical sensor.

(2). Magnetic and inductive sensor.

(3). Capacitive sensor.

(4). Resistive sensor.

(5). Ultrasonic and sonar sensor

Touch sensor/switch

- A **touch switch** is a type of switch that only has to be touched by an object to operate.
- It is used in many lamps and wall switches that have a metal exterior as well as on public computer terminals. A touch screen includes an array of touch switches on a display.
- A touch switch is the simplest kind of tactile sensor.

1. Binary sensors
2. Analog sensors

Types

There are two types of switches called touch switches:

Capacitance touch switch

- A capacitance switch needs only one electrode to function.
- The electrode can be placed behind a non-conductive panel such as wood, glass, or plastic.
- The switch works using body capacitance, a property of the human body that gives it great electrical characteristics.
- The lamp keeps charging and discharging its metal exterior to detect changes in capacitance. When a person touches it, it increases the capacitance and triggers the switch.

Resistance touch switch

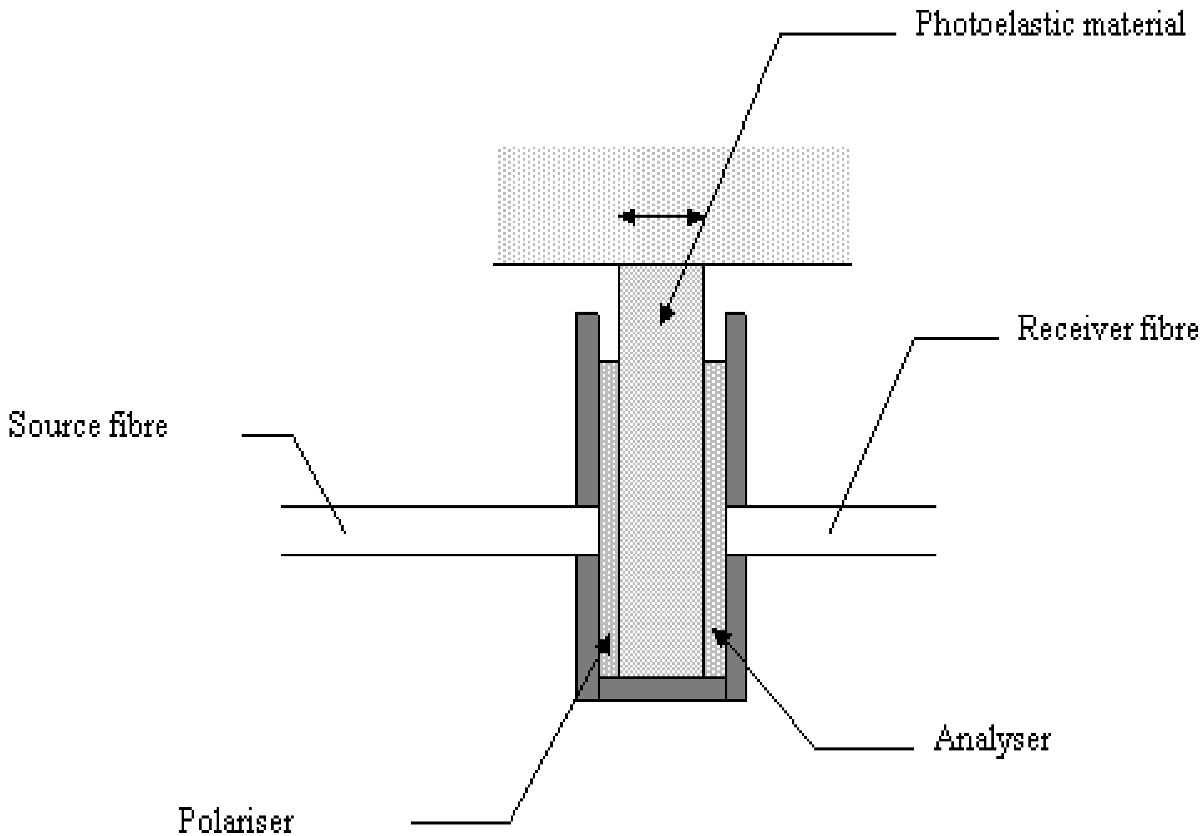
- A resistance switch needs two electrodes to be physically in contact with something electrically conductive (for example a finger) to operate.
- They work by lowering the resistance between two pieces of metal. It is thus much simpler in construction compared to the capacitance switch.
- Placing one or two fingers across the plates achieves a turn on or closed state. Removing the finger(s) from the metal pieces turns the device off.
- One implementation of a resistance touch switch would be two darlington-paired transistors where the base of the first transistor is connected to one of the electrodes.
- Also, an N-Channel, enhancement-mode, metal oxide field effect transistor can be used. Its gate can be connected to one of the electrodes and the other electrode through a resistance to a positive voltage.

Slip Sensing

- Slip may be regarded as the relative movement of one object's surface over an other when in contact.
- The relative movement ranges from simple translational motion to a combination of translational and rotational motions.
- When handling an object, the detection of slip becomes necessary so as to prevent the object being dropped due to the application of a low grip force.
- In an assembly operation, it is possible to test the occurrence of slip to indicate some predetermined contact forces between the object and the assembled part.
- For the majority of applications some qualitative information on object slip may be sufficient, and can be detected using a number of different approaches.

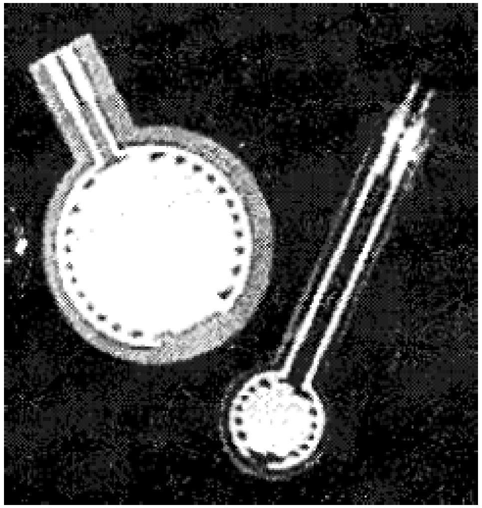
1. Interpretation of tactile-array information

2. Slip sensing based on touch-sensing information



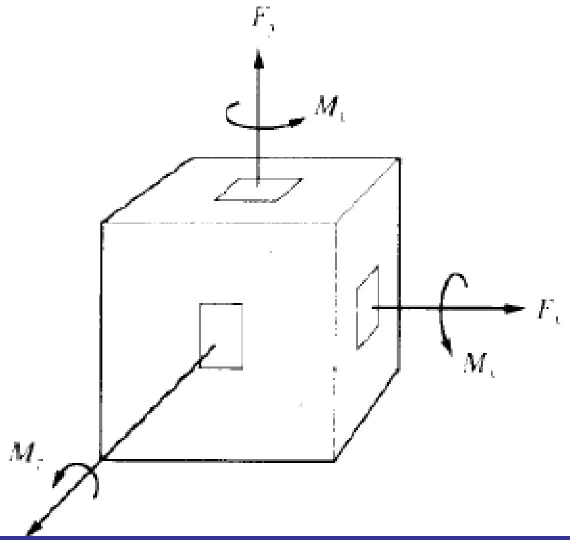
Force-Sensing Resistor

- The Force Sensing Resistor(FSR) is a polymer thick-film device that exhibits a decreasing resistance with increasing force applied normal to its surface.
- For a changing force of 10 to 10,000 gram, its resistance changes from about 500 *KΩ to about 1 KΩ.*
- *Figure shows a typical force-sensing resistor.*



TORQUE SENSORS

- Torque can be measured by a pair of strategically placed force sensors.
- Suppose that two force sensors are placed on a shaft, opposite of each other, on opposite sides.
- If a torque is applied to the shaft, it generates two opposing forces on the shafts body, causing opposite direction strains.
- The two force sensors can measure the forces, which can be converted to a torque.



WRIST SENSORS

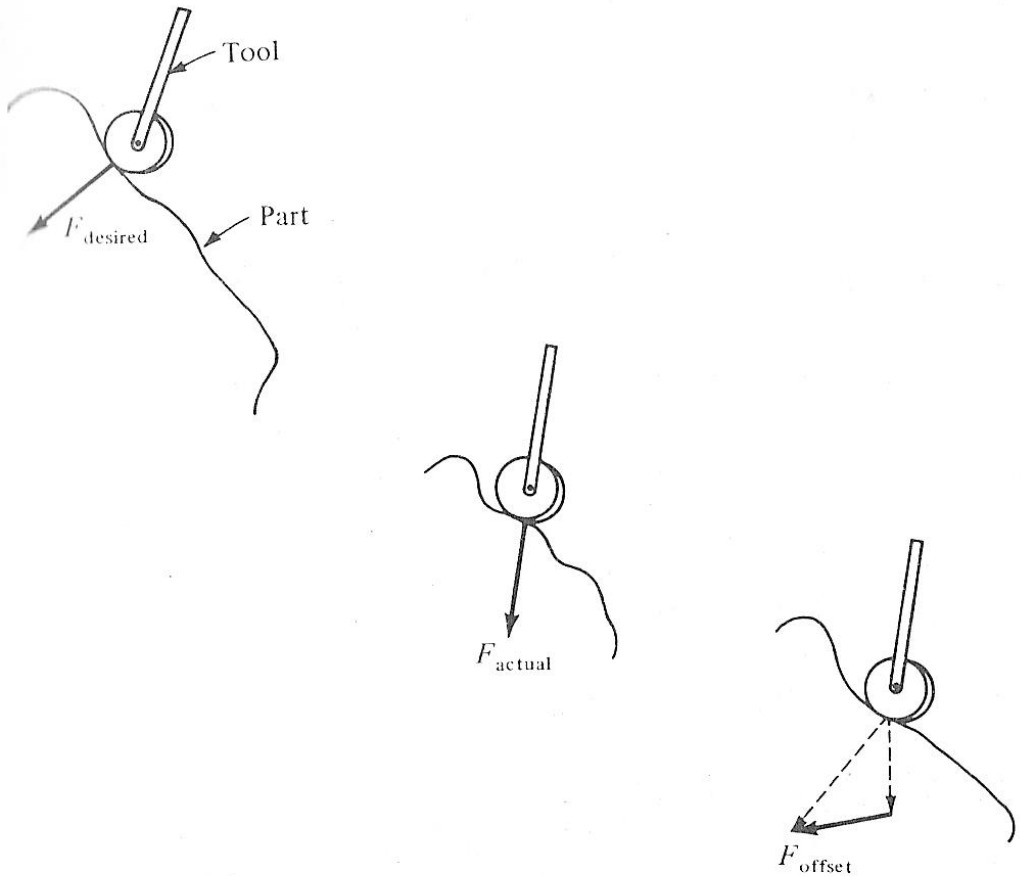


Figure 6-2 Force accommodation, showing how the required offset force would compensate for the difference between actual force and desired force.

TACTILE ARRAY SENSOR

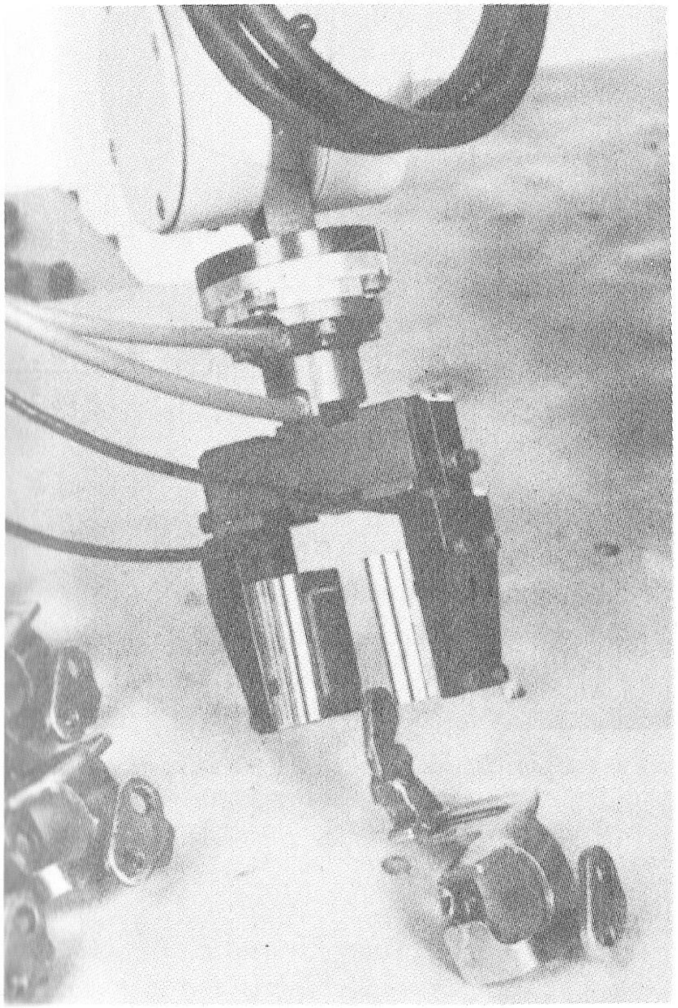


Figure 6-3 Tactile array sensor device mounted in a mechanical gripper. (Photo courtesy of Lord Corporation.)

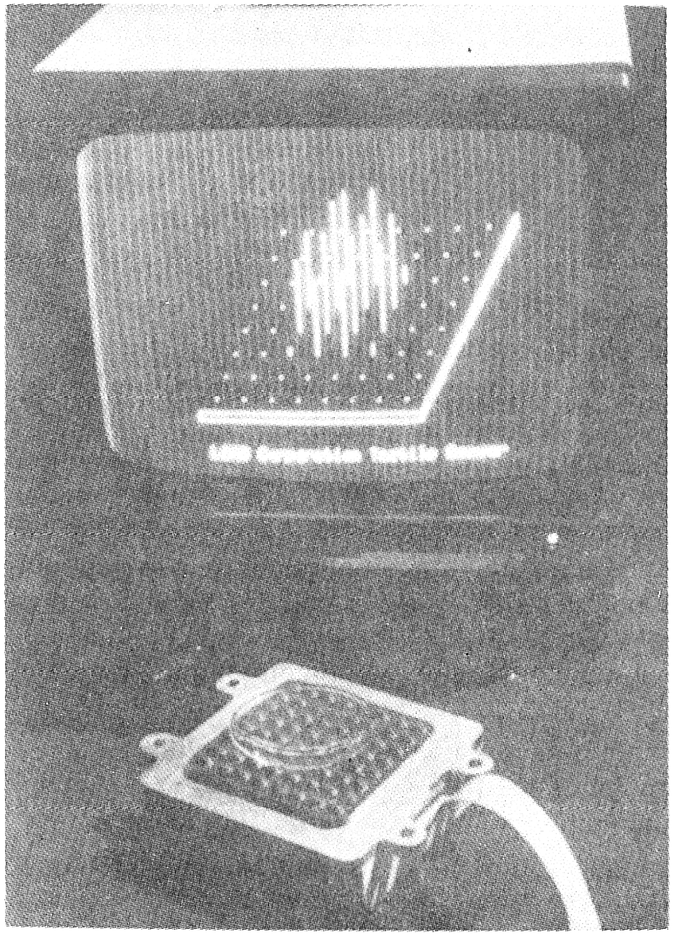


Figure 6-5 Tactile array sensor using 8×8 sensor array with display of tactile impression. (Photo courtesy of Lord Corporation.)

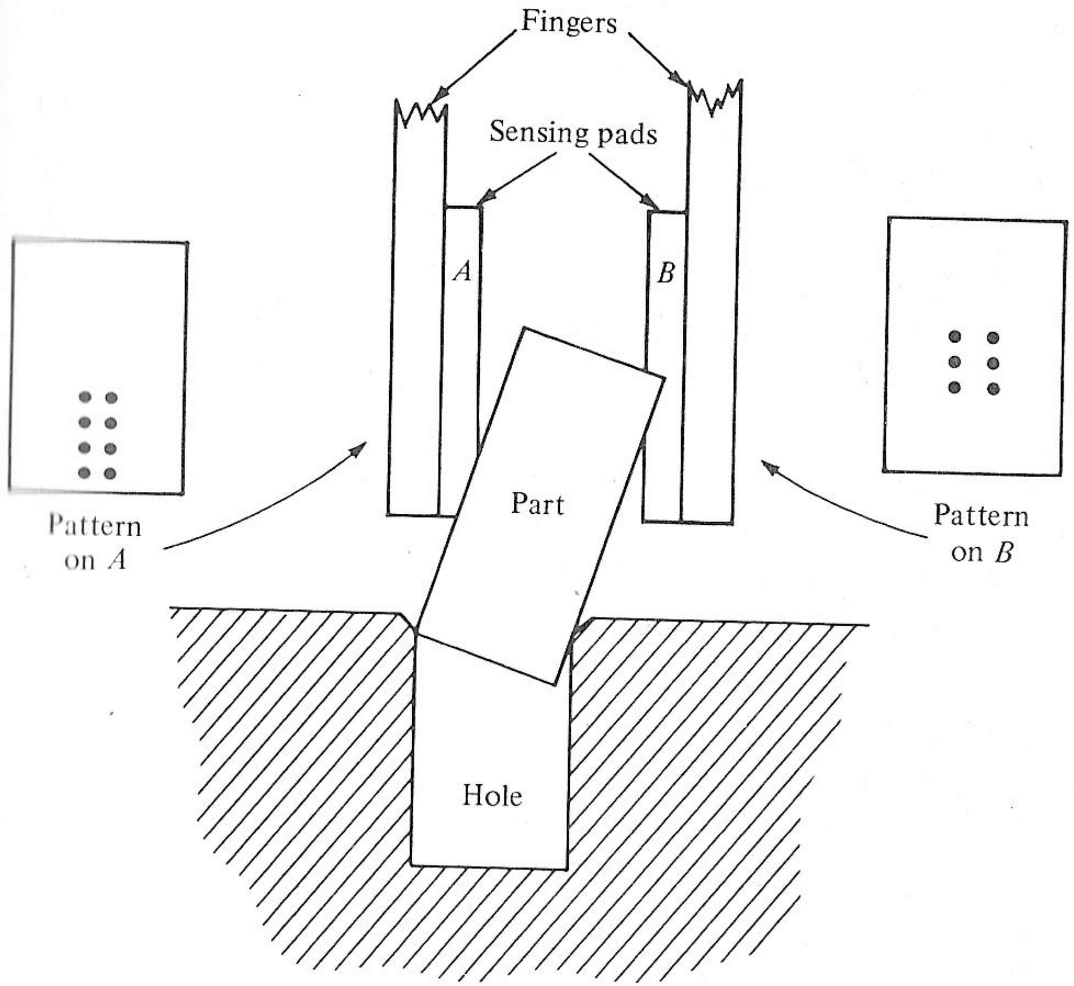


Figure 6-6 Possible binding action in an insertion task of Example 6-1 showing pattern of forces of the tactile array sensor surfaces.

USES OF SENSORS IN ROBOTICS

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

MACHINE VISION

Criteria for Design of Vision Systems

1. Low cost vision systems
2. Relatively rapid response time needed for robot

Advances in Vision Technology

1. Vision-based guidance of the robot arm.
2. Complex inspection for close dimensional tolerances.
3. Improved recognition and part location capabilities.
4. Permit applications not only in manufacturing, but also in hazardous environments autonomous navigation, cartography, and medical image analysis.

MACHINE VISION

Classifications

1. 2D/3D vision systems
   - 2D – Binary image
   - 3D – Stereoscopic view of the scene
2. Acc. to no. of gray levels (light intensity levels)
   - Binary image – black & white
   - 3D image – All colures (gray scale)

Cameras

Older – Vidicon black and white camera

Newer – Solid state cameras – 1. charge coupled device (CCD), charge injection device (CID) and silicon bipolar sensor cameras.

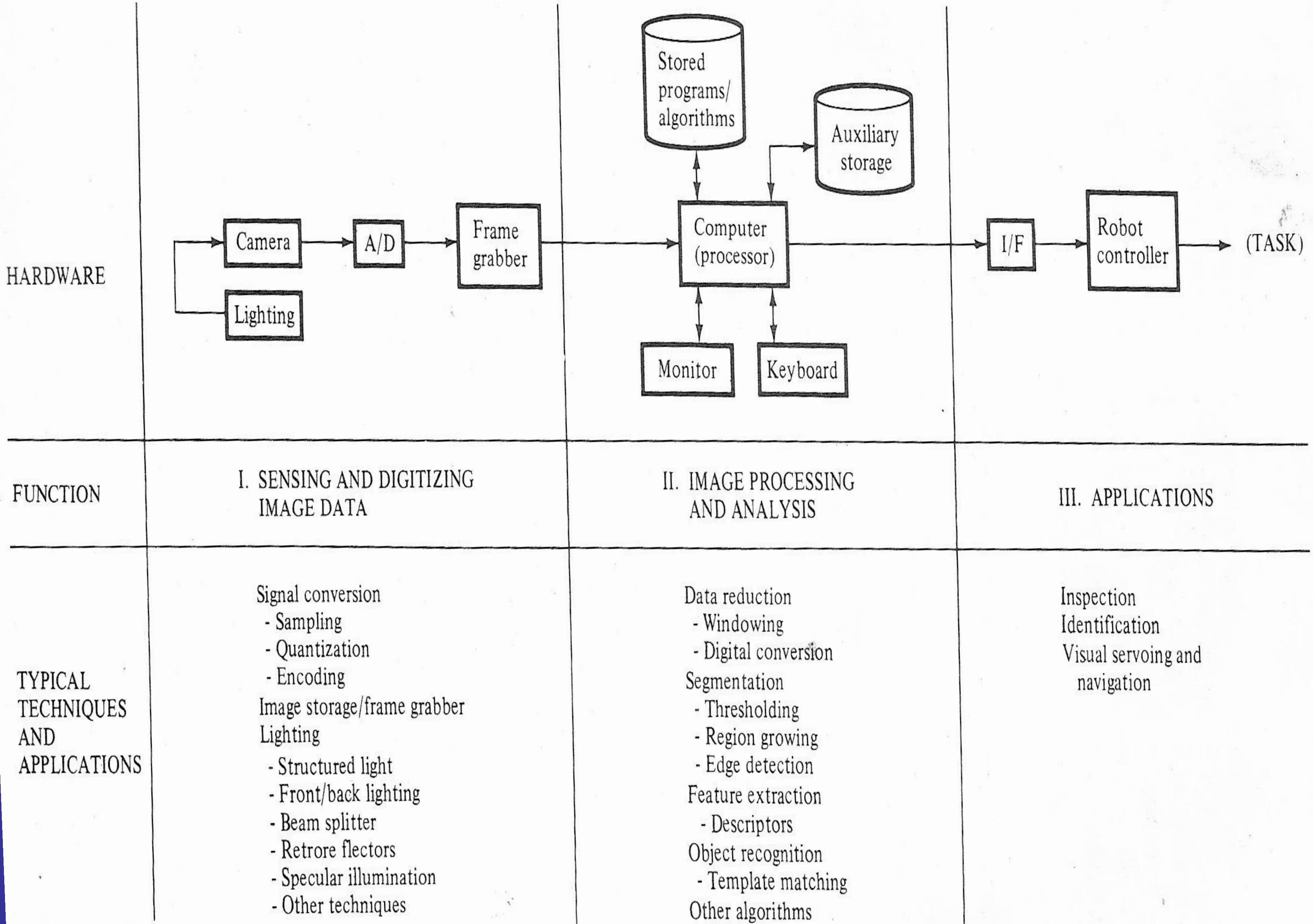


Figure 7-1 Functions of a machine vision system.

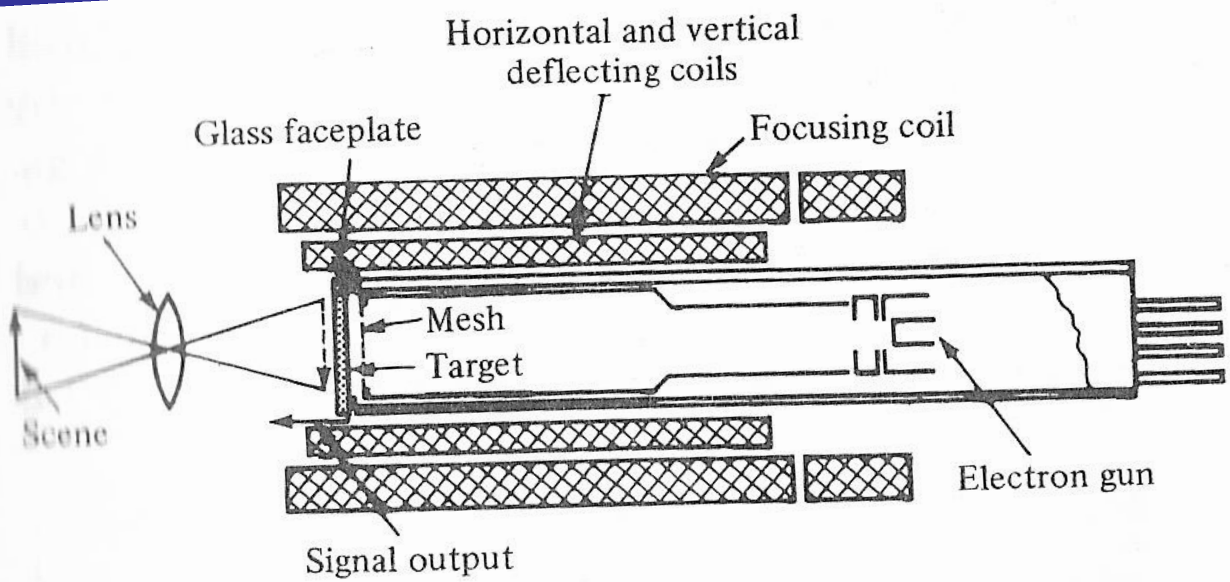


Figure 7-2 Cross section of a videcon tube and its associated deflection and focusing tube. (Reprinted with permission of McGraw-Hill, Inc. [10].)

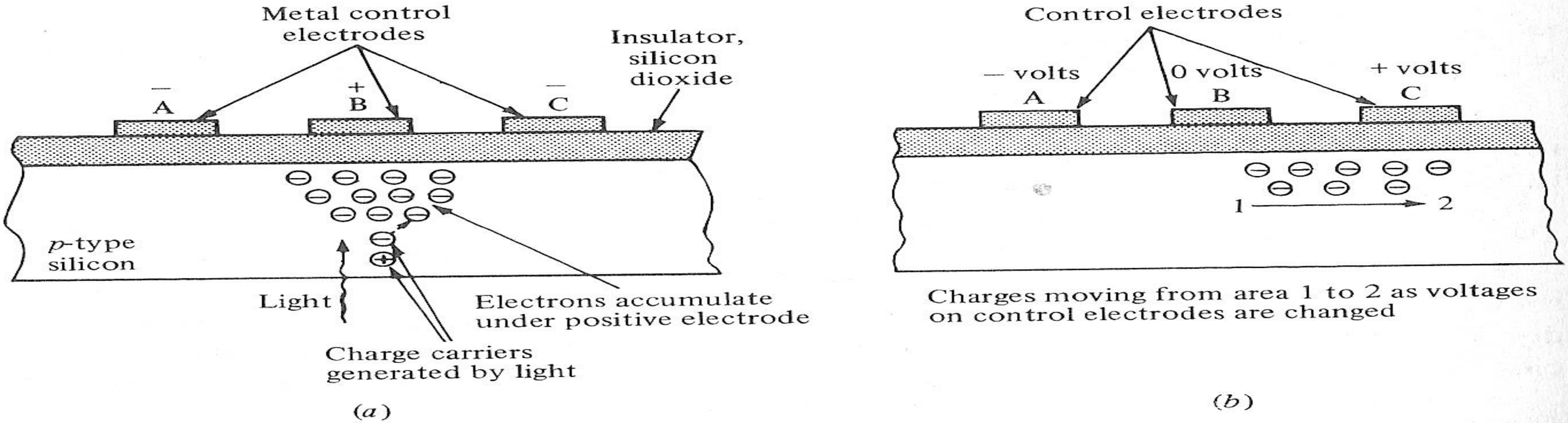


Figure 7-3 Basic principle of charge-coupled device. (a) accumulation of an electron charge in a pixel element (b) movement of accumulated charge through the silicon by changing the voltages on the electrodes A, B, and C. (Reprinted with permission of McGraw-Hill, Inc. [10].)

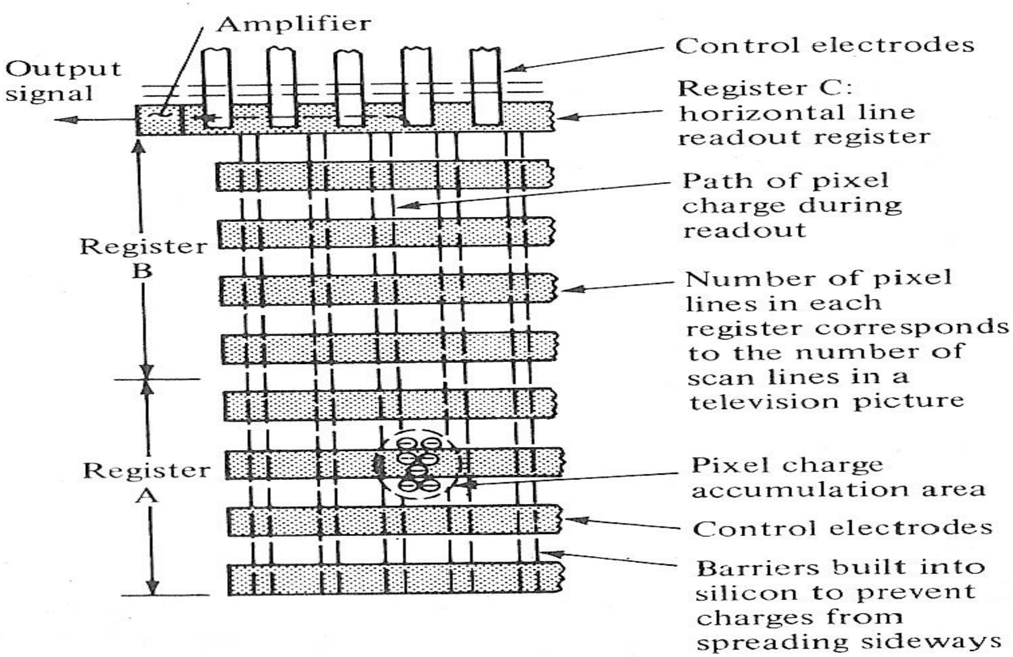


Figure 7-4 One type of charge-coupled-device imager. Register A accumulates the pixel charges produced by photoconductivity generated by the light image. The B register stores the lines of pixel charges and transfers each line in turn into register C. Register C reads out the charges laterally as shown into the amplifier. (Reprinted with permission of McGraw-Hill, Inc. [10].)

Table 7-1 Illumination techniques

Technique	Function/use
A. Front light source	
1. Front illumination	Area flooded such that surface is defining feature of image
2. Specular illumination (dark field)	Used for surface defect recognition (background dark)
3. Specular illumination (light field)	Used for surface defect recognition; camera in-line with reflected rays (background light)
4. Front imager	Structured light applications; imaged light superimposed on object surface—light beam displaced as function of thickness
B. Back light source	
1. Rear illumination (lighted field)	Uses surface diffusor to silhouette features; used in parts inspection and basic measurements
2. Rear illumination (condenser)	Produces high-contrast images; useful for high magnification application
3. Rear illumination (collimator)	Produces parallel light ray source such that features of object do not lie in same plane
4. Rear offset illumination	Useful to produce feature highlights when feature is in transparent medium
C. Other miscellaneous devices	
1. Beam splitter	Transmits light along same optical axis as sensor; advantage is that it can illuminate difficult-to-view objects
2. Split mirror	Similar to beam splitter but more efficient with lower intensity requirements
3. Nonselective redirectors	Light source is redirected to provide proper illumination
4. Retroreflector	A device that redirects incident rays back to sensor; incident angle capable of being varied; provides high contrast for object between source and reflector
5. Double density	A technique used to increase illumination intensity at sensor; used with transparent media and retroreflector.

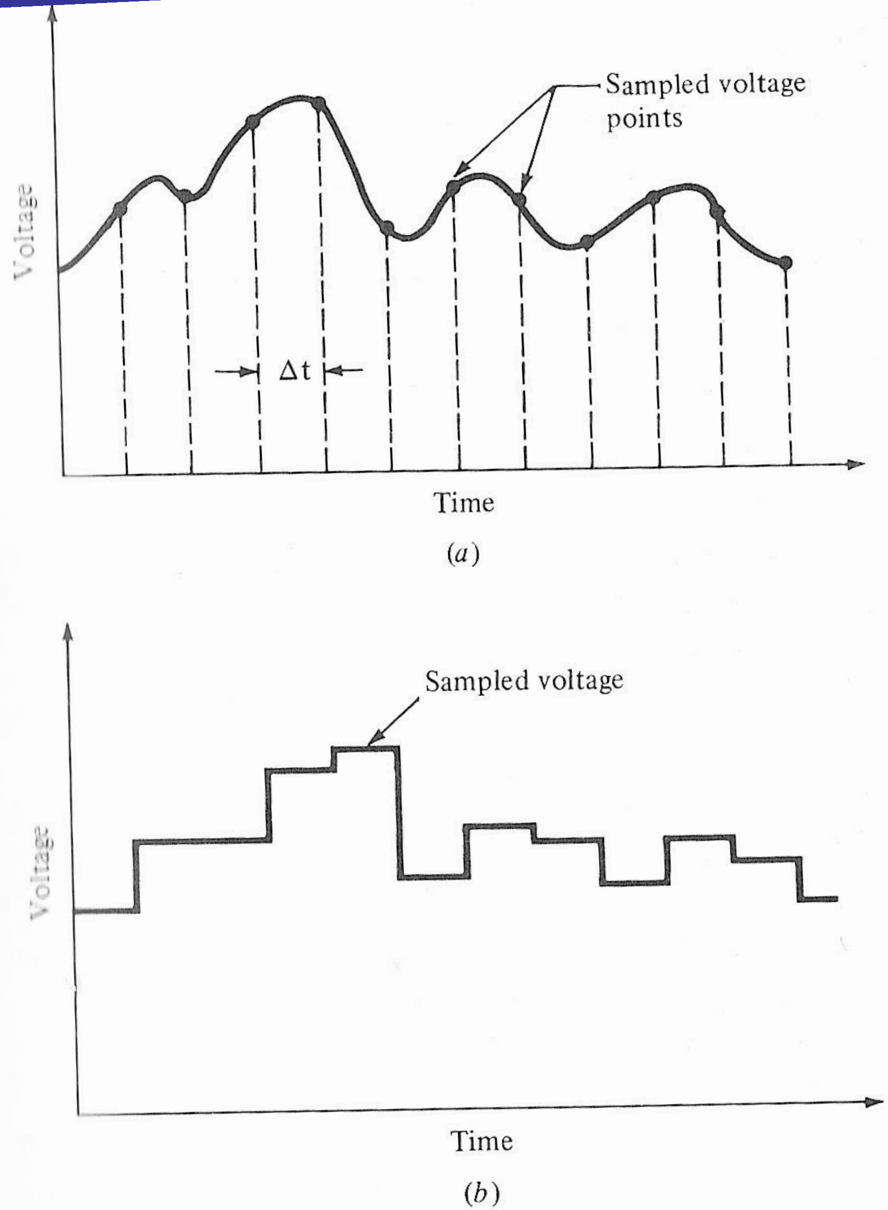
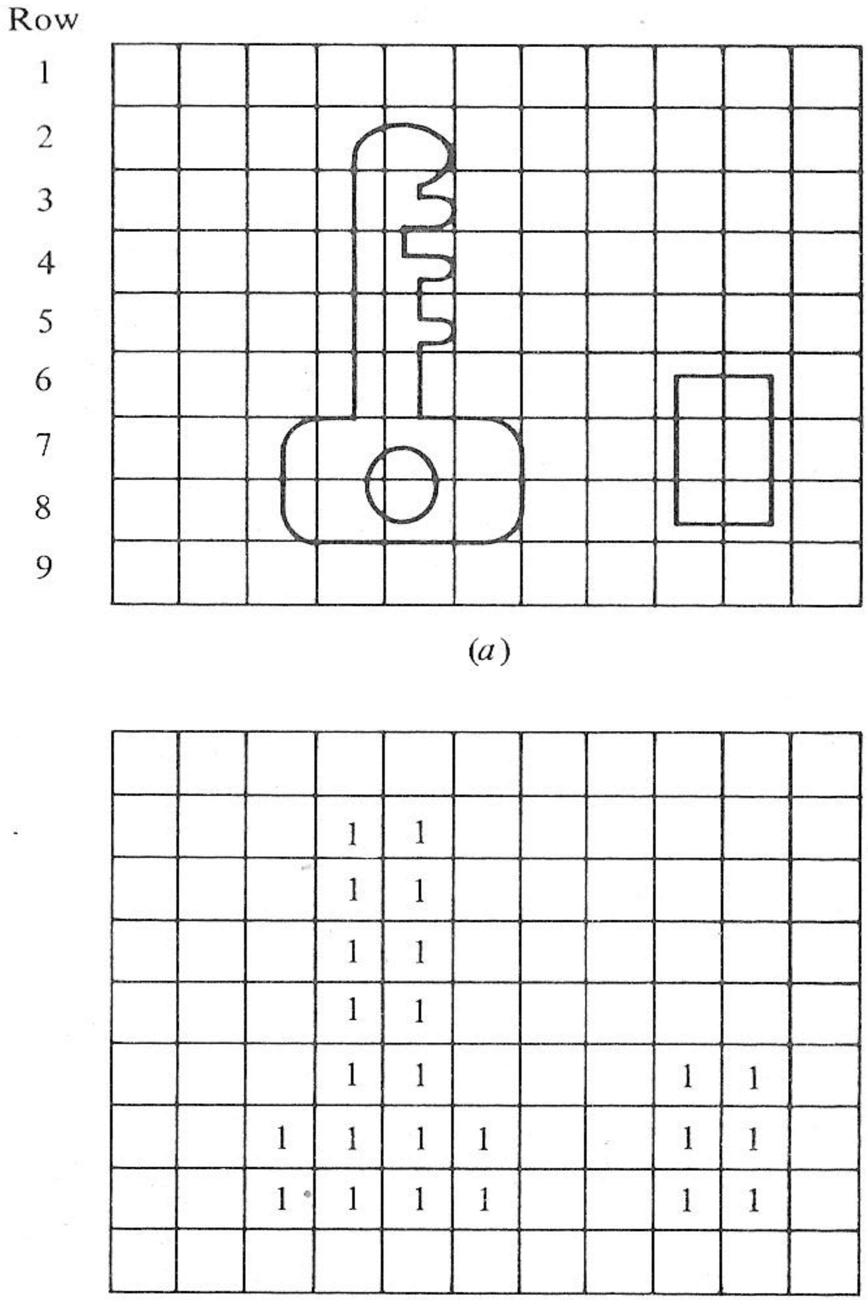


Figure 7-5 Sampling and digitizing an analog waveform. (a) analog waveform indicating sampling interval, *t*, and sampled voltage points. (b) digital approximation to analog signal.



(*a*)

(*b*)

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

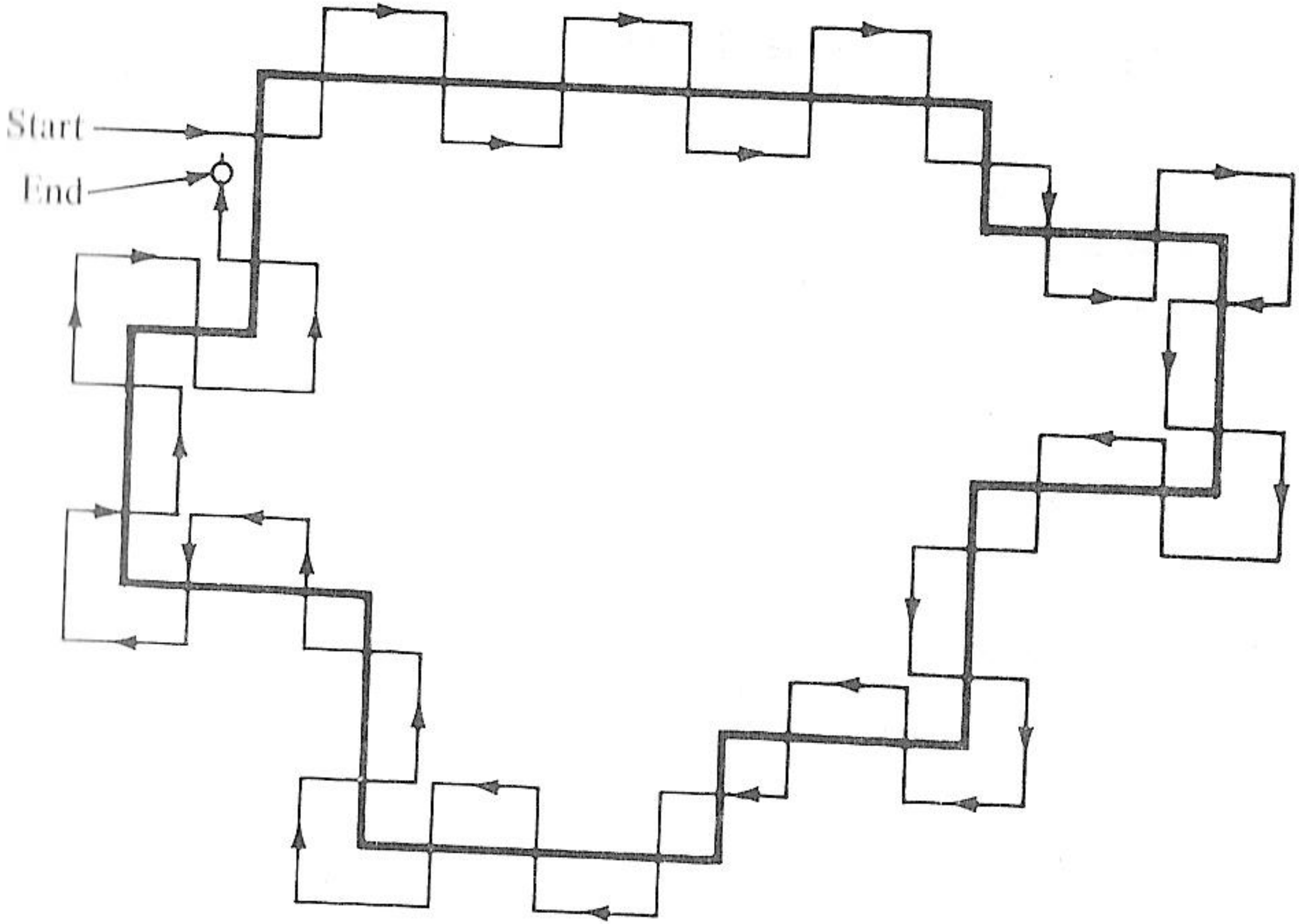


Figure 7-8 Edge following procedure to detect the edge of a binary image.

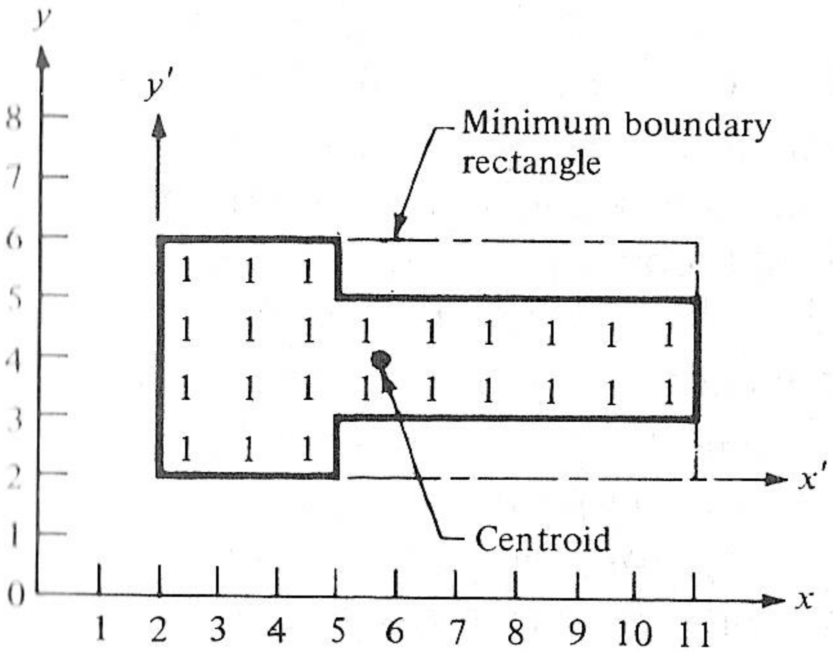


Figure 7-9 Schematic of pixel pattern for Example 7-5.

Table 7-2 Basic features and measures for object identification for two-dimensional objects

---

Gray level (maximum, average, or minimum)

Area

Perimeter length

Diameter

Minimum enclosing rectangle

Center of gravity—For all pixels (n) in a region where each pixel is specified by (x, y) coordinates, the x and y coordinates of the center of gravity are defined as

$$C.G._x = \frac{1}{n} \sum_x x$$

$$C.G._y = \frac{1}{n} \sum_y y$$

Eccentricity—A measure of "elongation." Several measures exist of which the simplest is

$$\text{Eccentricity} = \frac{\text{maximum chord length } A}{\text{maximum chord length } B}$$

where maximum chord length B is chosen perpendicular to A.

Aspect ratio—The length-to-width ratio of a boundary rectangle which encloses the object. One objective is to find the rectangle which gives the minimum aspect ratio.

Thinness—This is a measure of how thin an object is. Two definitions are in use

$$(a)\ \text{Thinness} = \frac{(\text{perimeter})^2}{\text{area}}$$

This is also referred to as compactness.

$$(b)\ \text{Thinness} = \frac{\text{diameter}}{\text{area}}$$

The diameter of an object, regardless of its shape, is the maximum distance obtainable for two points on the boundary of an object.

Holes—Number of holes in the object.

Moments—Given a region, R, and coordinates of the points (x, y) in or on the boundary of the region, the pqth order moment of the image of the region is given as

$$M_{pq} = \sum_{x,\,y} x^p y^q$$

Example 5.1 *For an image digitized at 128 points per line and 128 lines, determine*

(1) the total number of bits to represent the grey level values required if an 8 bit A/D converter is used to indicate various shades of gray;

(2) the reduction in data volume if only black and white values and digitized.

(8)

☺ **Solution: Given Data:**

$$\text{Point per line} = 128$$

$$\text{Total line} = 128$$

$$\text{For grey scale image } 2^n = 2^8$$

$$\text{Levels of grey scale image} = 256$$

$$\text{Number of bits} = \left\{\begin{matrix}\text{Point per} \\ \text{line}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Total} \\ \text{line}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Levels of} \\ \text{Grey scale} \\ \text{Image}\end{matrix}\right\}$$

$$= 128 \times 128 \times 256$$

(*i*) $$\left.\begin{matrix}\text{Number of bits} \\ \text{for Grey scale Image}\end{matrix}\right\} = 4{,}194{,}304 \text{ bits}$$

For black and white

$$\left.\begin{array}{r}\text{Number of bits}\\ \text{for black and white}\end{array}\right\} = \left\{\begin{array}{c}\text{Point}\\ \text{per line}\end{array}\right\} \times \left\{\begin{array}{c}\text{Total}\\ \text{line}\end{array}\right\} \times 2^1$$

$$= 128 \times 128 \times 2$$

$$= 16{,}384 \text{ bits} \ \text{x } 2$$

(*ii*)

$$\left.\begin{array}{r}\text{Reduction in data}\\ \text{volume}\end{array}\right\} = \left\{\begin{array}{c}\text{Number of bits}\\ \text{for Grey scale}\\ \text{Image}\end{array}\right\} - \left\{\begin{array}{c}\text{Number of bits}\\ \text{for black and white}\end{array}\right\}$$

$$= 4{,}194{,}304 - 16{,}384 \ \text{x } 2$$

Reduction in data volume = 41,61,536 bits

THANK YOU FOR YOUR PATIENCE AND TIME