1501322 Electronics and Electric Drives

Course Description:
Basic dc circuit analysis; Theory, applications, and circuit implementation of electronic devices such as diode, transistor, and opamp; Basic electronic circuits such as amplifiers, converters, filters, relay drivers; Principle of power electronics; Industrial equipment and sensors*.
(*modified in the framework of an Erasmus + project: Asean Factori 4.0 Across South East Asian Nations: From Automation and Control Training to the Overall Roll-out of Industry 4.0 609854-EPP-1-2019-1-FR-EPPKA2-CBHE-JP)

Learning outcome:
1. Students can discuss the content of electronic engineering.
2. Students can analyze the behavior of electronic components.
3. Students understand the function of industrial equipment and sensors.

Lecturer:
Assoc. Prof. Punnarumol Temdee, Ph.D.
Asst. Prof. Roungsan Chaisricharoen, Ph.D.
Asst. Prof. Santichai Wicha, Ph.D.
Lect. Chayapol Kamyod, Ph.D.

Credit: 3(3-0)
Lecture: 45 Hours (9 hours of modified content)

Assessments:

Attendance	10%
HW/CW	20%
Midterm	25%
Final	25%
Project	20%

Lecture (seminar):

Content	Hours
DC analysis of RLC circuits	12
Electronic devices and applications	12
Power electronic	12
Industrial components*	3
Industrial equipment*	3
Industrial sensors*	3

(*modified in the framework of an Erasmus + project: Asean Factori 4.0 Across South East Asian Nations: From Automation and Control Training to the Overall Roll-out of Industry 4.0 609854-EPP-1-2019-1-FR-EPPKA2-CBHE-JP)

1501221Electronics and Electric Drives

Program: Bachelor program in Computer Engineering

Credit: 3(3-0)   Lecture: 45 Hours

FACTORI 4.0 Erasmus +

Co-funded by the Erasmus+ Programme of the European Union

2nd Semester, Academic Year: 2022

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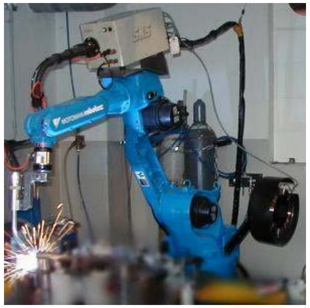
609854-EPP-1-2019-1-FR-EPPKA2-CBHE-JP

Agenda

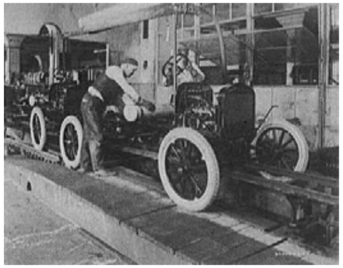
- Industrial 4.0
- Industrial Processes
- Standard IEC 61508/ 61511
- Industrial Components
- Industrial Equipment
- Industrial Sensor
  - Smart sensor/intelligence sensor with embedded components
  - Applications
  - Security function
  - Diagnostic -> improve global availability of the system
  - Sensor network/collaboration/ sharing information->again improve global availability

Industrial Evolution

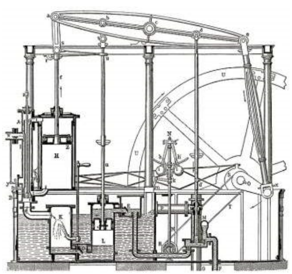
4. Industrial revolution
Based on cyber-physical-systems



3. Industrial revolution
Through the use of electronics and IT further progression in autonomous production



2. Industrial revolution
Introducing mass production lines powered by electric energy



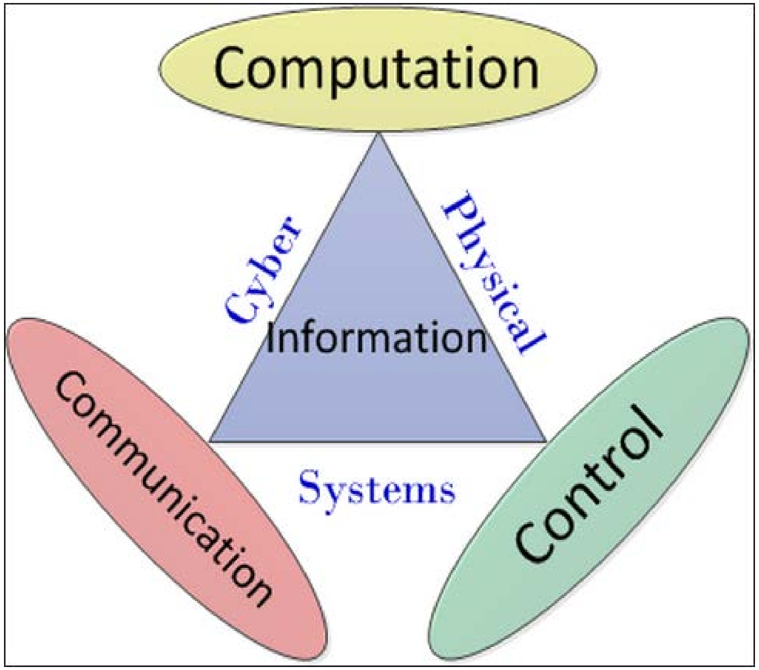
1. Industrial revolution
Introducing mechanical production machines powered by water and steam

Level of complexity

Industry 1.0	Industry 2.0	Industry 3.0	Industry 4.0
End of the 18th century.	**Beginning of the 20th century**	**Beginning of the 70th**	**Today**

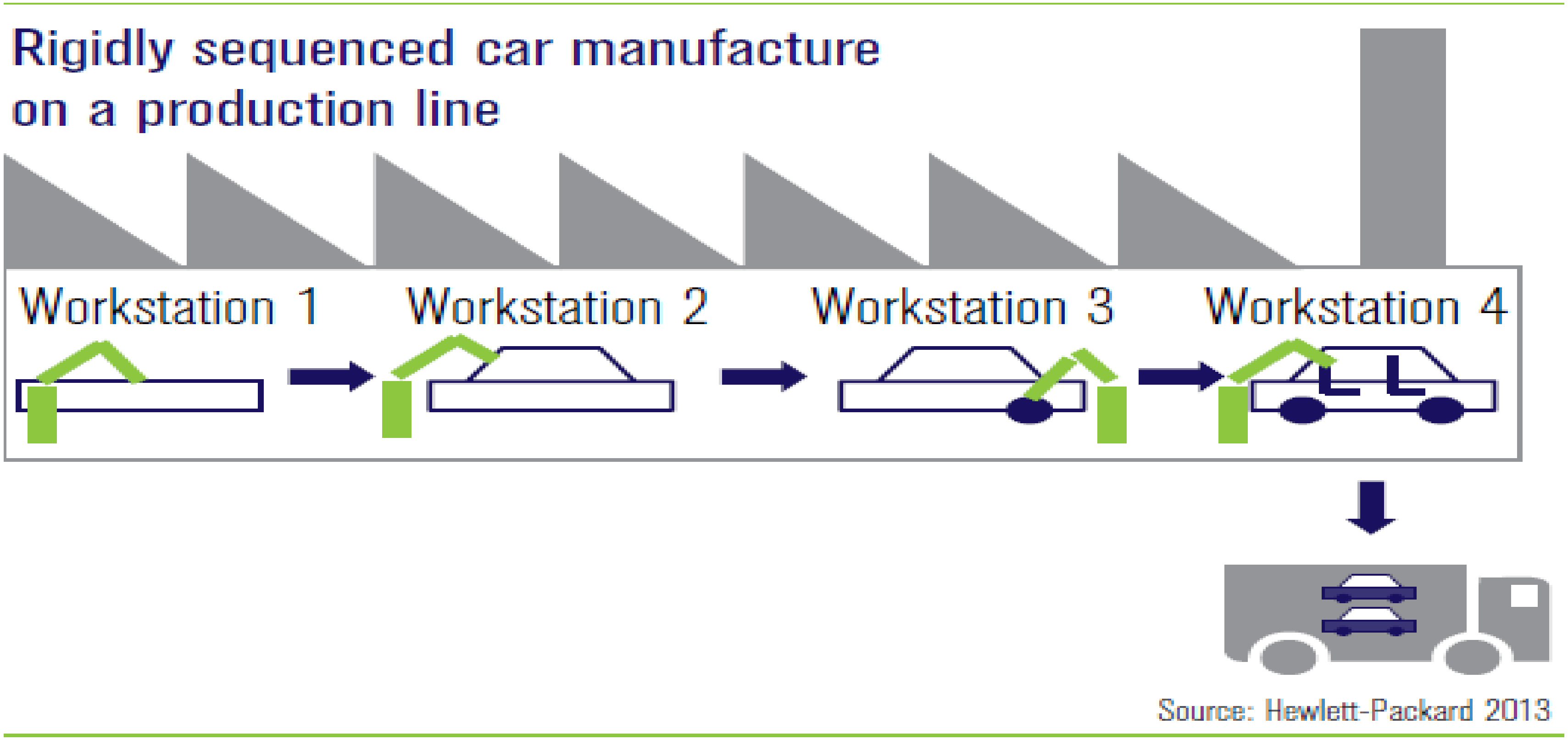
Source: DFKI/Bauer IAO

Cyber Physical Systems

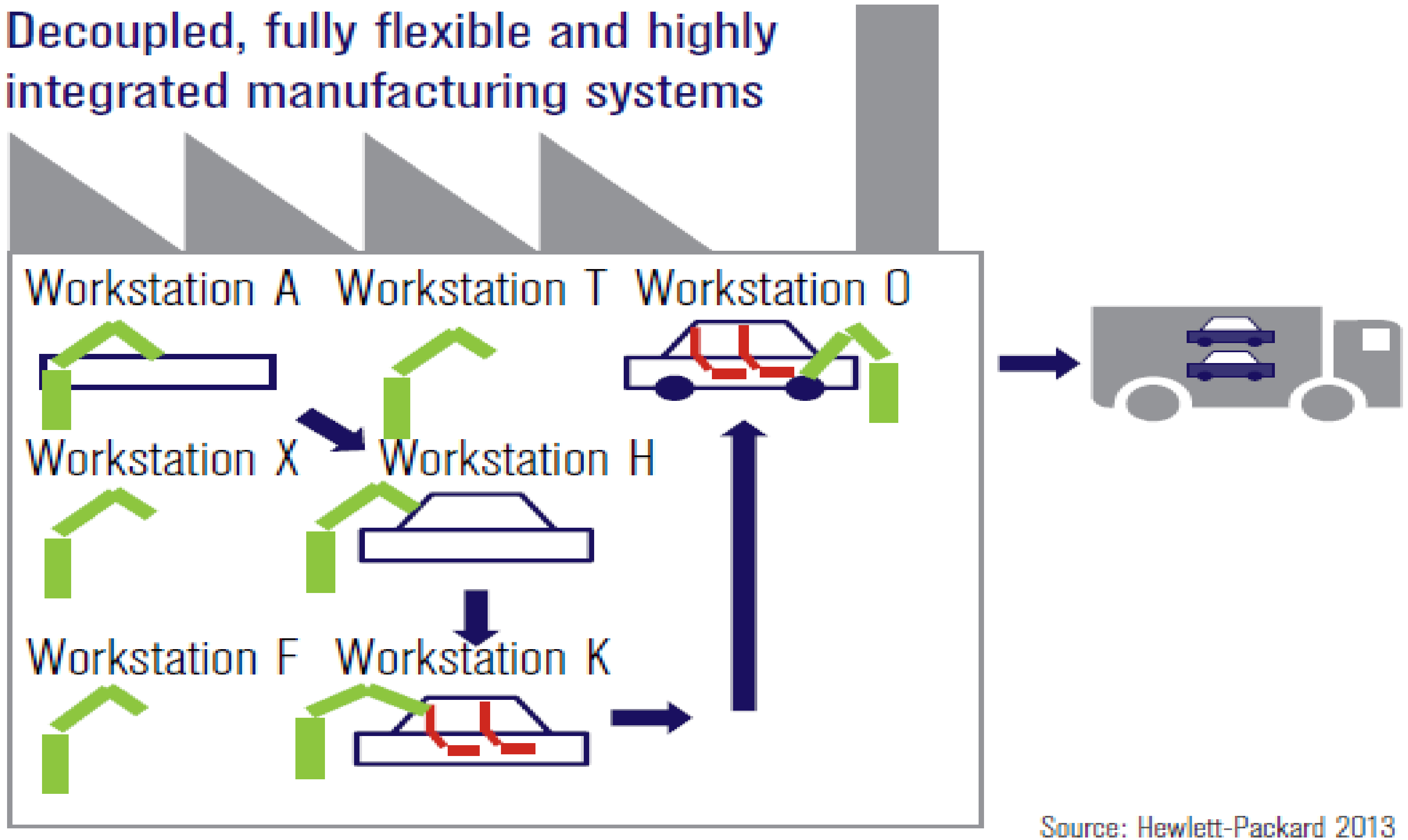


A **cyber-physical system** (**CPS**) is a system of collaborating computational elements controlling physical entities. CPS are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. They allow us to add capabilities to physical systems by merging computing and communication with physical processes.

Today’s Factory



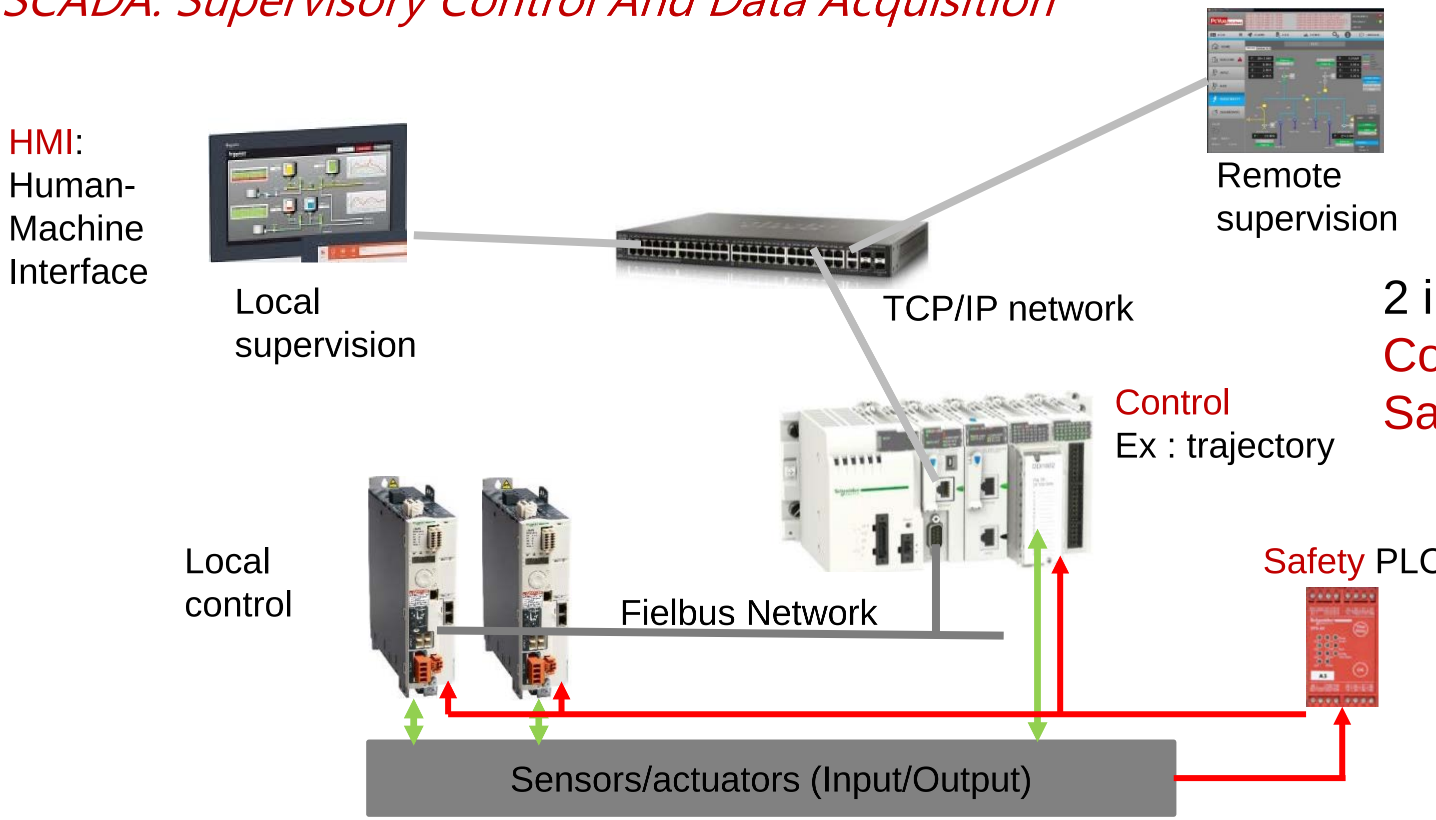
Tomorrow's Factory



Source: Hewlett-Packard 2013

An example

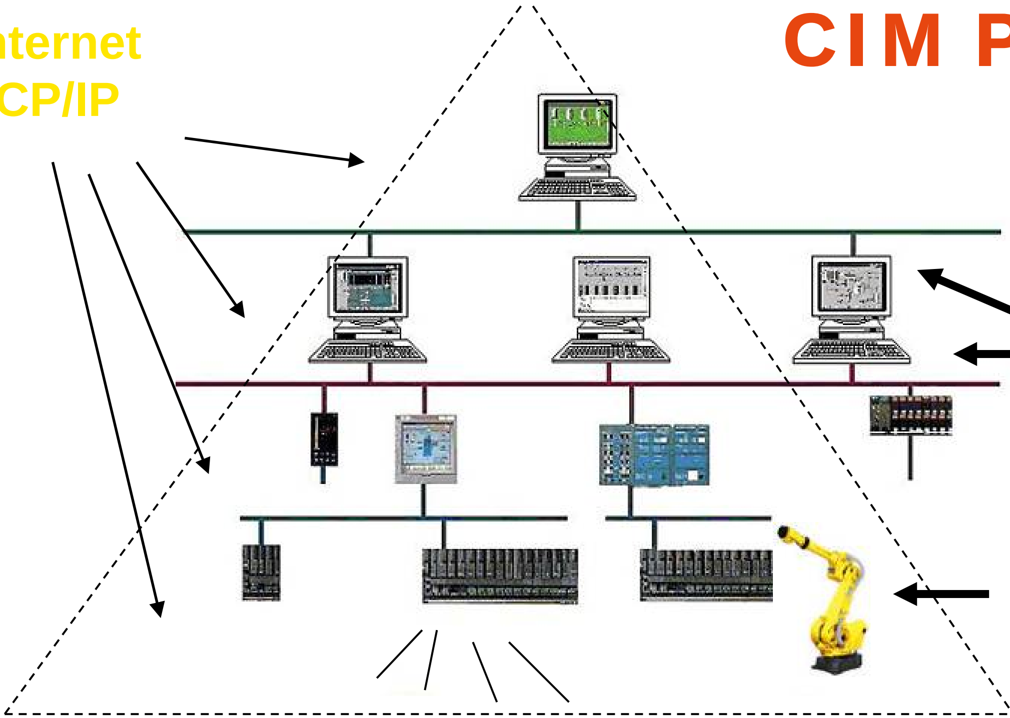
SCADA: Supervisory Control And Data Acquisition



2 important aspects:
Control
Safety

CIM Pyramid

Internet
TCP/IP



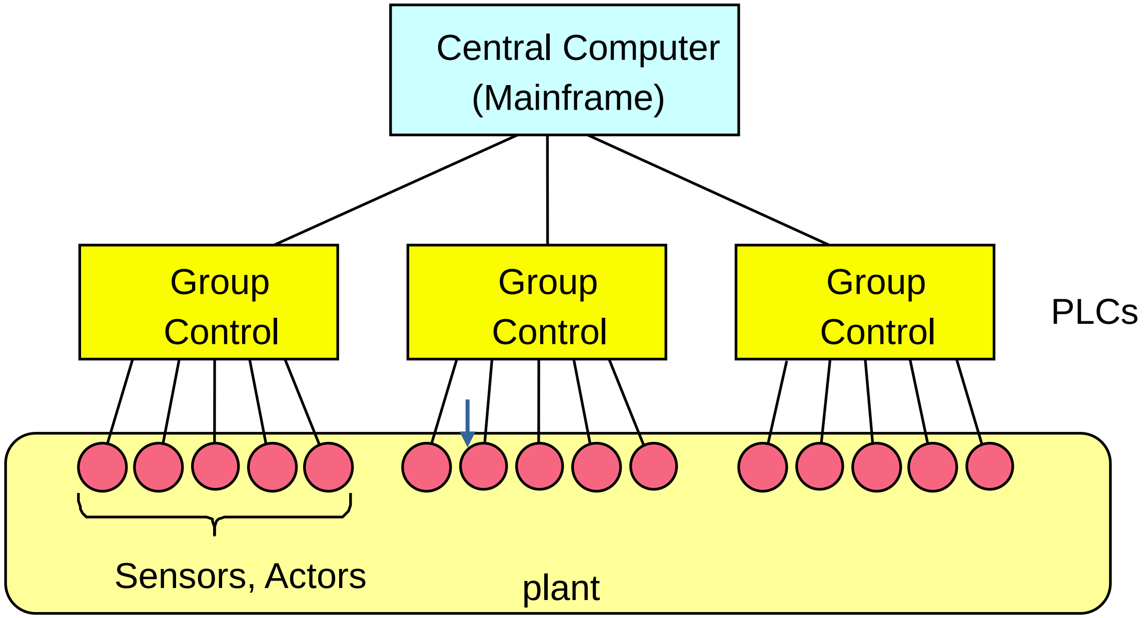
Ethernet &
TCP/IP
Network

Fieldbus Network

CAN, FIP, DeviceNet,
Interbus,Profibus…

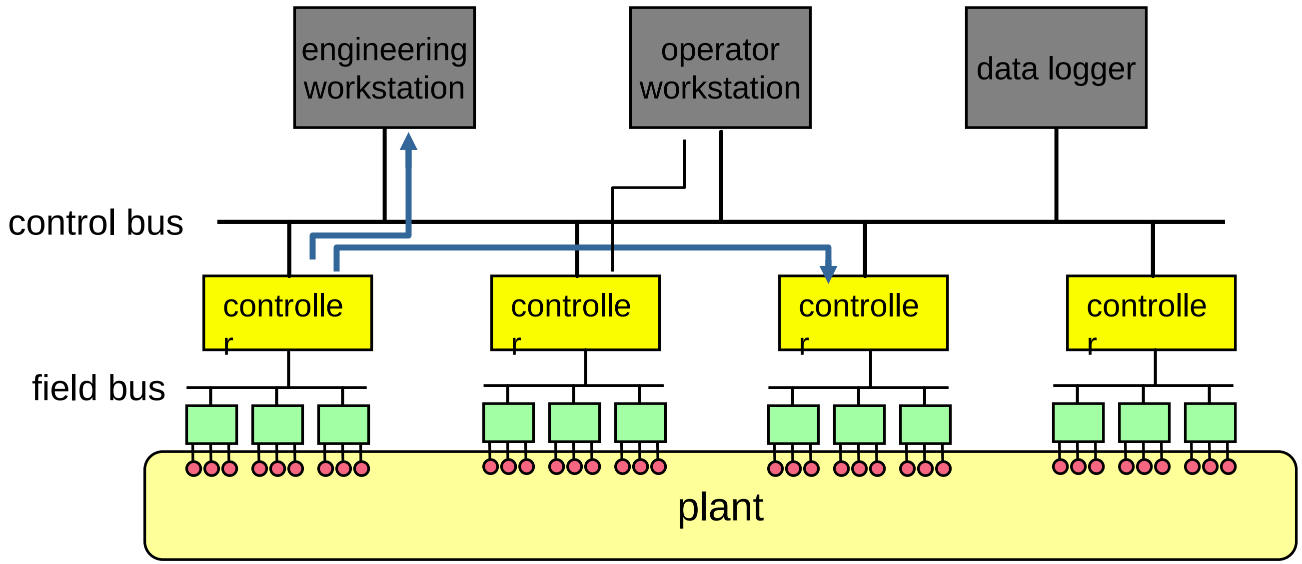
Computer-integrated manufacturing **(CIM)**
Describe the complete automation of manufacturing processes
Several network layers

Centralized Control Architecture



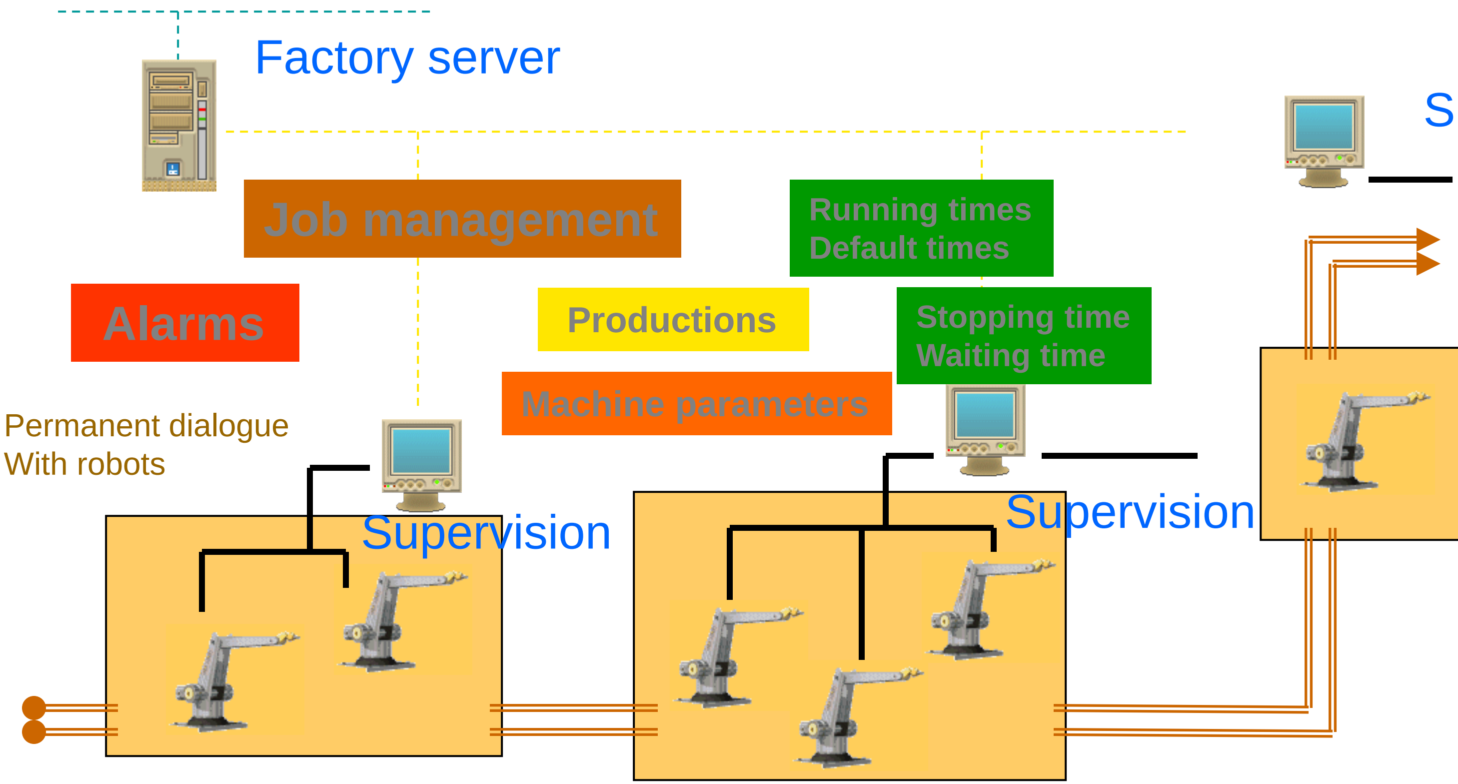
Classical, hierarchical, centralised architecture.
The central computer only monitors and forwards commands to the PLCs

Decentralized Control System (DCS)



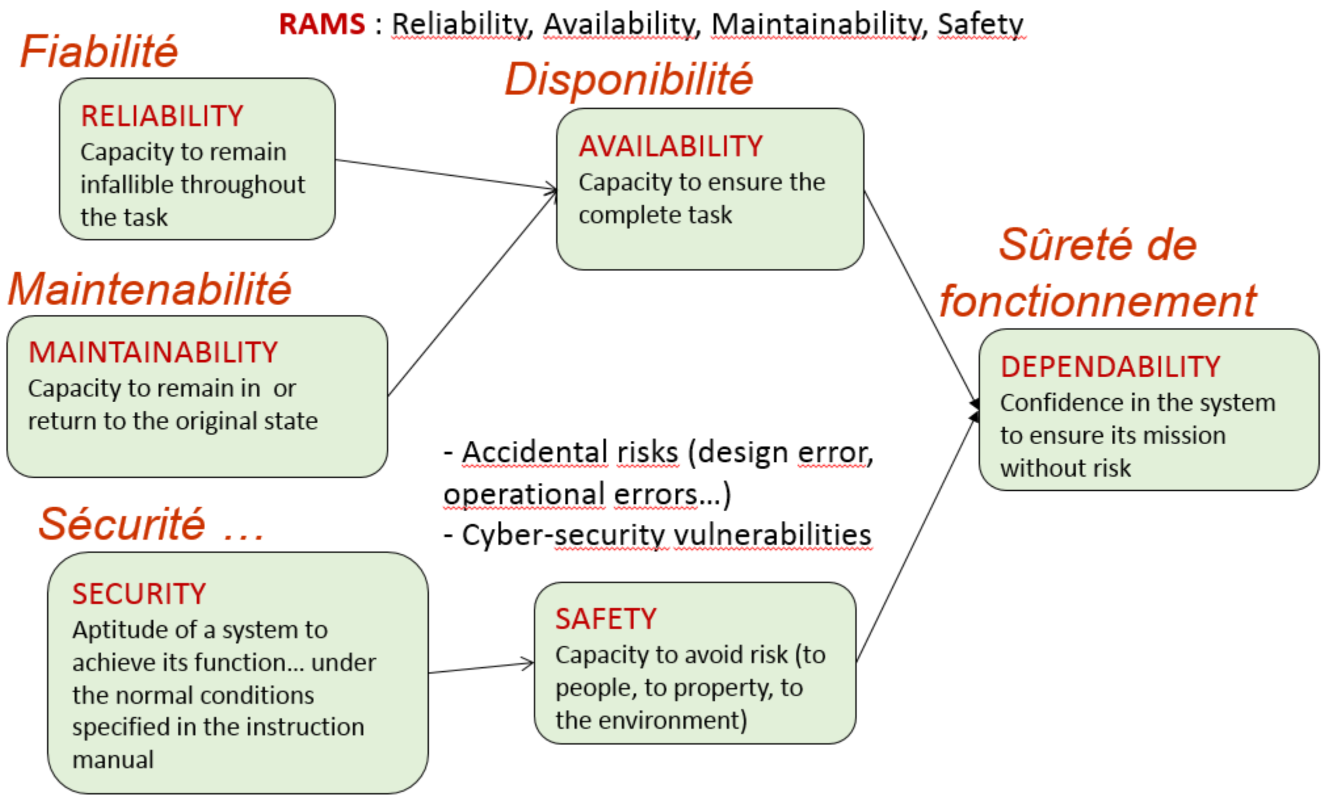
All controllers can communicate as peers (without going through a central master), restricted only by throughput and modularity considerations.

Supervision

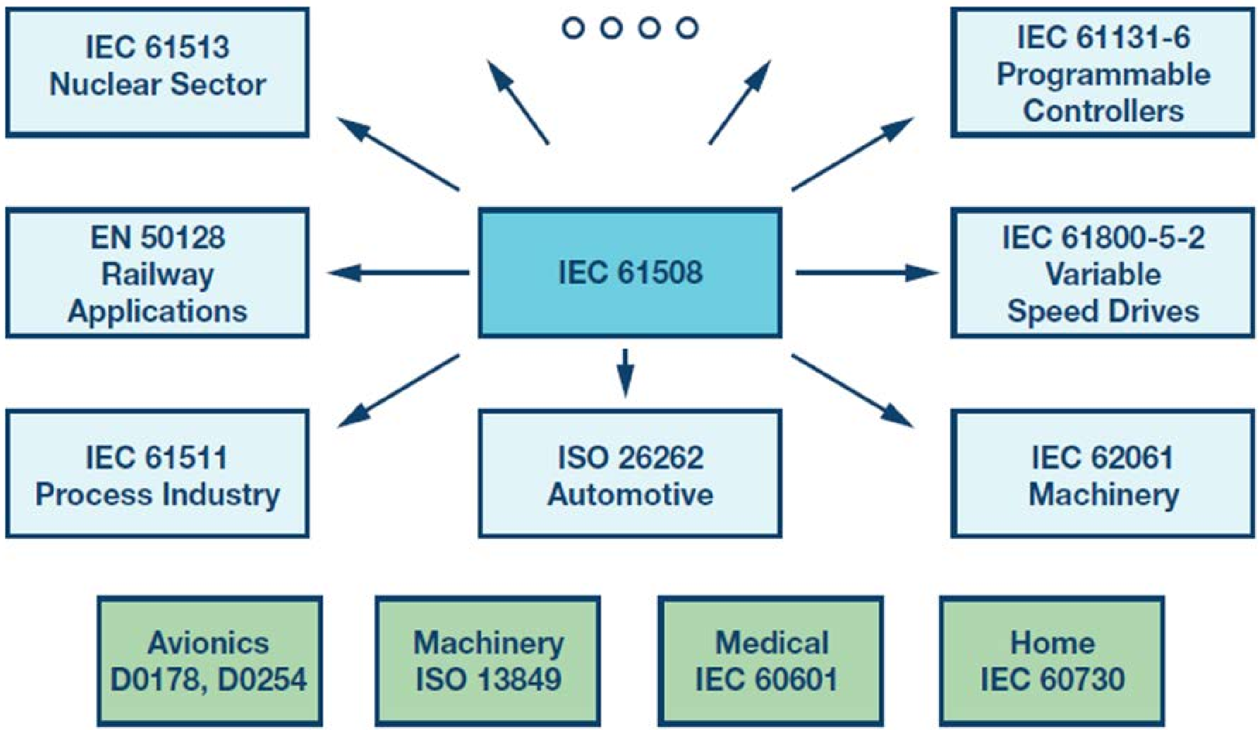


Supervisors
Collect and process information from the robots
Basis of the factory's information system

Dependability



Functional Safety



Safety Integrated Level (SIL)

- Generic standard IEC-**61508**/IEC-61511

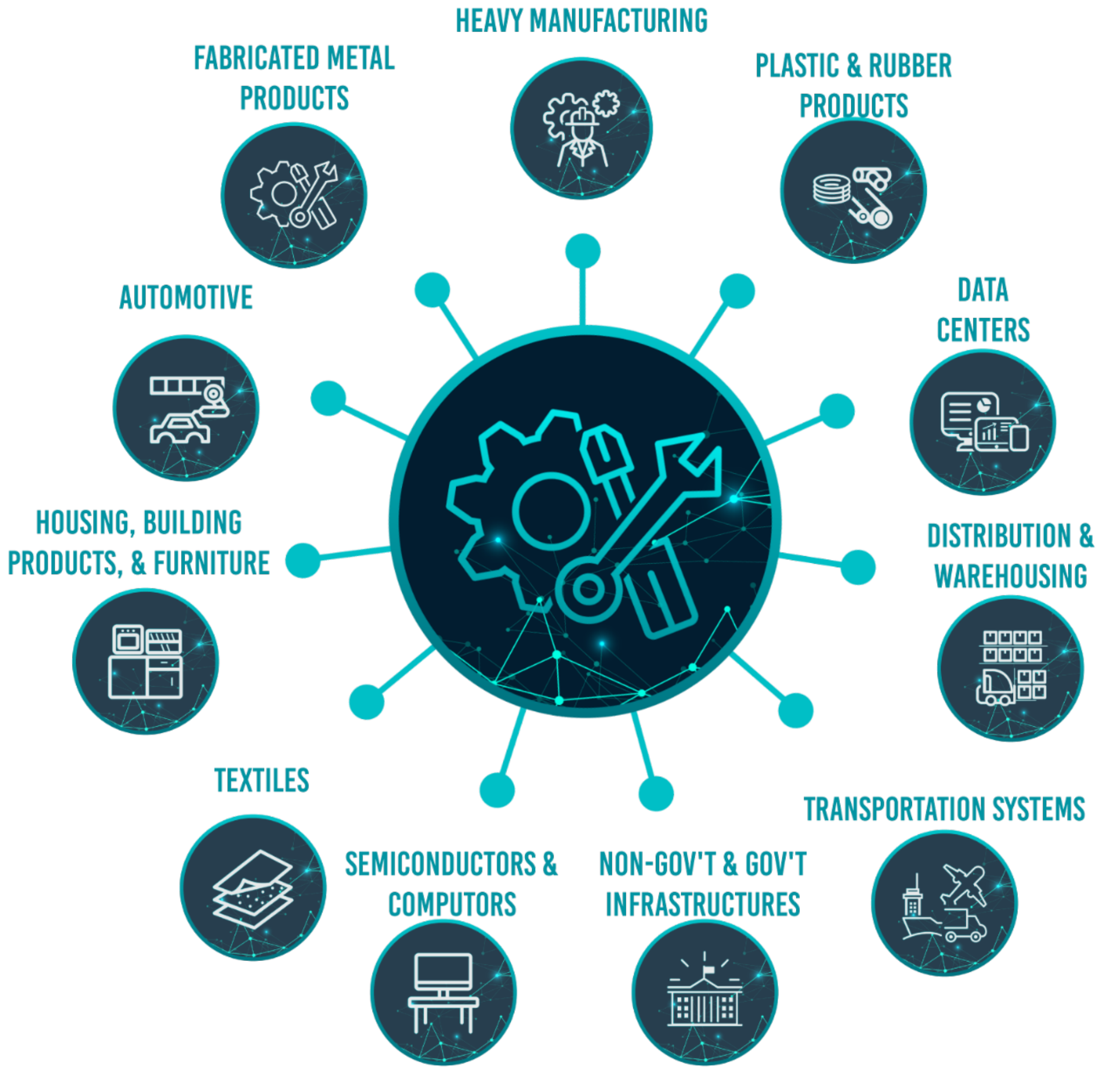
  Functional safety of electrical/electronic/programmable electronic safety-related systems

- SIL (*Safety Integrated Level*)

Prescriptions of a security system and corresponding SIL levels		
SIL	Demand operation Average **probability of failure on demand** (PFD) Failure rate per year	Continuous operation λ Failure rate per hour
SIL4	10^{-4} < PFDavg < 10^{-5}	$10^{-8} < \lambda < 10^{-9}$
SIL3	10^{-3} < PFDavg < 10^{-4}	$10^{-7} < \lambda < 10^{-8}$
SIL2	10^{-2} < PFDavg < 10^{-3}	$10^{-6} < \lambda < 10^{-7}$
SIL1	10^{-1} < PFDavg < 10^{-2}	$10^{-5} < \lambda < 10^{-6}$

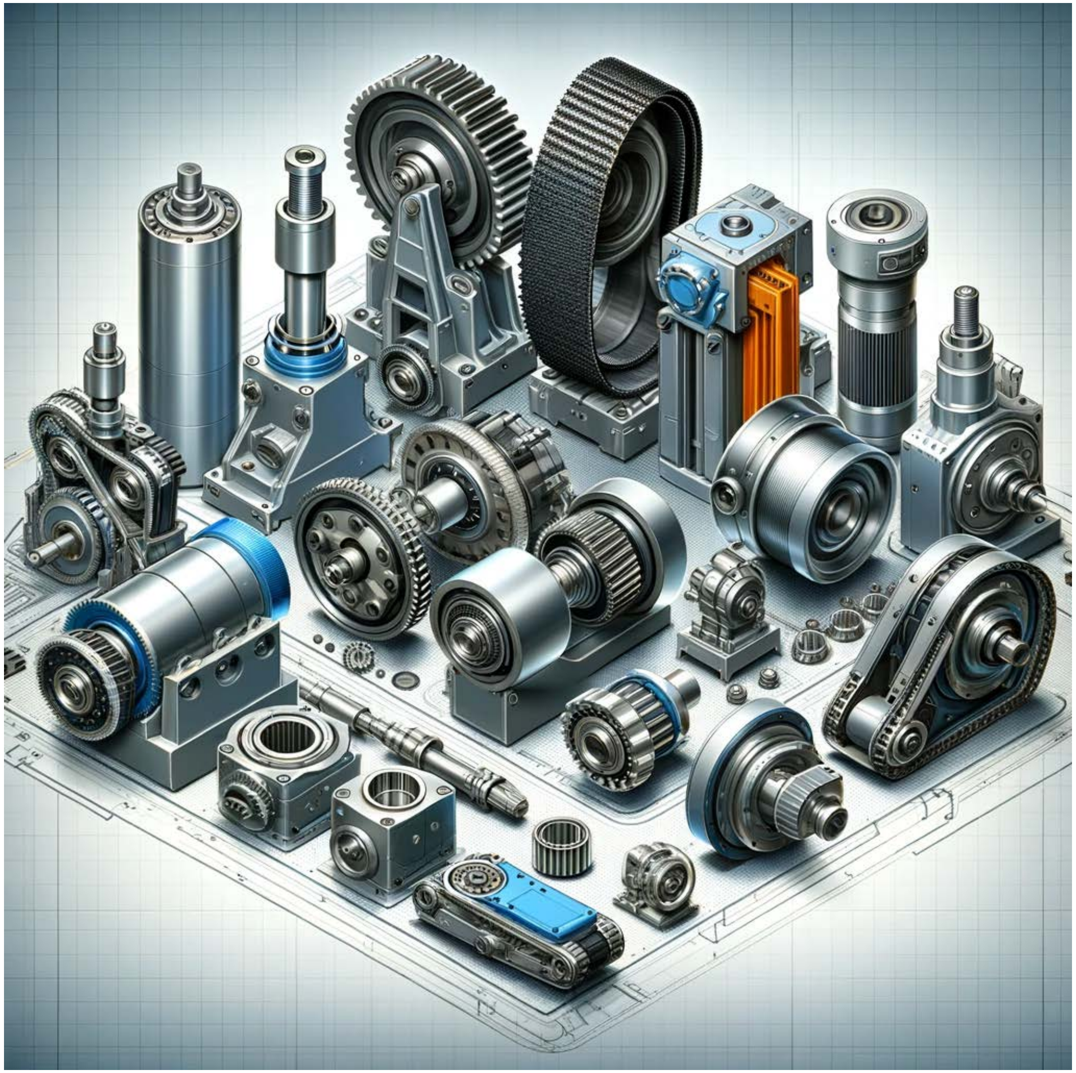
Problems:
- SIL of a component
- SIL of physical architecture
- SIL of a functional architecture
- SIL of a computer and network-based architecture

Industrial types



Industrial Components

- Industrial components are parts, tools, and equipment utilized in manufacturing and production. These parts ensure industrial machines and systems run smoothly. Components might be as simple as screws and nuts or as complicated as gears and motors. These components affect industrial machinery performance and longevity, thus quality and durability are essential.



Industrial Components Examples

- Bearings: Reduce friction between moving parts.
- Valves: Control the flow of liquids or gases.
- Motors: Convert electrical energy into mechanical energy.
- Pumps: Move liquids or gases from one place to another.

Industrial Equipment

- Industrial equipment includes heavy-duty machinery used in production, manufacturing, and construction. Durable and efficient, this equipment handles large-scale operations. This equipment needs regular maintenance to work well to prevent breakdowns.

Examples:

- Milling Machines: Used to shape metals and other solid materials.
- Cranes: Used for lifting and moving heavy objects.
- Forklifts: Used in warehouses to lift and transport goods.
- Conveyors: Used to move materials from one part of a production facility to another.

Robotics

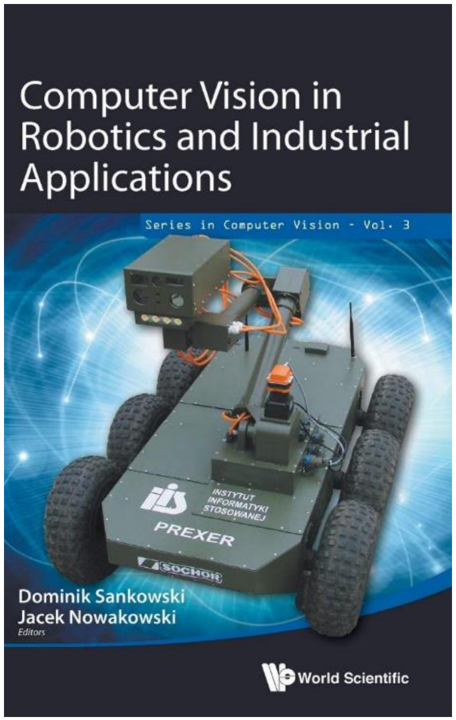
End 1970s

2020s: Many dimensions

Robotics

Training an Industrial Robot Using AI

Robotics & Visions



Vision-guided robotics

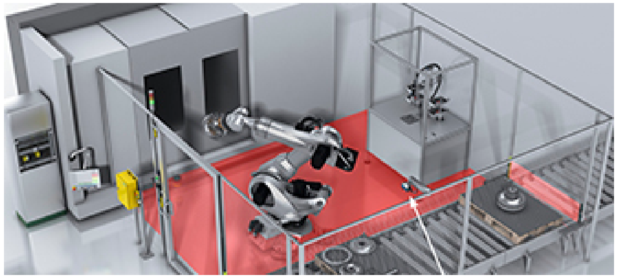
2D-Vision
3D-Vision
Radars
Lasers

Robotics

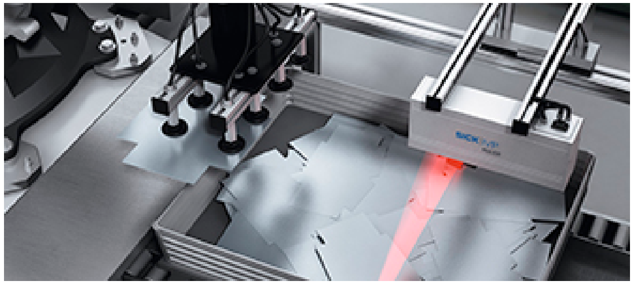
Industrial Robots in Extreme Conditions

Robotics

Autonomous trans-pallet

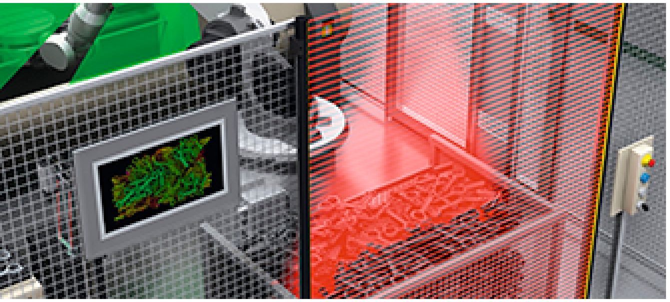


Robotic preparation of parts orders on the assembly line

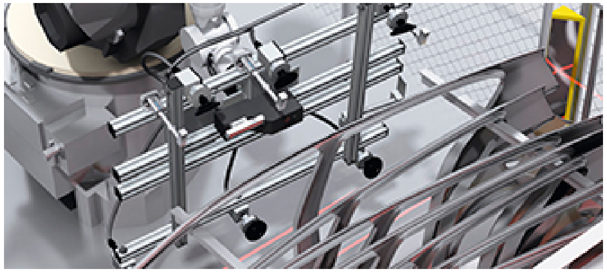


Automated part picking (bulk items)

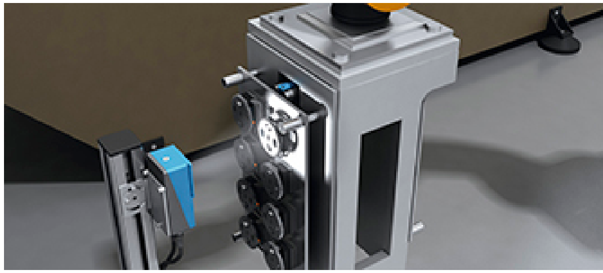
Simplified guidance of a Universal Robots robot



Locating parts in boxes



Picking up raw components for assembly



On-line quality control

3D sampling on tape

Robotics

COBOT

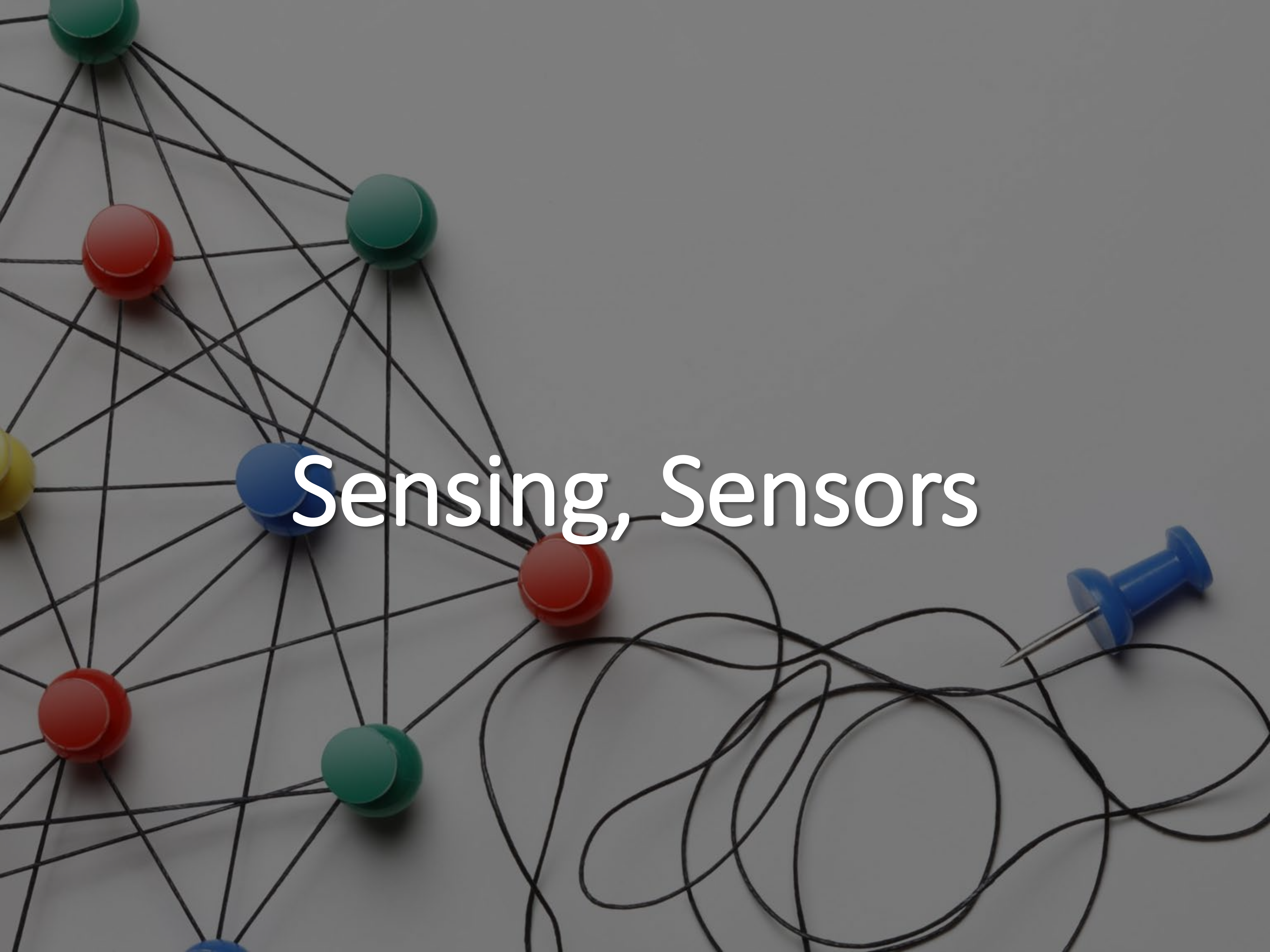
Industrial
Collaborative
Robot

Industrial Sensors

- Industrial sensors detect and respond to environmental input. The input could be light, heat, motion, moisture, pressure, or other environmental occurrences. Signals are transformed to human-readable representations at the sensor or transferred electronically through a network for reading or processing.

Examples:

- Temperature Sensors: Measure the amount of heat energy or coldness that is generated by an object or system.
- Proximity Sensors: Detect the presence or absence of an object or its relative position.
- Pressure Sensors: Measure the force exerted by a liquid or gas.
- Motion Sensors: Detect movement in a certain area.


Sensing, Sensors

Introduction

Industrial robot requires sensory feedback to:

- Locate randomly placed object;
- Allow for variations in shape of objects;
- Protect against dangerous and unexpected situations. Especially if the robot must work close to humans:
- Allow “intelligent” recovery form error conditions;
- Perform quality control.

The main objective of incorporating sensors in robotic system is to enable robots to work in nonstructural and random environments.

Sensors will make robots more intelligent. But the associated robotic software must have the ability to receive data from the sensors and to process the necessary real time information and commands needed for the decision making.

What is Sensing ?

Collect information about the world

Sensor - an electrical/mechanical/chemical device that maps an environmental attribute to a quantitative measurement

Each sensor is based on a ***transduction principle*** - conversion of energy from one form to another

Transduction to electronics

THERMISTOR: TEMPERATURE-TO-RESISTANCE

ELECTROCHEMICAL: CHEMISTRY-TO-VOLTAGE

PHOTOCURRENT: LIGHT INTENSITY-TO-CURRENT

PYROELECTRIC: THERMAL RADIATION-TO-VOLTAGE

HUMIDITY: HUMIDITY-TO-CAPACITANCE

LENGTH (LVDT: LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS) : POSITION-TO-INDUCTANCE

MICROPHONE: SOUND PRESSURE-TO-<ANYTHING>

Human sensing and organs

Vision: eyes (optics, light)

Hearing: ears (acoustics, sound)

Touch: skin (mechanics, heat)

Odor: nose (vapor-phase chemistry)

Taste: tongue (liquid-phase chemistry)

Counterpart?

Extended ranges and modalities

Vision outside the RGB spectrum

- Infrared Camera, see at night

Active vision

- Radar and optical (laser) range measurement

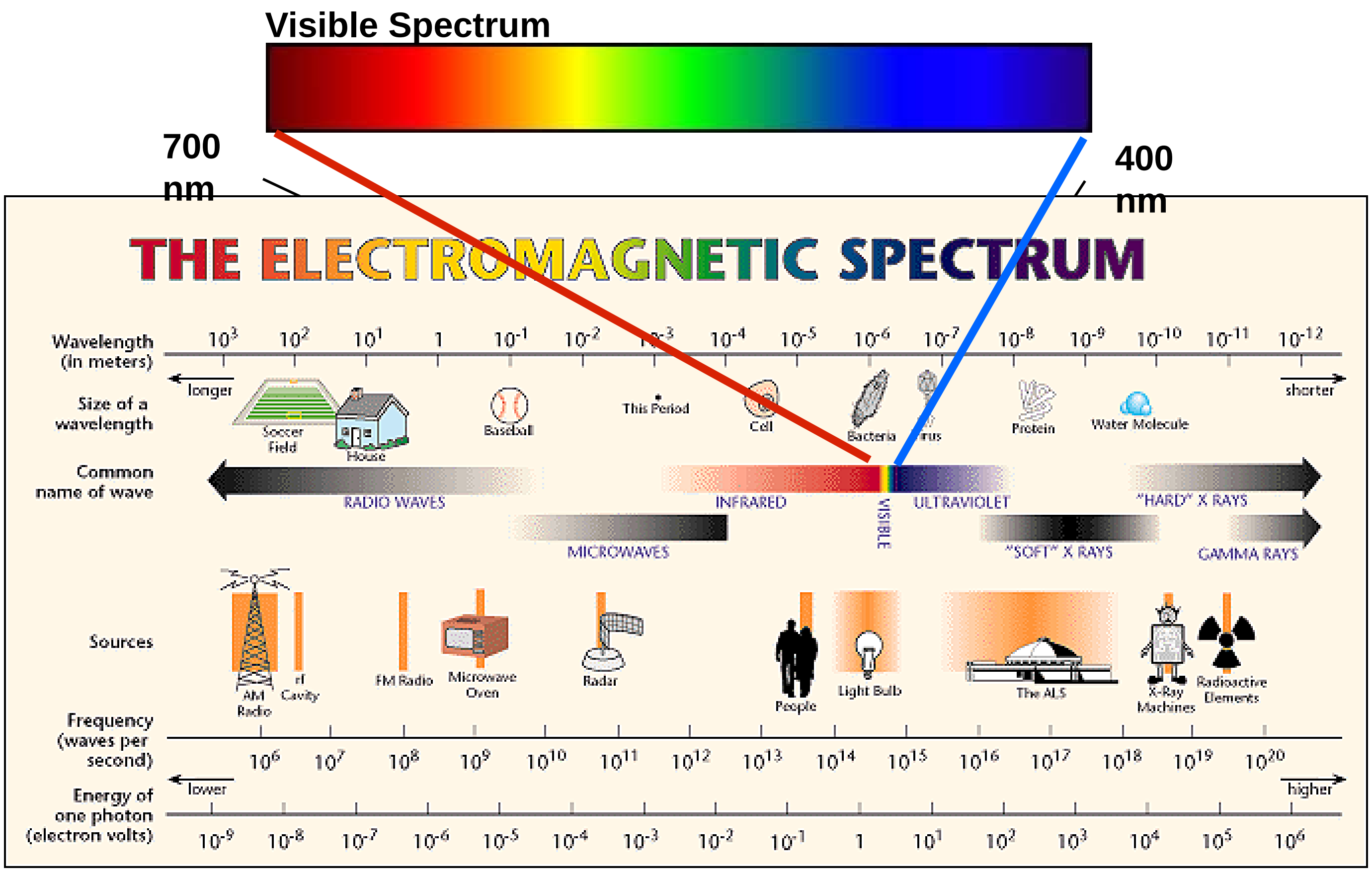
Hearing outside the 20 Hz – 20 kHz range

- Ultrasonic range measurement

Chemical analysis beyond taste and smell

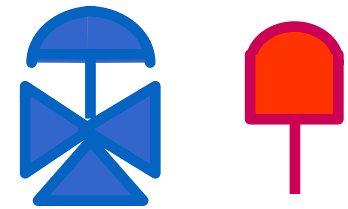
Radiation: a, b, g-rays, neutrons, etc

Electromagnetic Spectrum

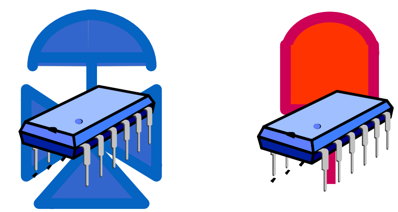


From analog to digital and from smart to intelligent…

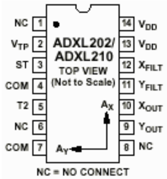
- Analog sensors and actuators
  - Hardware and analytical Redundancies
  - « Classiques" studies of dependability



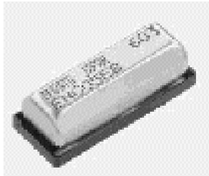
- Digital sensors and actuators
  - A/D Interfaces, processing units, delays…
  - Software, implementation



- « Smart » sensors and actuators
  - Embedded intelligence, local decision
- « Intelligents » sensors and actuators
  - Communicating Interface
  - Diagnosic, monitoring, checking, embedded decision
  - Instrument contributing of the global « intelligence » of the system
- Intelligence vs. Complexity => consequences on Dependability ?



Accelerometer

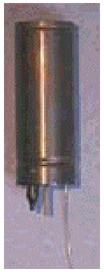

Gyro


Pendulum Resistive Tilt Sensors

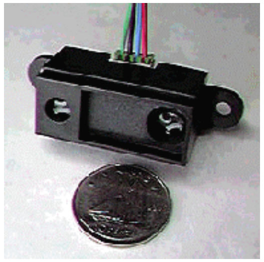

Piezo Bend Sensor

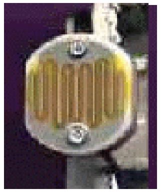

Metal Detector

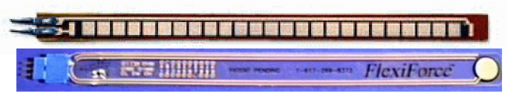
Gas Sensor


Gieger-Muller Radiation Sensor

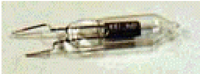

Pyroelectric Detector

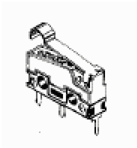

Digital Infrared Ranging

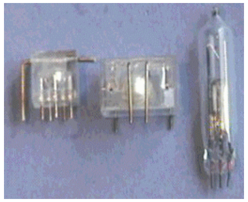

CDS Cell Resistive Light Sensor



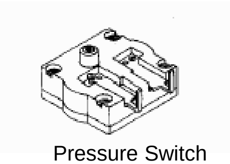
Resistive Bend Sensors

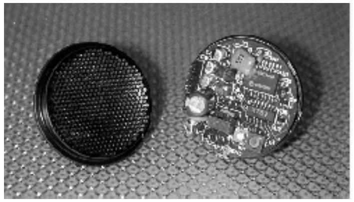

UV Detector

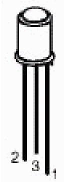

Limit Switch

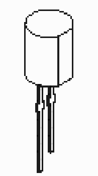

Mechanical Tilt Sensors

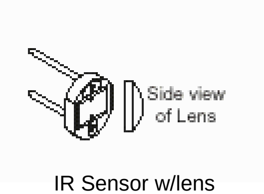

Touch Switch


Pressure Switch

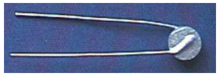

Miniature Polaroid Sensor

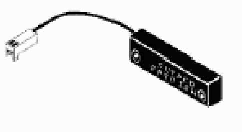


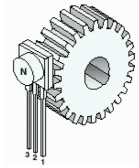

IR Pin Diode

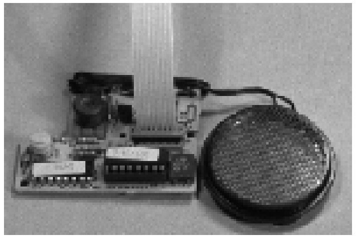


IR Sensor w/lens


Thyristor

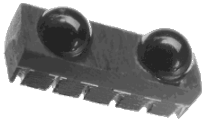

Magnetic Sensor


Hall Effect Magnetic Field Sensors

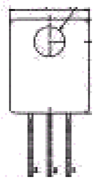

Polaroid Sensor Board

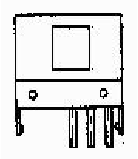

IR Reflection Sensor

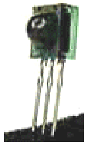

IR Amplifier Sensor

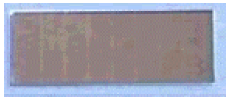

IRDA Transceiver

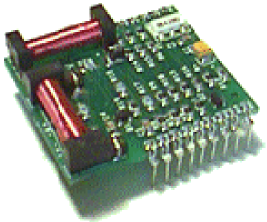

Magnetic Reed Switch

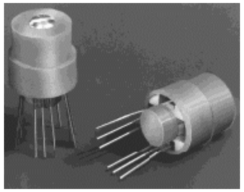

Lite-On IR Remote Receiver

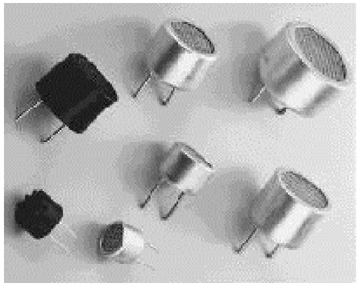

Radio Shack Remote Receiver


IR Modulator Receiver


Solar Cell


Compass


Compass


Piezo Ultrasonic Transducers

Sensors used in robot navigation

Resistive sensors

- bend sensors, potentiometer, resistive photocells, ...

Tactile sensors

- contact switch, bumpers…

Infrared sensors

- Reflective, proximity, distance sensors…

Ultrasonic Distance Sensor

Inertial Sensors (measure the second derivatives of position)

- Accelerometer, Gyroscopes,

Orientation Sensors

- Compass, Inclinometer

Laser range sensors

Vision

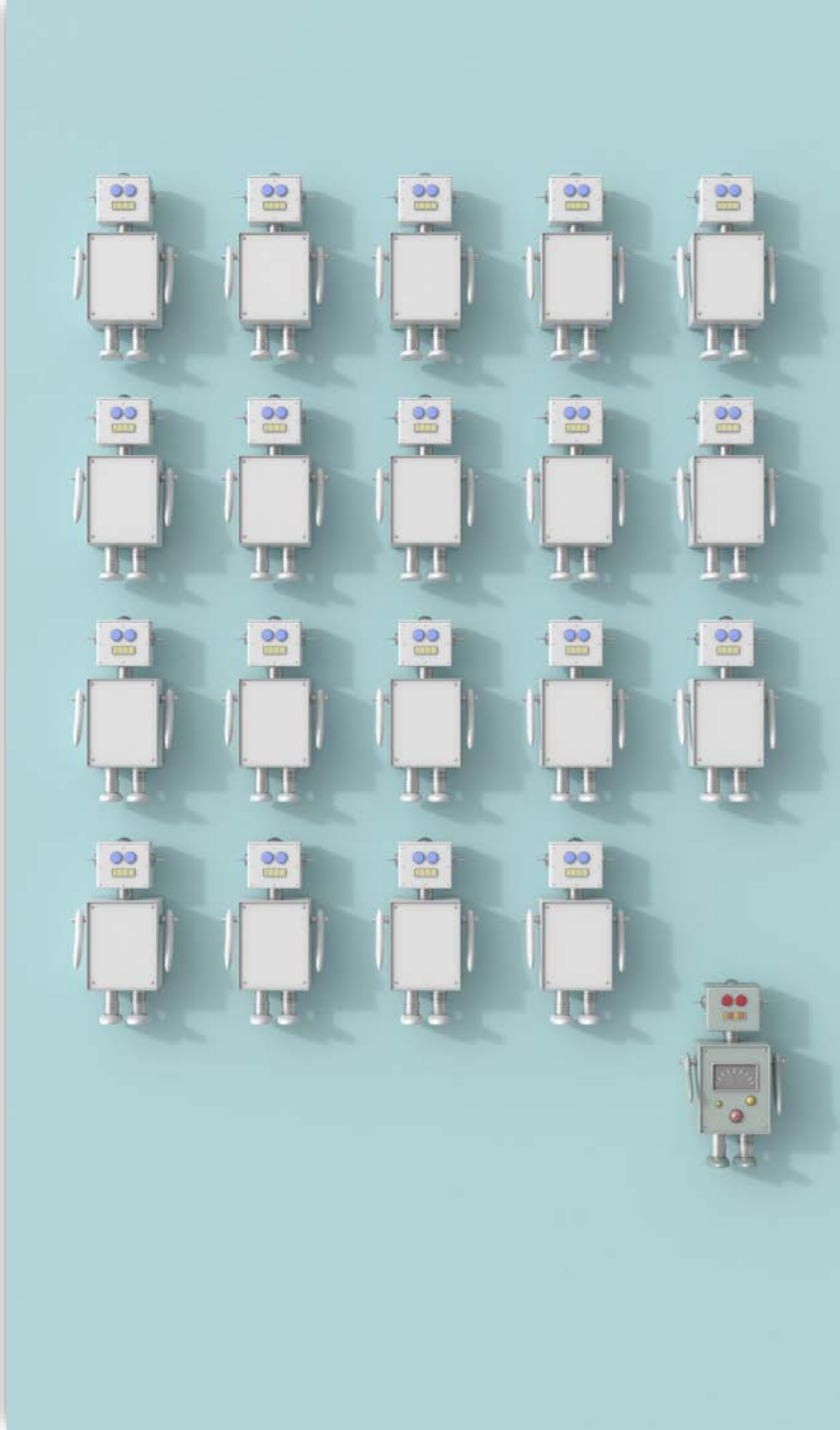
Global Positioning System

Classification of Sensors

- Internal state (proprioception) v.s. external state (exteroceptive)
    - feedback of robot internal parameters, e.g. battery level, wheel position, joint angle, etc,
    - observation of environments, objects
- Active v.s. non-active
    - emitting energy into the environment, e.g., radar, sonar
    - passively receive energy to make observation, e.g., camera
- Contact v.s. non-contact
- Visual v.s. non-visual
    - vision-based sensing, image processing, video camera

Sensor Selection/Sensing Taxonomy

- There are many different types of robot sensors available and there are many different parameter measured by these sensors.
- The application process, should be carried out in a top down manner, starting with task requirements, and going through several levels of analysis, eventually leading to the selection of a specific device.
- A taxonomy for sensing to aid this process consists of five levels of refinement leading to sensor selection:
  1. **Specification of task requirements** :eg localization, slippage detection, size confirmation, inspection, defect testing.
  2. **Choice of modality** :eg,vision, force, tactile
  3. **Specification on sensor attributes** :eg,output, complexity, discrete or continuous variable, imaging or non-imaging, local or global
  4. **Specification of operational parameters** :eg size, accuracy, cost
  5. **Selection of mechanism** :eg switching devices, inductive sensors, CCD vision imaging



Some tasks requirements features:

- Insertion Monitoring
- Assembly Verification
- Detection of Reject Parts
- Recognition of Part Types
- Assembly Test Operations
- Check Gripper/Tool Operation
- Location & Orientation of Parts
- Workspace Intrusion Detection
- Check Correct Manipulation of Parts
- Analysis of Spatial Relations Between Parts

Some typical sensor operational data:

Ultrasonics

Resistive Effects

Capacitive Efects

Piezo-Electric Effects

Visible Light Imaging

Photo-Electric & Infrared

Mechanical Switching

Inductive Effects

Thermal Effects

Hall Effect

Primary physical mechanisms employed in sensors:

Cost

Range

Accuracy

Repeatability

Power Requirements

Output Signal Specification

Processing Requirements

Sensitivity

Reliability

Weight

Size

PROXIMITY AND RANGE SENSORS

PROXIMITY & RANGE SENSORS

It is a technique of detecting the presence or absence of an object with electronic noncontact sensors.

Typical application of proximity sensors includes:

- ש Object detection
- ש Collision avoidance
- ש Object verification & counting

Commonly available proximity sensors are:

- 1. Photoelectric/optical sensors

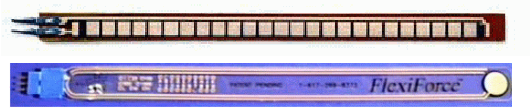
2. Inductive proximity sensors

- 3. Capacitive proximity sensors
- 4. Ultrasonic proximity sensors

Resistive Sensors

Bend Sensors

- Resistance = 10k to 35k
- As the strip is bent, resistance increases



Resistive Bend Sensor

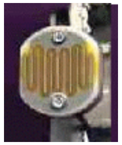
Potentiometers

- Can be used as position sensors for sliding mechanisms or rotating shafts
- Easy to find, easy to mount

Potentiometer

Light Sensor (Photocell)

- Good for detecting direction/presence of light
- Non-linear resistance
- Slow response to light changes

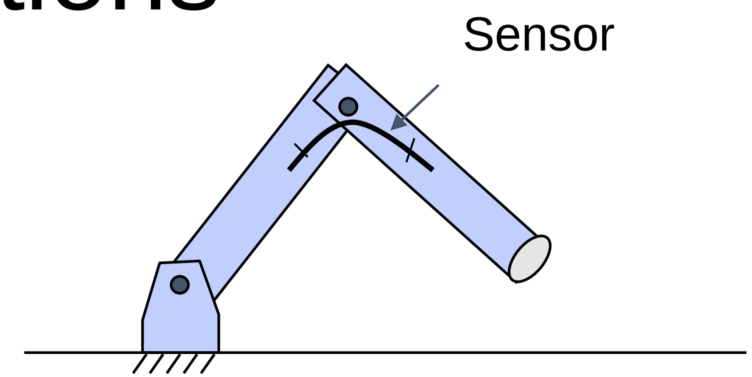


Photocell

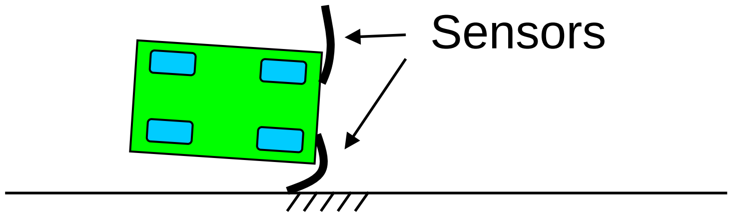
R is small when brightly illuminated

Applications

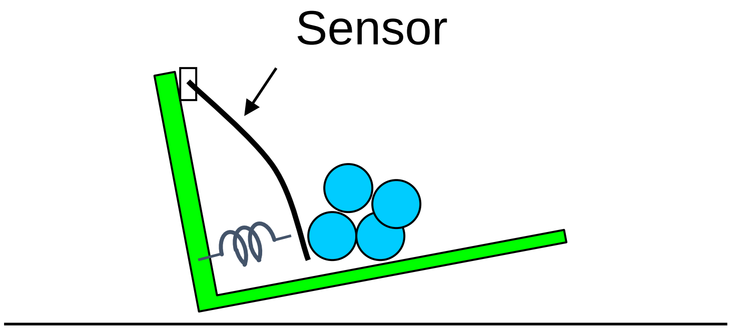
- Measure bend of a joint



- Wall Following/Collision Detection



- Weight Sensor

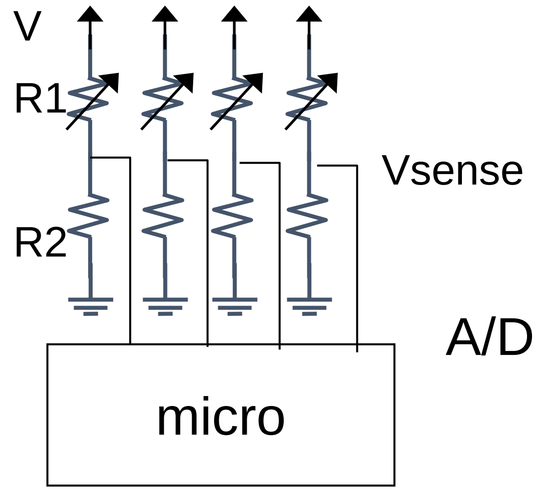


Inputs for Resistive Sensors

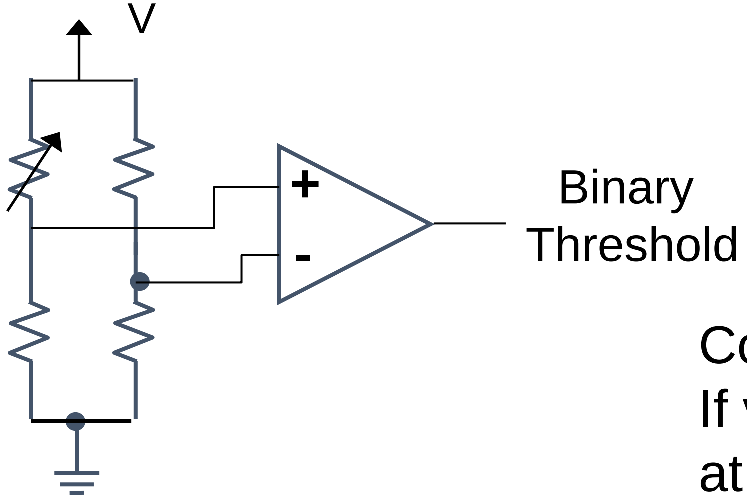
Voltage divider:

You have two resisters, one is fixed and the other varies,
as well as a constant voltage

$$V_{sense} = \frac{R_2}{R_1 + R_2} V$$



A/D converter



Digital I/O

Comparator:
If voltage at + is greater than at -, digital high out

Infrared Sensors

Intensity based infrared

- Reflective sensors
- Easy to implement
- susceptible to ambient light

↓

Modulated Infrared

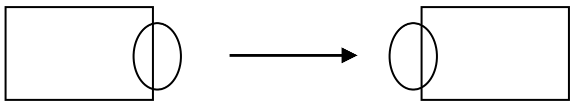
- Proximity sensors
- Requires modulated IR signal
- Insensitive to ambient light

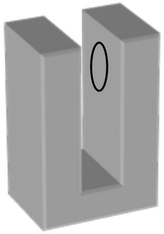
↓

Infrared Ranging

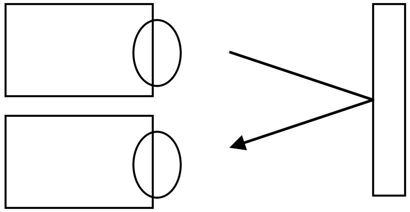
- Distance sensors
- Short range distance measurement
- Impervious to ambient light, color and reflectivity of object

Intensity Based Infrared

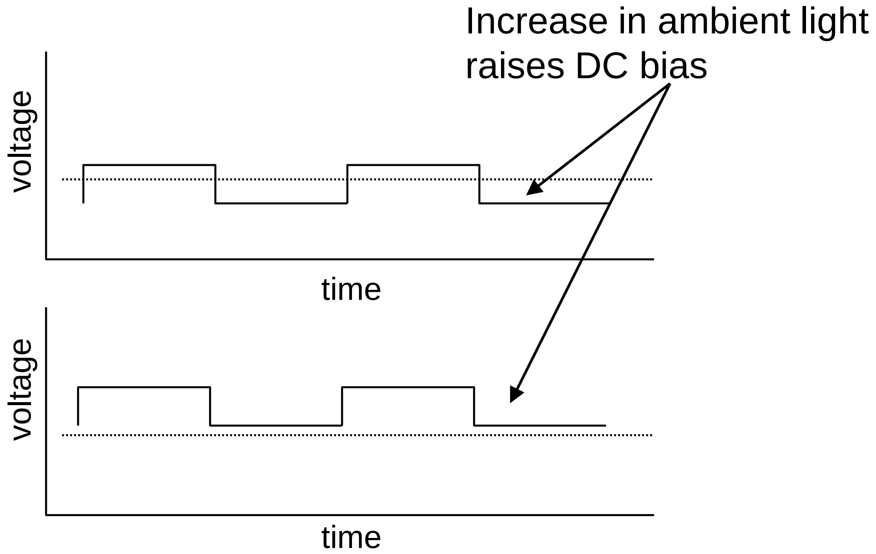




Break-Beam sensor



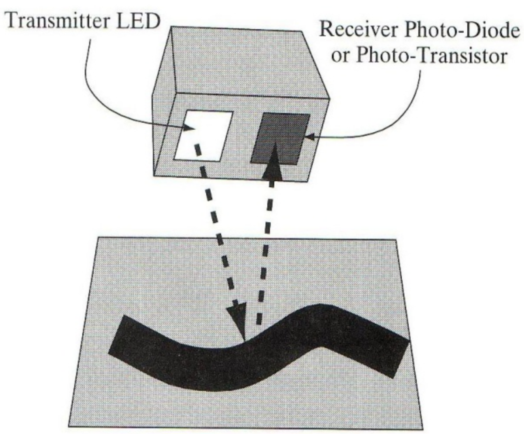
Reflective Sensor



- Easy to implement (few components)
- Works very well in controlled environments
- Sensitive to ambient light

IR Reflective Sensors

- Reflective Sensor:
  - Emitter IR LED + detector photodiode/phototransistor
  - Phototransistor: the more light reaching the phototransistor, the more current passes through it
  - A beam of light is reflected off a surface and into a detector
  - Light usually in infrared spectrum, IR light is invisible

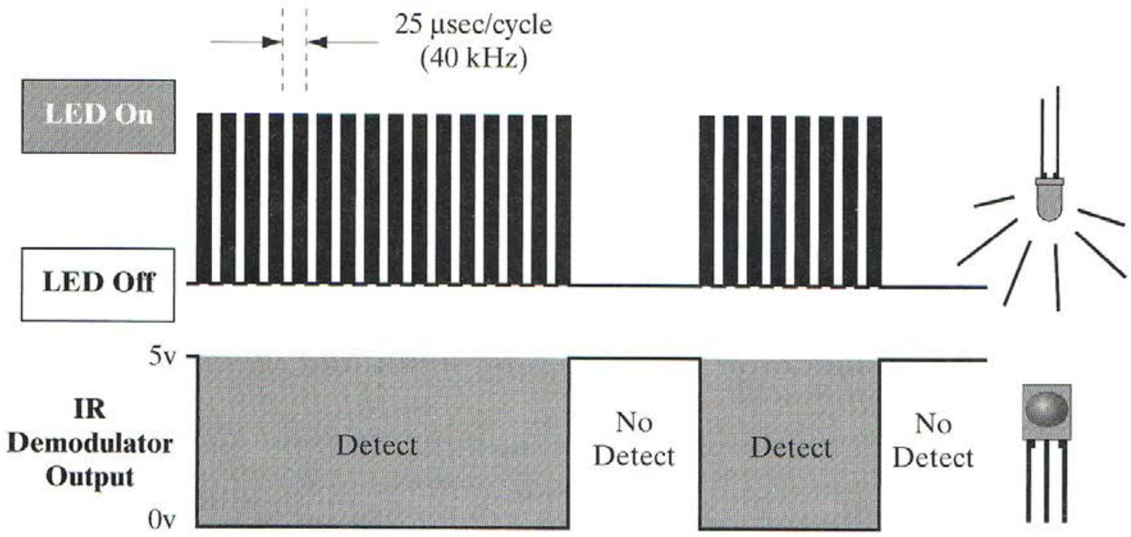


- Applications:
  - Object detection,
  - Line following, Wall tracking
  - Optical encoder (Break-Beam sensor)

- Drawbacks:
  - Susceptible to ambient lighting
    - Provide sheath to insulate the device from outside lighting
  - Susceptible to reflectivity of objects
  - Susceptible to the distance between sensor and the object

Modulated Infrared

- Modulation and Demodulation
  - Flashing a light source at a particular frequency
  - Demodulator is tuned to the specific frequency of light flashes. (32kHz~45kHz)
  - Flashes of light can be detected even if they are very week
  - Less susceptible to ambient lighting and reflectivity of objects
  - Used in most IR remote control units, proximity sensors

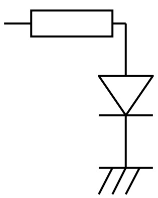


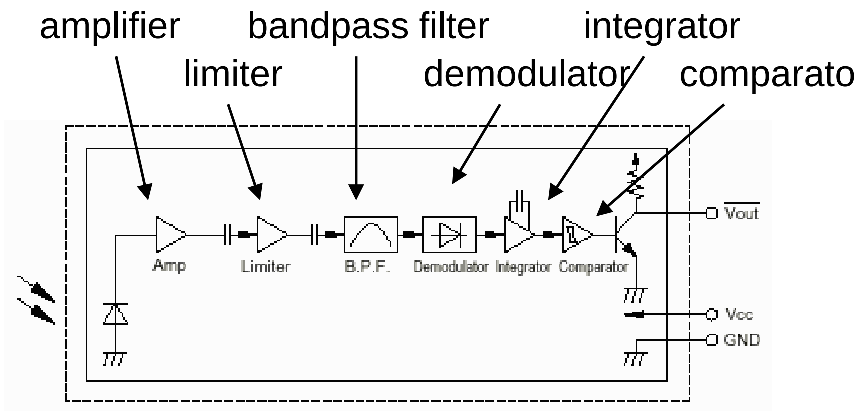
Negative true logic:

Detect = 0v

No detect = 5v

IR Proximity Sensors

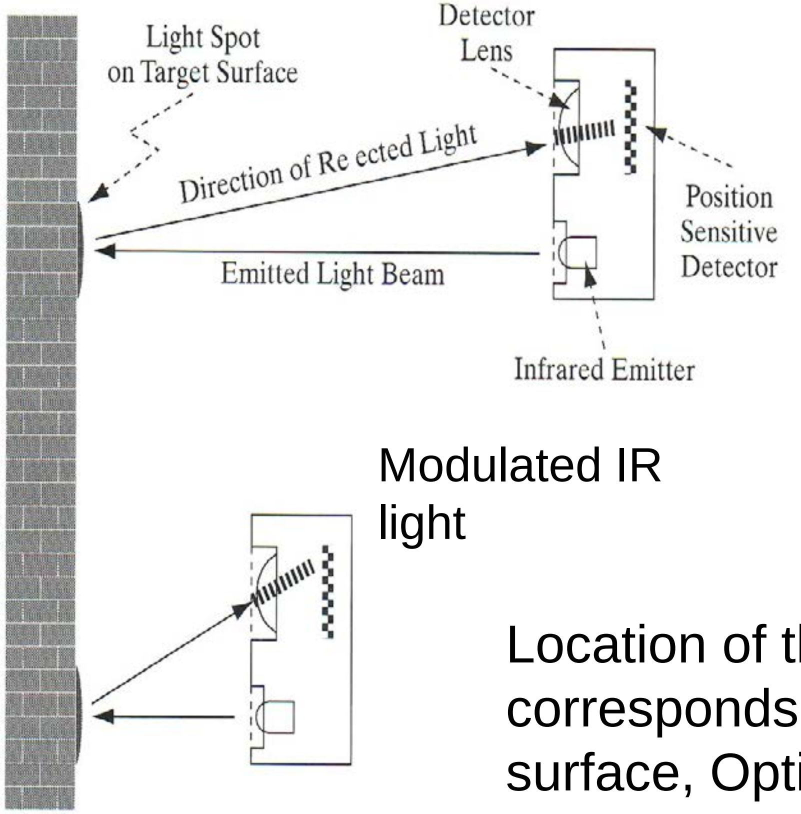




- Proximity Sensors:
  - Requires a modulated IR LED, a detector module with built-in modulation decoder
  - Current through the IR LED should be limited: adding a series resistor in LED driver circuit
  - Detection range: varies with different objects (shiny white card vs. dull black object)
  - Insensitive to ambient light
- Applications:
  - Rough distance measurement
  - Obstacle avoidance
  - Wall following, line following

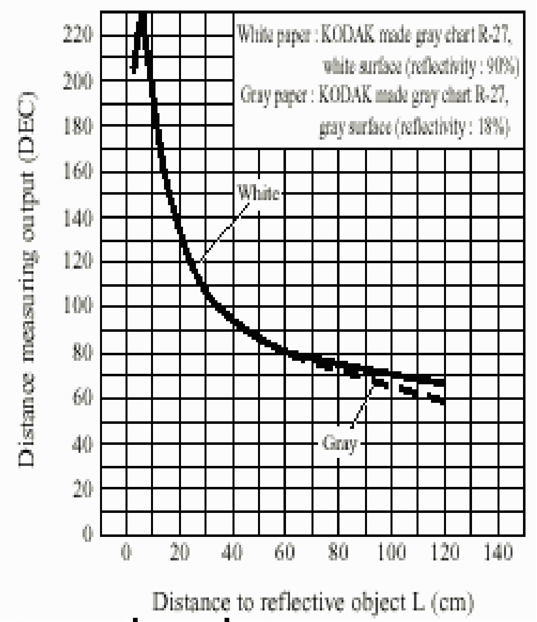
IR Distance Sensors

- Basic principle of operation:
  - IR emitter + focusing lens + position-sensitive detector



Modulated IR light

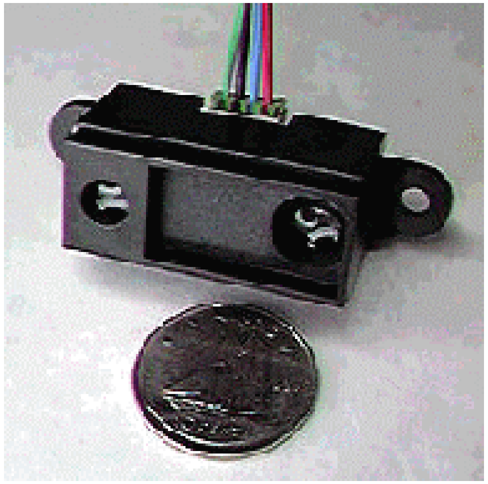
Fig. 1 Distance Measuring Output vs. Distance to Reflective Object



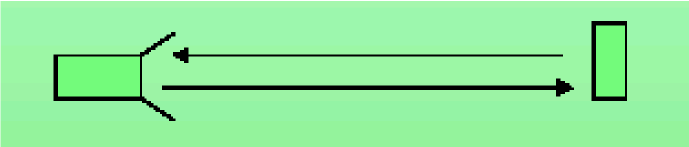
Location of the spot on the detector corresponds to the distance to the target surface, Optics to covert horizontal distance to vertical distance

IR Distance Sensors

- Sharp GP2D02 IR Ranger
  - Distance range: 10cm (4") ~ 80cm (30").
  - Moderately reliable for distance measurement
  - Immune to ambient light
  - Impervious to color and reflectivity of object
  - Applications: distance measurement, wall following, …



Range Finder



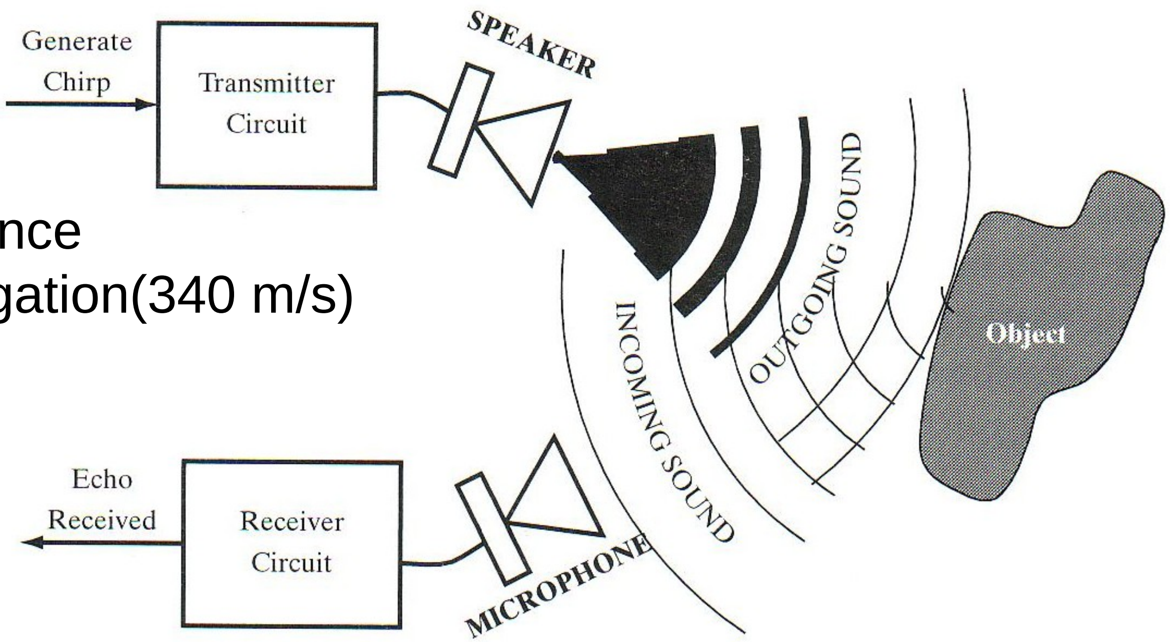
- Time of Flight
- The measured pulses typically come form ultrasonic, RF and optical energy sources.
  - **D = v * t**
  - D = round-trip distance
  - v = speed of wave propagation
  - t = elapsed time
- Sound = 0.3 meters/msec
- RF/light = 0.3 meters / ns (Very difficult to measure short distances 1-100 meters)

Ultrasonic Sensors

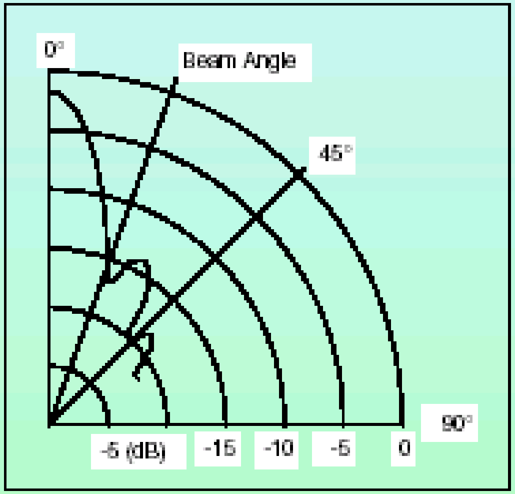
- Basic principle of operation:
  - Emit a quick burst of ultrasound (50kHz), (human hearing: 20Hz to 20kHz)
  - Measure the elapsed time until the receiver indicates that an echo is detected.
  - Determine how far away the nearest object is from the sensor

- **D = v * t**

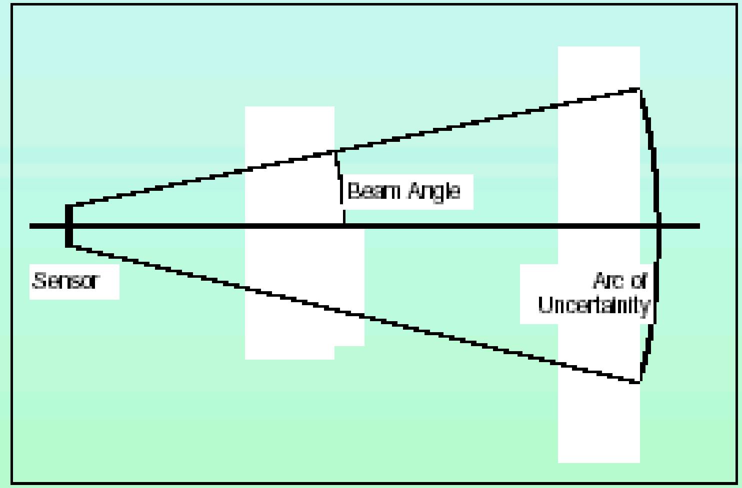
D = round-trip distance
v = speed of propagation(340 m/s)
t = elapsed time



Bat, dolphin, …



Sensor Specification



Sensor Model, angle = 15 degrees

Ultrasonic Sensors

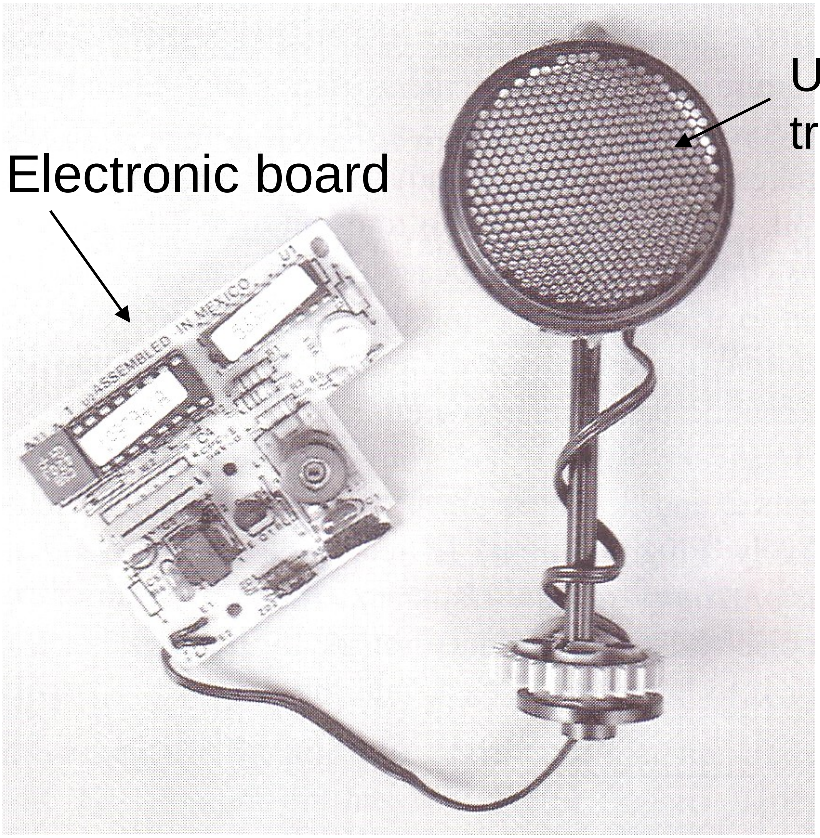
- Ranging is accurate but bearing has a 30 degree uncertainty. The object can be located anywhere in the arc.
- Typical ranges are of the order of several centimeters to 30 meters.
- Another problem is the propagation time. The ultrasonic signal will take 200 msec to travel 60 meters. (30 meters roundtrip @ 340 m/s)

Ultrasonic Sensors

- Polaroid ultrasonic ranging system
  - It was developed for auto-focus of cameras.
  - Range: 6 inches to 35 feet

Transducer Ringing:

- transmitter + receiver @ 50 KHz
- Residual vibrations or ringing may be interpreted as the echo signal
- Blanking signal to block any return signals for the first 2.38ms after transmission



http://www.acroname.com/robotics/info/articles/sonar/sonar.html

Operation with Polaroid Ultrasonic

The Electronic board supplied has the following I/0

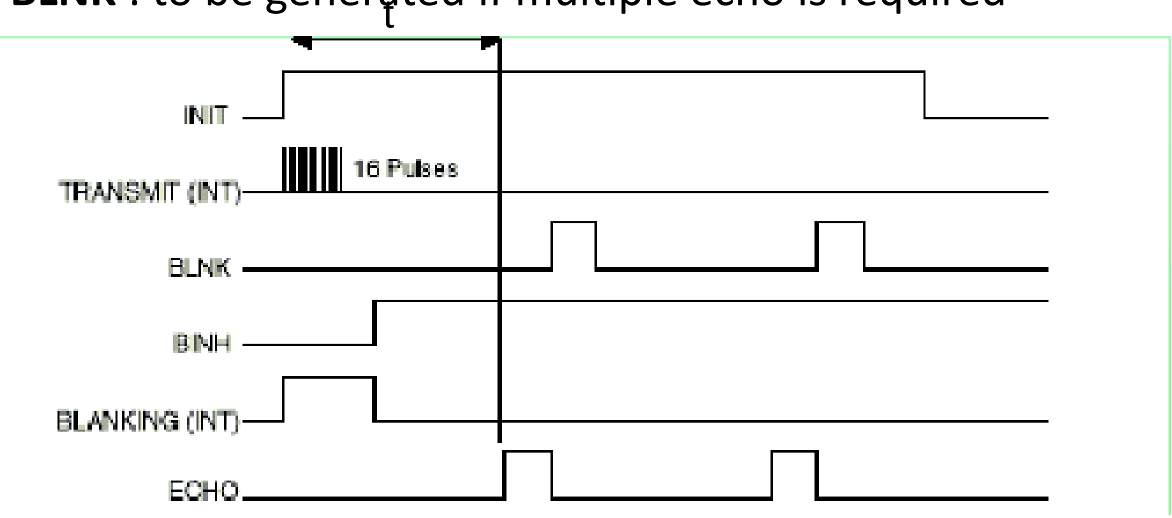
INIT : trigger the sensor, (16 pulses are transmitted)

BLANKING : goes high to avoid detection of own signal

ECHO : echo was detected.

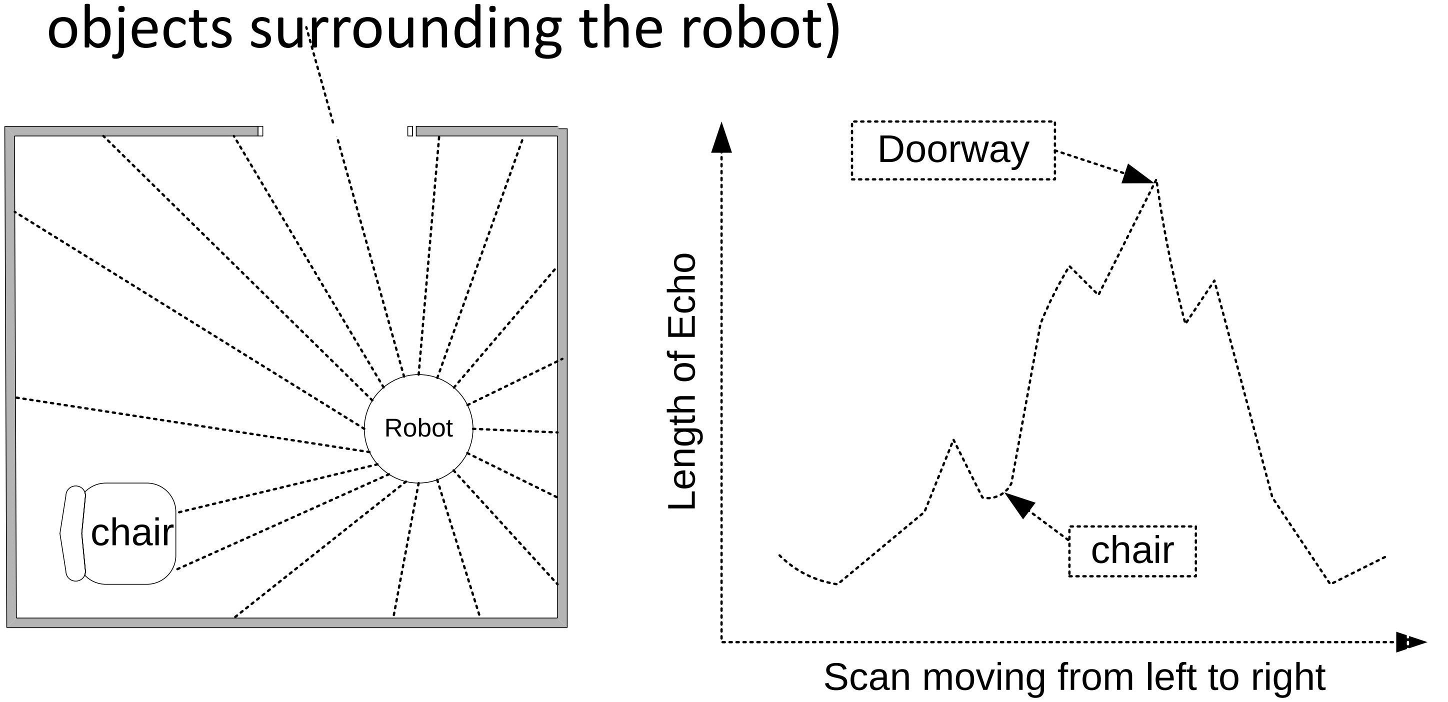
BINH : goes high to end the blanking (reduce blanking time < 2.38 ms)

BLNK : to be generated if multiple echo is required



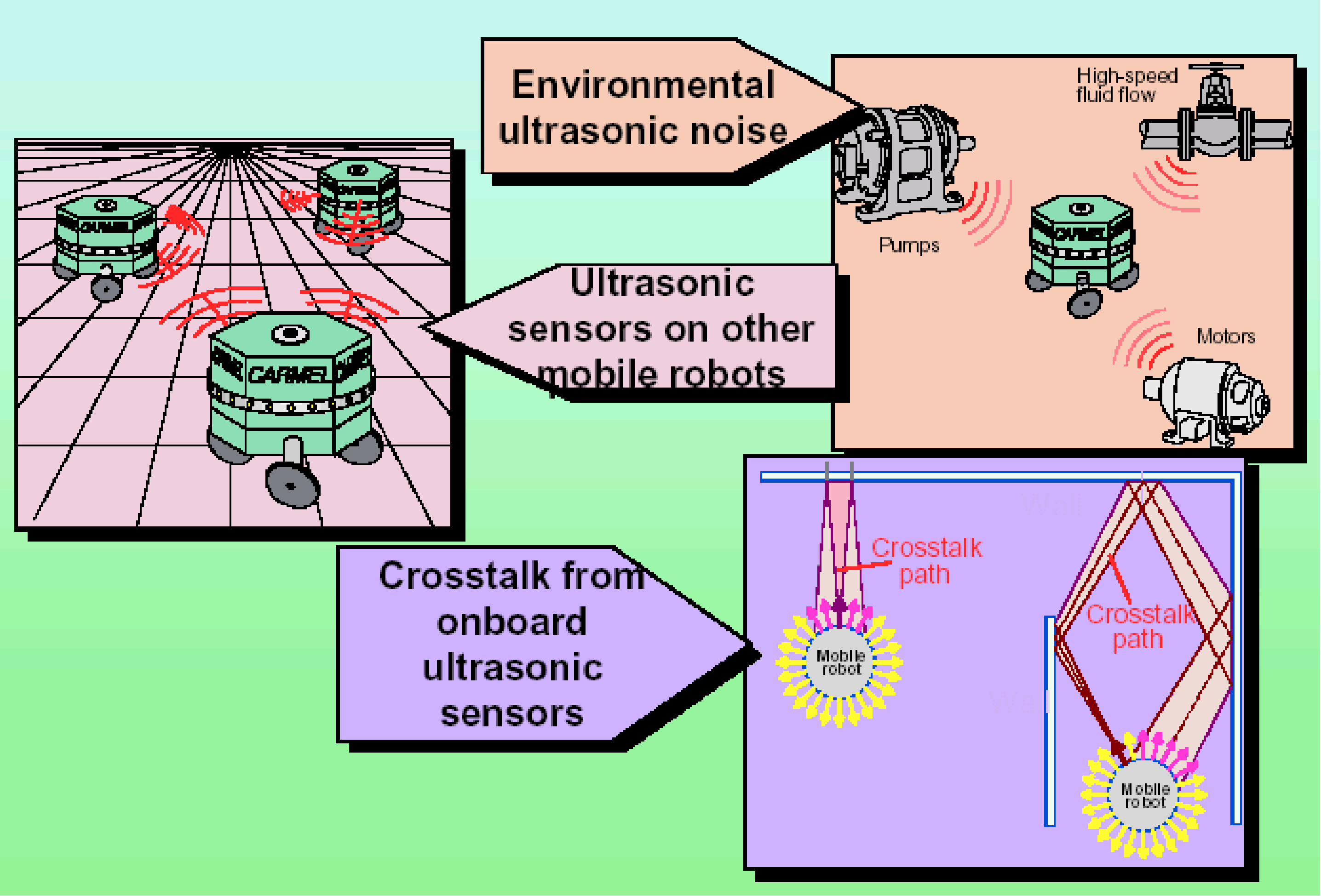
Ultrasonic Sensors

- Applications:
  - Distance Measurement
  - Mapping: Rotating proximity scans (maps the proximity of objects surrounding the robot)



Scanning at an angle of 15º apart can achieve best results

Noise Issues



Laser Ranger Finder

Range 2-500 meters

Resolution : 10 mm

Field of view : 100 - 180 degrees

Angular resolution : 0.25 degrees

Scan time : 13 - 40 msec.

These lasers are more immune to Dust and Fog

http://www.sick.de/de/products/categories/safety/

ROBOT VISION

Vision is the most powerful robot sensory capabilities. Enables a robot to have a sophisticated sensing mechanism that allows it to respond to its environment in intelligent and flexible manner. Therefore machine vision is the most complex sensor type.

→ Robot vision may be defined as the process of extracting, characterizing, and interpreting information from images of a three-dimensional world. This process, also known as machine or computer vision may be subdivided into six principle areas. These are:

→ **Sensing** : the process that yields visual image

→ **Preprocessing** : deals with techniques such as noise reduction and enhancement of details

→ **Segmentation** : the process that partitions an image into objects of interest

→ **Description**: deals with that computation of features for example size or shape, suitable for differentiating one type of objects from another.

→ **Recognition:** the process that identifies these objects (for example wrench, bolt, engine block, etc.)

→ **Interpretation**: assigns meaning to an ensemble of recognized objects.

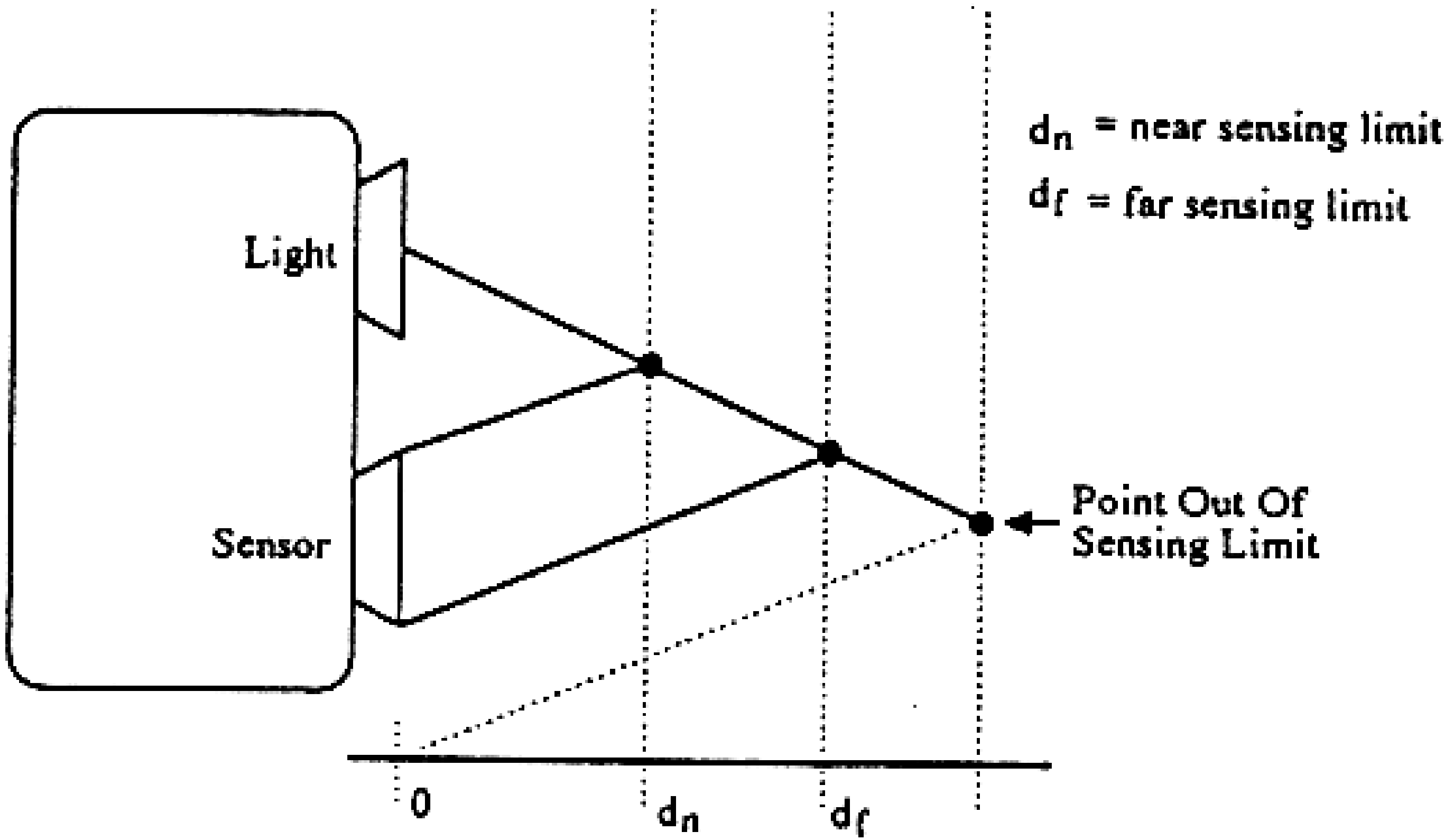
IMAGING COMPONENTS

- The imaging component, the “eye” or sensor, is the first link in the vision chain. Numerous sensors may be used to observe the world. There are four type of vision sensors or imaging components:

- 1. Point sensors

  capable of measuring light only at a single point in space. These sensor using coupled with a light source (such as LED) and used as a noncontact ‘feeler’

  It also may be used to create a higher – dimensions set of vision Information by scanning across a field of view by using mechanisms such as orthogonal set of scanning mirrors



Noncontact feeler-point sensor

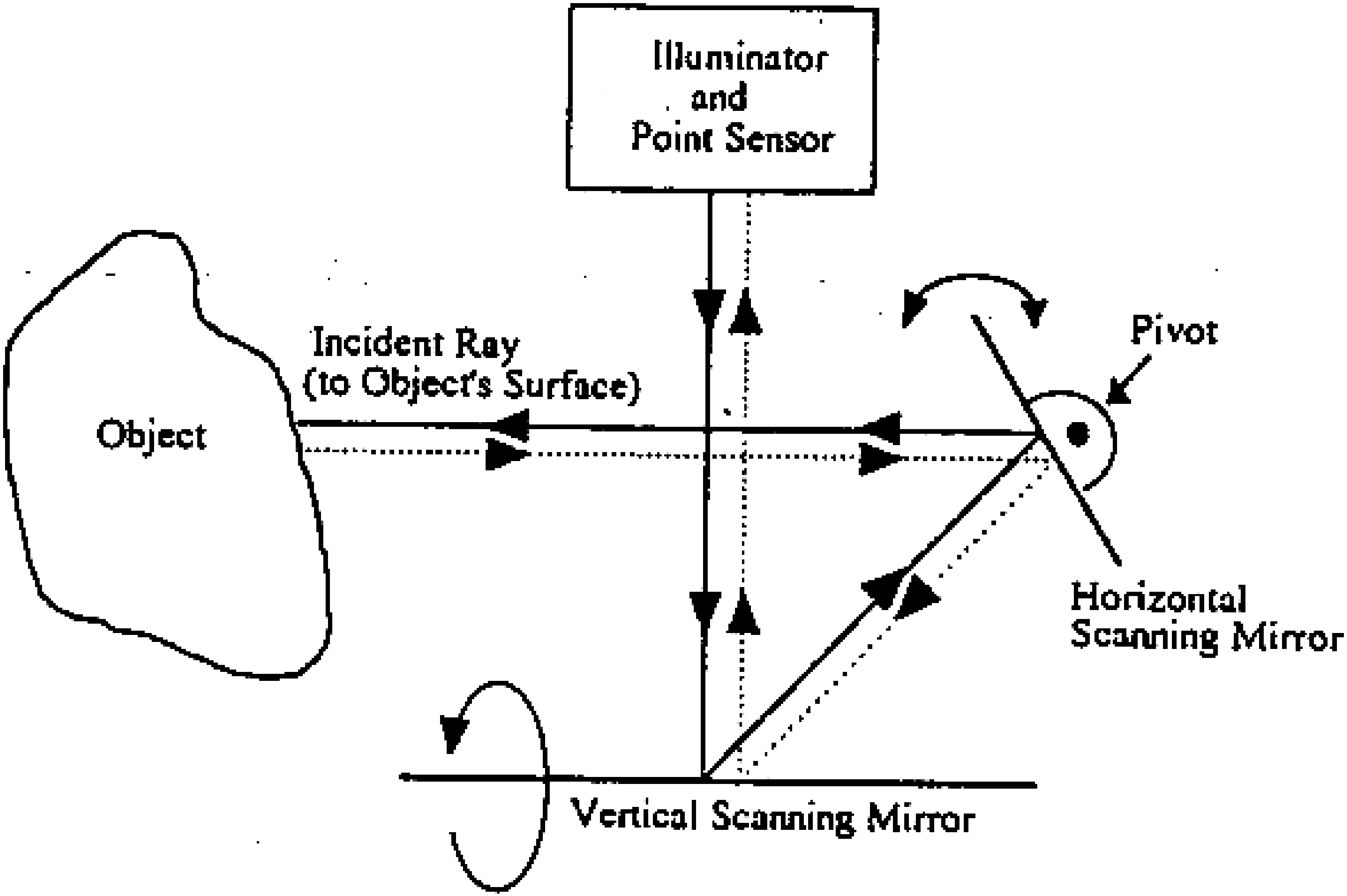
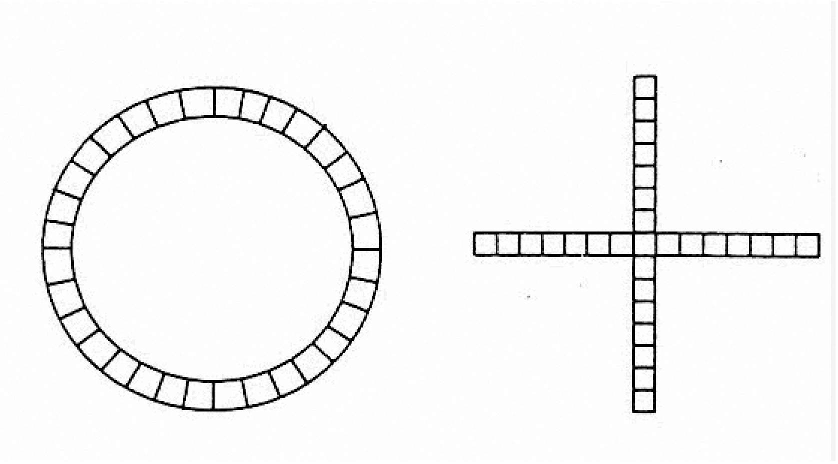


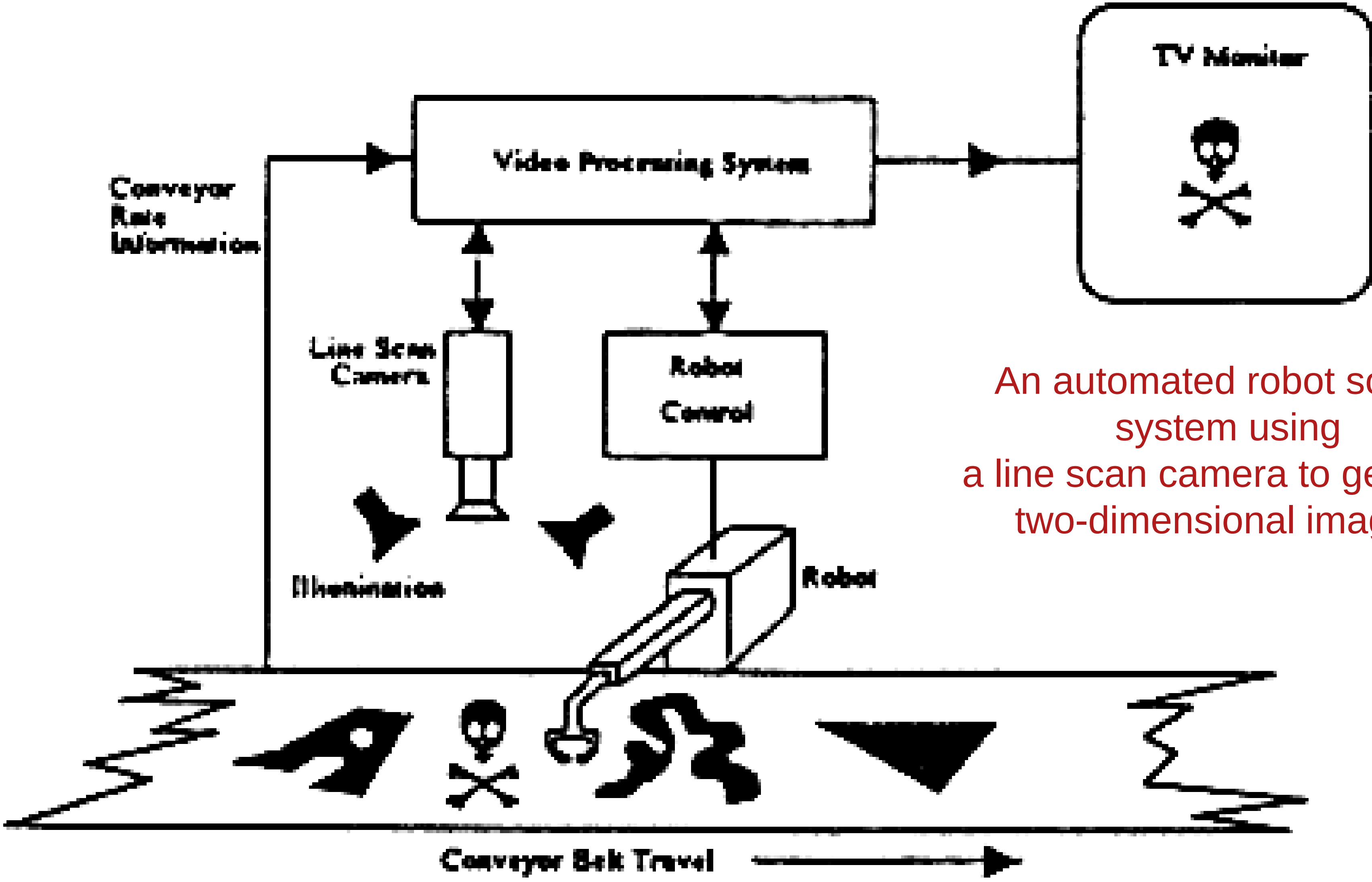
Image scanning using a point sensor
and oscillating deflecting mirrors

2. Line Sensor

- Line sensors are one-dimensional devices used to collect vision information from a real scene in the real world.
- The sensor most frequently used is a “line array” of photodiodes or charger-couple-device components.
- It operates in a similar manner to analog shift register, producing sequential, synchronized output of electrical signals, corresponding to the light intensity falling on an integrated light-collecting cell.



Circular and cross configurations of light sensors



An automated robot sorting system using
a line scan camera to generate two-dimensional images.

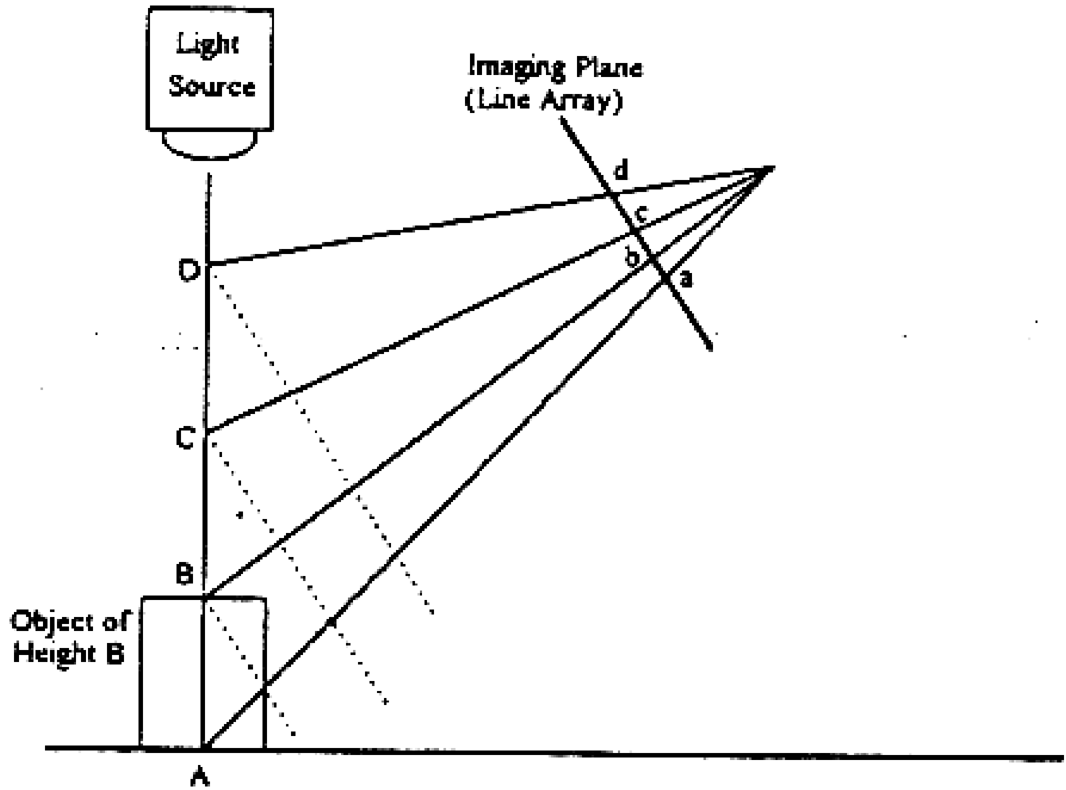
- Line array may be used to image scene. E.g. by fixing the position of a straight-line sensor and moving an object orthogonally to the orientation of the array, one may scan the entire object of interest.

3. Planar Sensor

- A two dimensional configuration of the line-scan concept. Two generic types of these sensors generally in use today are scanning photomultipliers and solid-state sensors.
- Photomultipliers are represented by television cameras, the most common of which is the vidicon tube, which essentially an optical-to-electrical signal converter.
- In addition to vidicon tubes, several types of solid-state cameras are available. Many applications require the solid-state sensors because of weight and noise factor (solid-state arrays are less noisy but more expensive). This is important when mounting a camera near or on the end-effector of a robot.

4. Volume Sensor

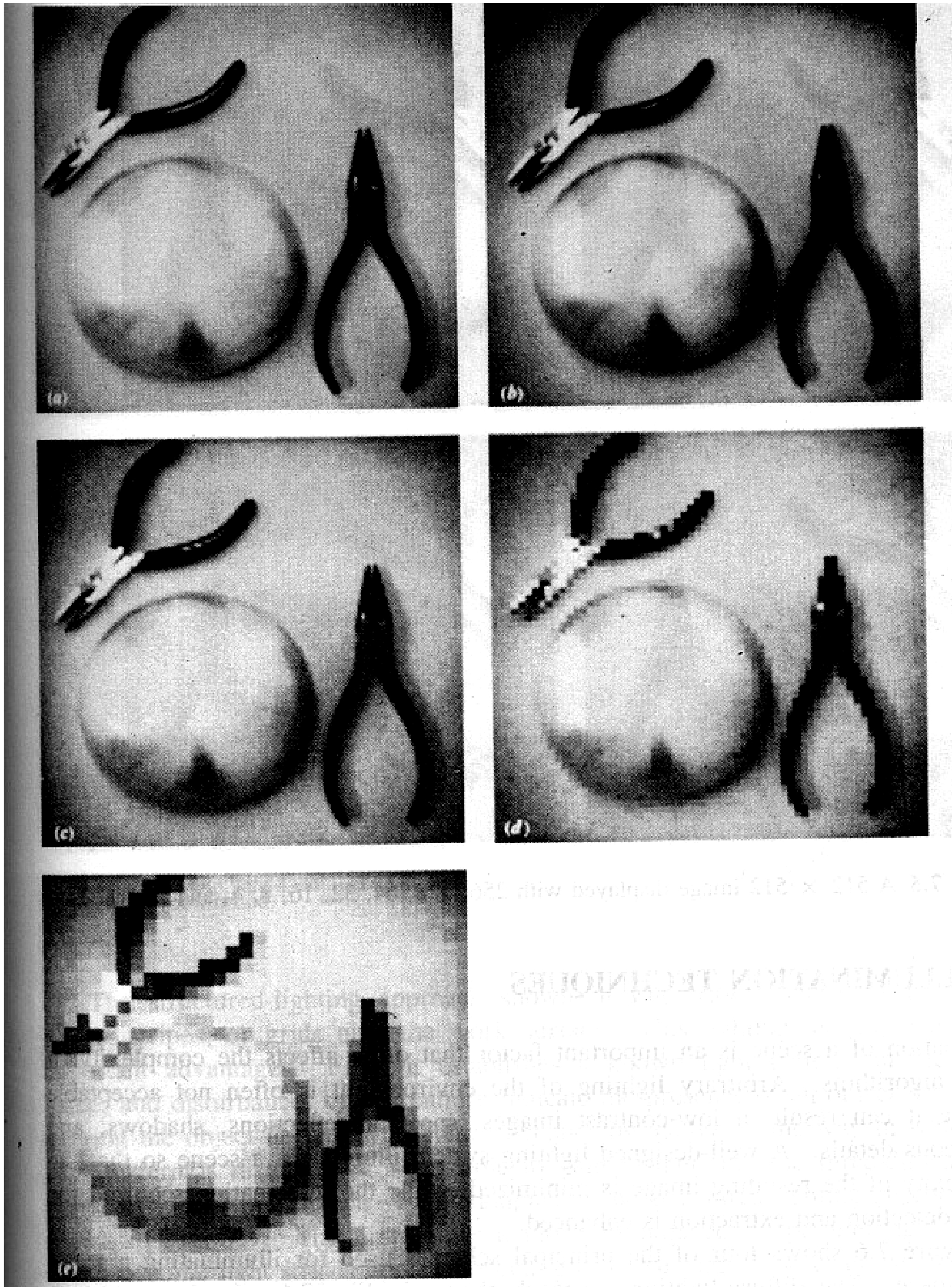
- A sensor that provide three-dimensional information. The sensor may obtain the information by using the directional laser or acoustic range finders.



Schematic representation
of a triangulation range finder

IMAGE REPRESENTATION

- From the diagram below. F(x,y) is used to denote the two-dimensional image out of a television camera or other imaging device.
- “x” and “y” denote the spatial coordinates (image plane)
- “f” at any point (x,y) is proportional to the brightness (intensity) of the image at that point.
- In form suitable for computer processing, an image function f(x,y) must be digitized both spatially and in amplitude (intensity). Digitization of the spatial coordinates (x,y) will be known as image sampling, while amplitude digitization is known as intensity or grey-level quantization.
- The array of (N, M) rows and columns, where each sample is sampled uniformly, and also quantized in intensity is known as a digital image. Each element in the array is called image element, picture element (or pixel).



Effects of reducing sampling grid size.

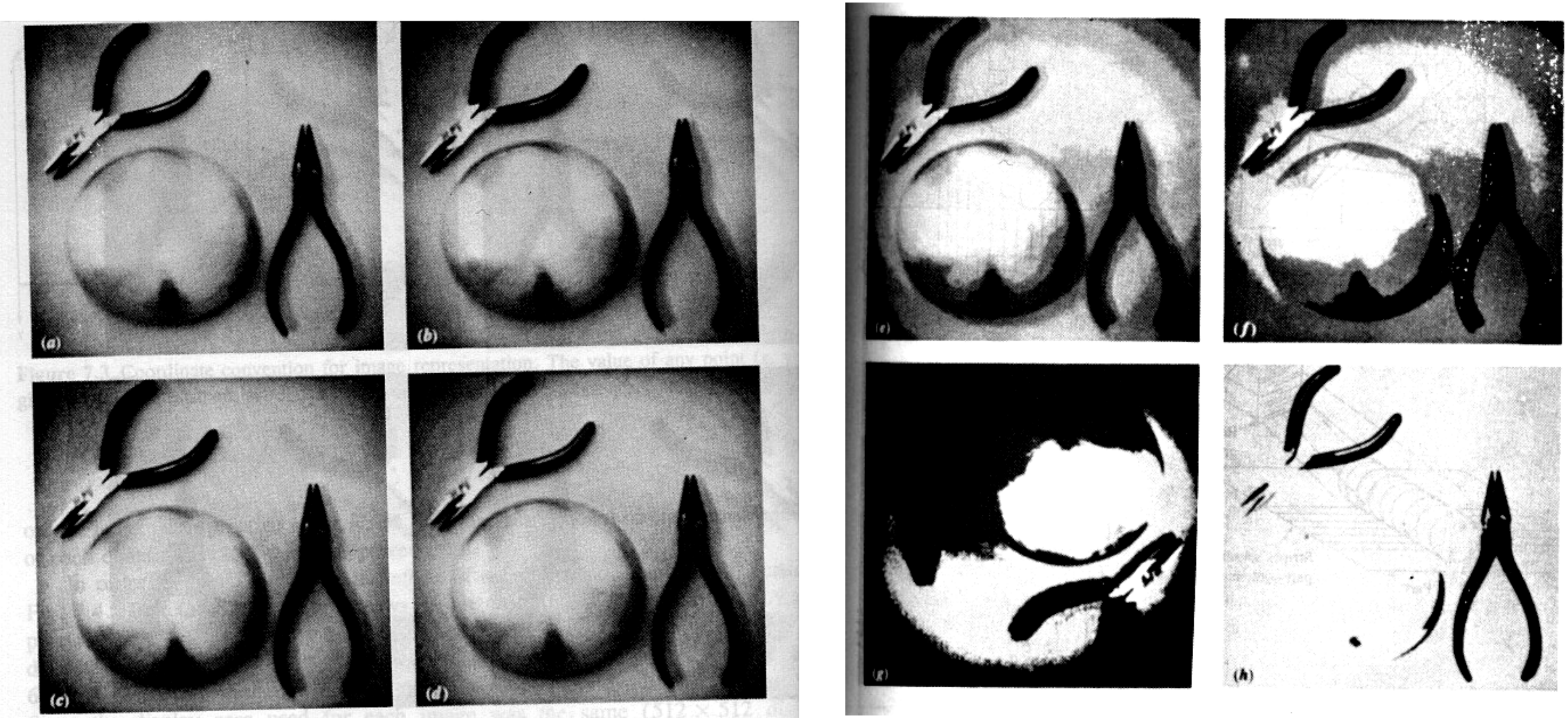
a) 512x512.

b) 256x256.

c) 128x128.

d) 64x64.

e) 32x32.



Effect produced by reducing the number of intensity levels while maintaining the spatial resolution constant at 512x512. The 256-, 128- and 64-levels are of acceptable quality.

a) 256, b) 128, c) 64, d) 32, e) 16, f) 8, g) 4, and h) 2 levels

ILLUMINATION TECHNIQUES

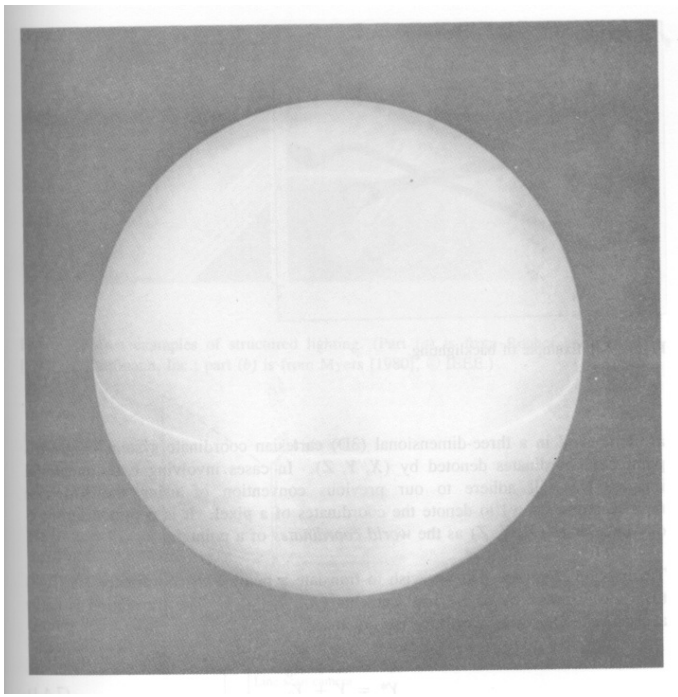
- Illumination of a scene is an important factor that often affects the complexity of vision algorithms.
- A well designed lighting system illuminates a scene so that the complexity of the resulting image is minimised, while the information required for object detection and extraction is enhanced.
- Arbitrary lighting of the environment is often not acceptable because it can result in low contras images, specular reflections, shadows and extraneous details.

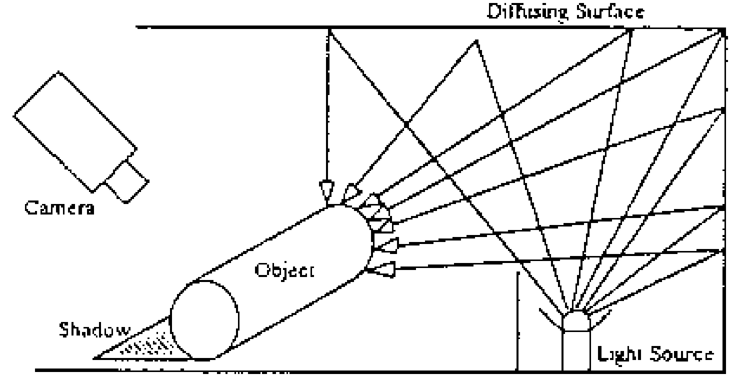
- There are 4 main illumination techniques for a robot work space :

ILLUMINATION TECHNIQUES

1. DIFFUSE-LIGHTING

- This technique is for smooth, regular surface object. It is used where surface characteristic are important.
- Example:



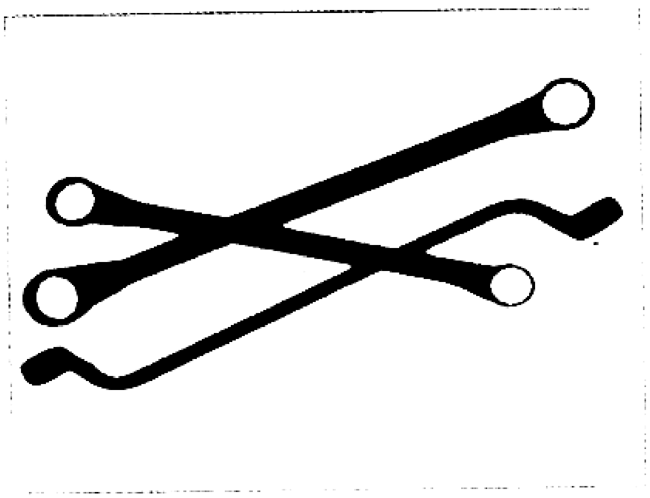


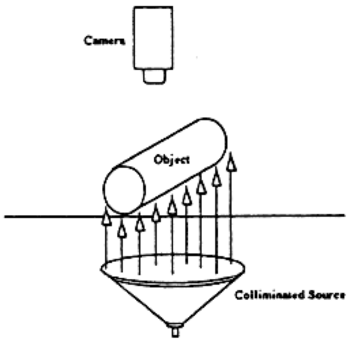
Diffuse-lighting technique

ILLUMINATION TECHNIQUES

2. BACKLIGHTING

- Produce black and white image. This technique suited for applications in which silhouettes of object are sufficient for recognition or other measurement.
- Example:





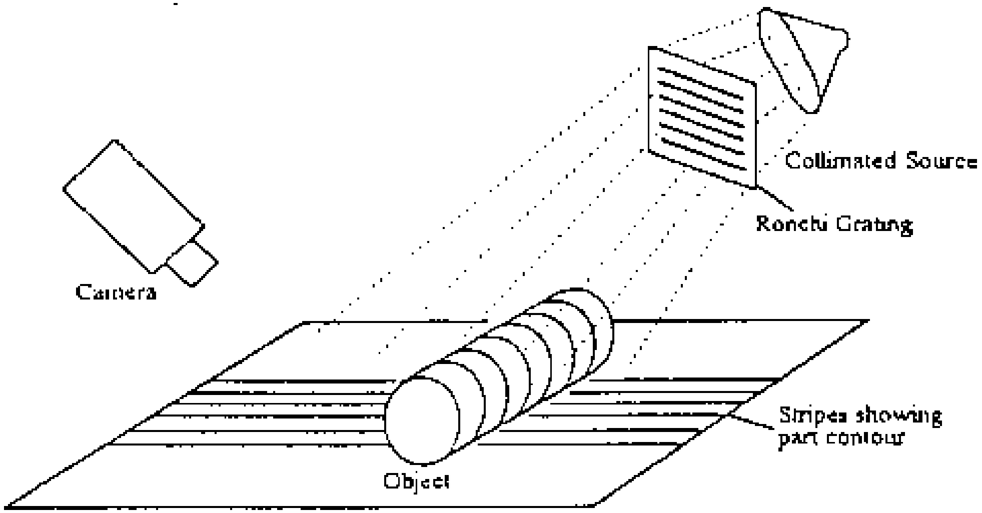
Backlighting technique

ILLUMINATION TECHNIQUES

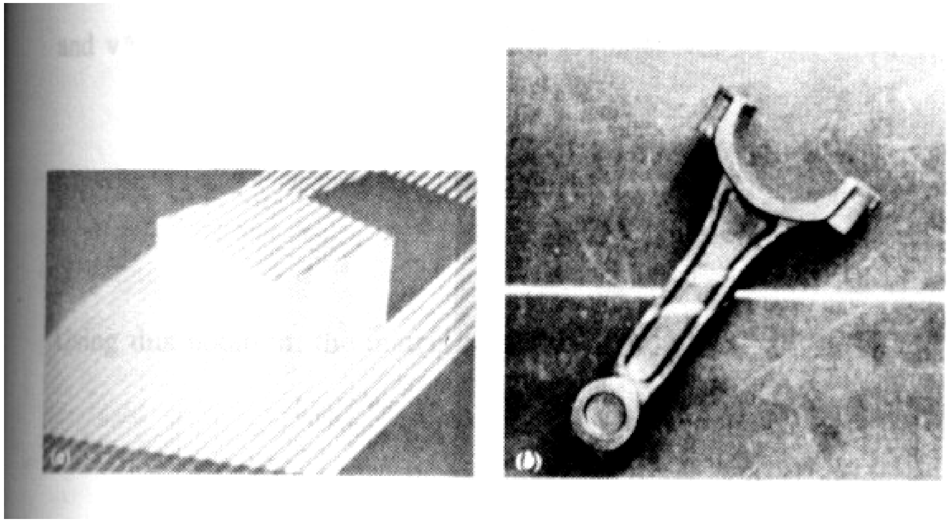
3. STRUCTURED LIGHTING

- Consist of projecting points, stripes, grids onto work surface.
- This lighting technique has 2 important advantages:

1. It establishes a known light pattern on the work space and disturbances of this indicate the presence of an object, thus simplifying the object detection problems.
2. By analysing the way which the light pattern distorted, it is possible to gain insight into three-dimensional characteristics of the object.



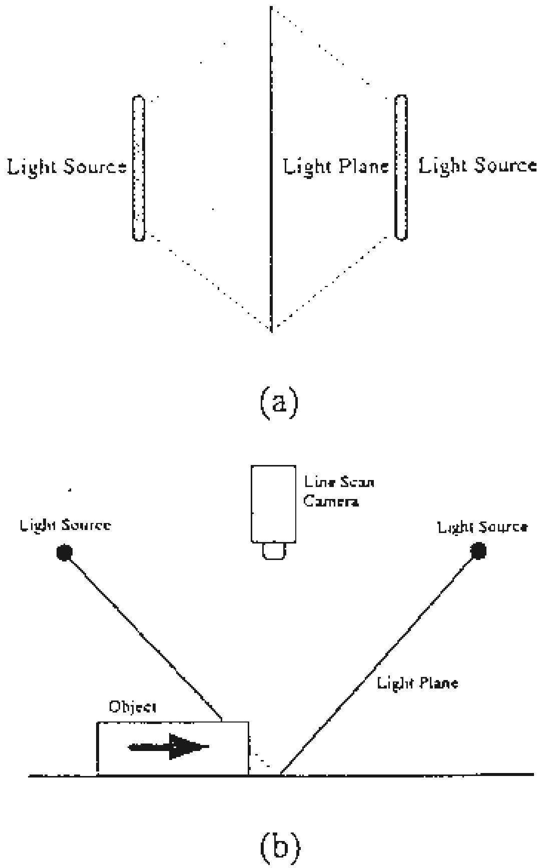
Structured lighting technique



3. STRUCTURED LIGHTING (cont.)

(a) Top view of two light planes intersecting in a line sight

- The following figure illustrates the structured lighting technique using two light planes projected from different directions, but converging on a single stripe on the surface. The two light sources guarantee that the object will break the light stripe only when it is directly below the camera.
- This technique is suitable for moving object.
- Note: “The line scan camera sees only the line on which the two light planes converge, but two-dimension information can be accumulated as the object move past the camera”



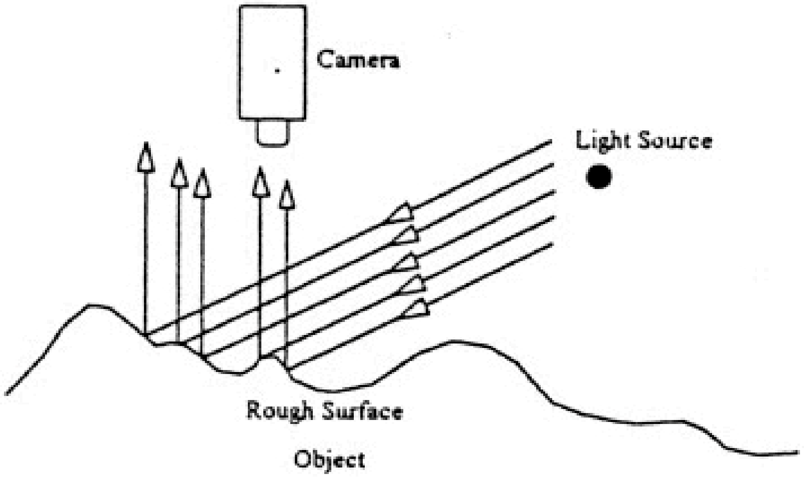
(b) Object will be seen by the camera only When it interrupts both light planes

ILLUMINATION TECHNIQUES

4. DIRECTIONAL LIGHTING

This method is used to inspection of object surfaces.

Defects on the surface such as scratches be detected by using a highly directed li beam (such as laser beam) and measuri amount of scatter

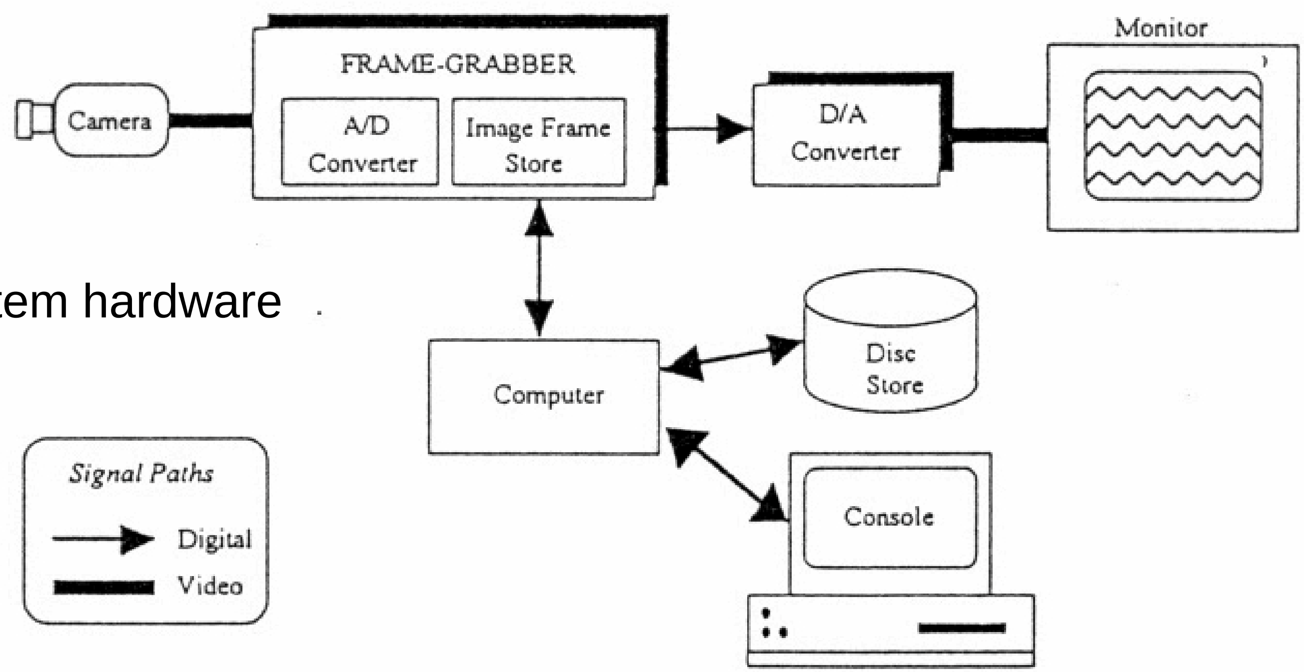


Directional lighting technique

ROBOT VISION SYSTEM

- There are several commercial packages that can be bought for vision processing work. A typical hardware configuration is shown below.
- Based on the technique used, the robotic vision systems can be grouped into the following major types:

1. Binary vision systems
2. Gray-level vision systems
3. Ad hoc special-purpose vision systems
4. Structured light vision systems
5. Character recognition vision systems

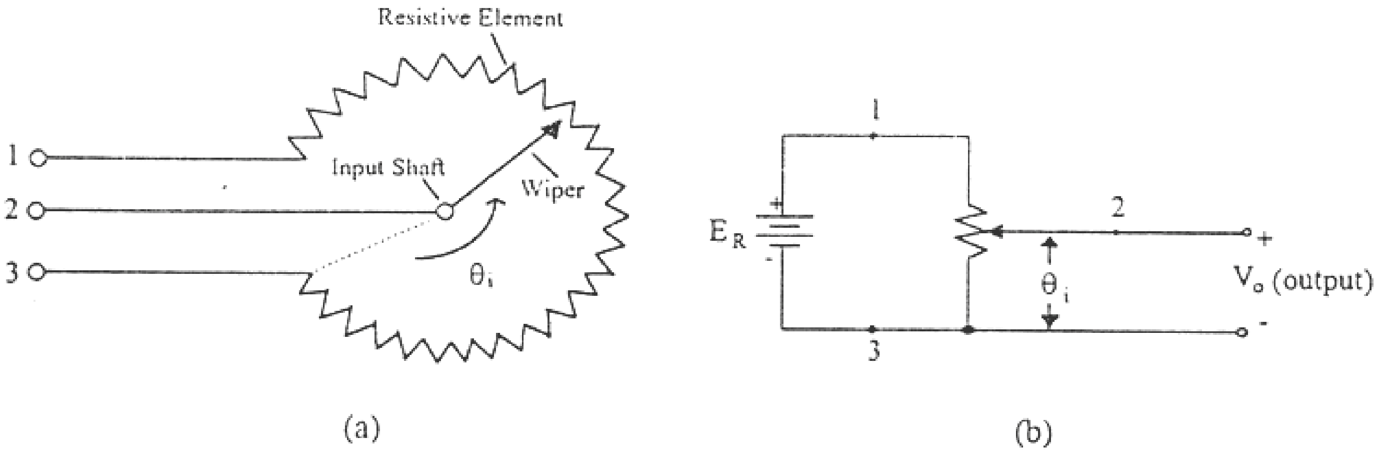


Vision system hardware

MISCELLANEOUS SENSORS

Potentiometer

Potentiometer transducers can be used to measure both linear and angular displacement

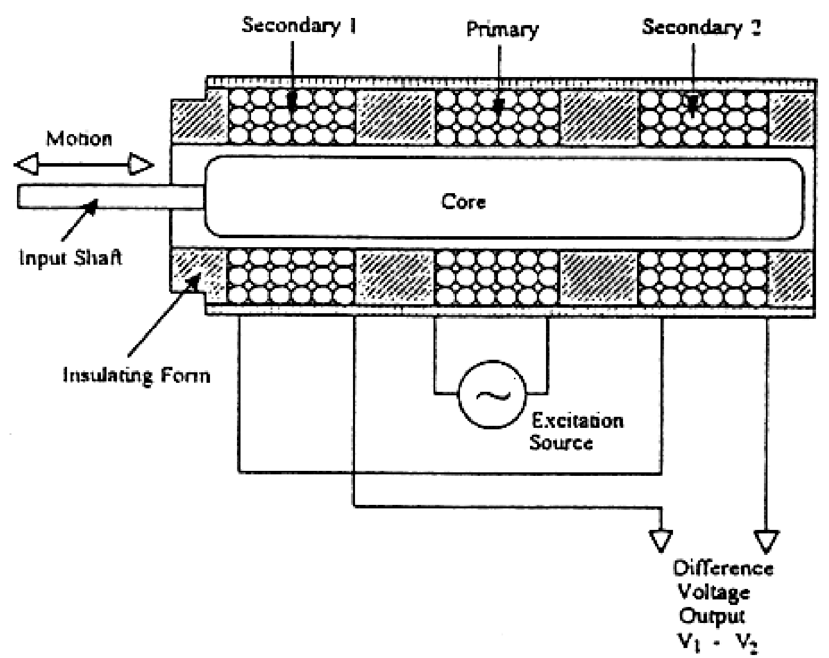


(a) Potentiometer

(b) (b) Schematic diagram of the potentiometer

Linear Variable Differential Transformer (LVDT)

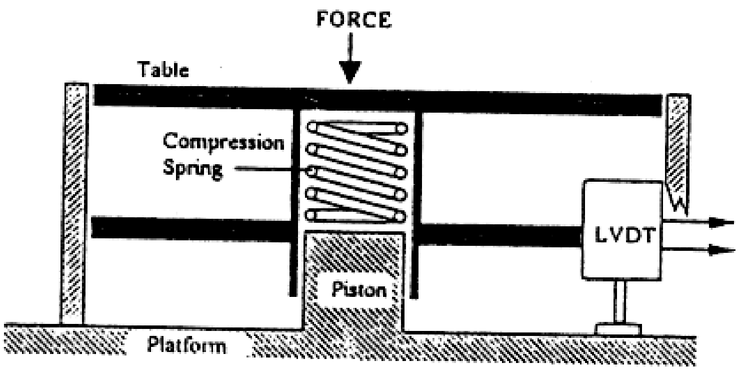
LDVT is a robust and precise device which produce a voltage output proportional to the displacement of a ferrous armature for measurement of robot joints or end-effectors. It is much expensive but outperforms the potentiometer transducer.



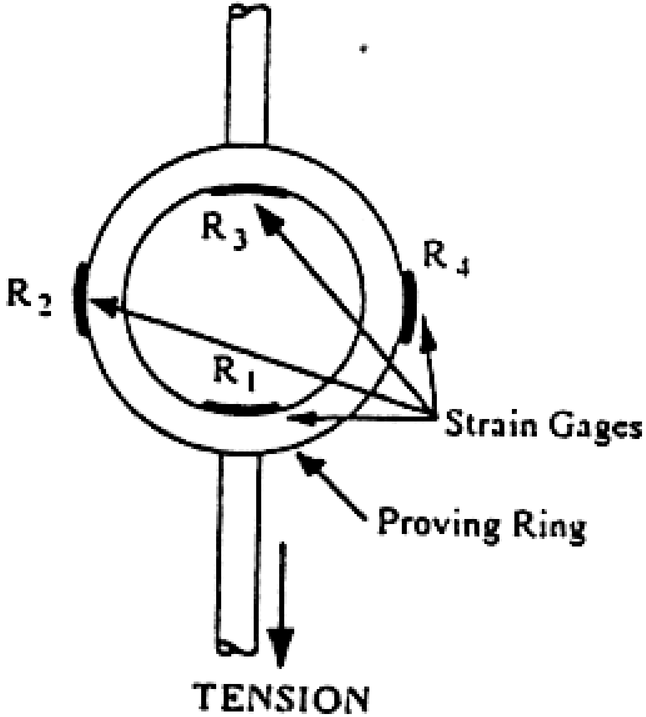
Linear Variable Differential Transformer (LVDT)

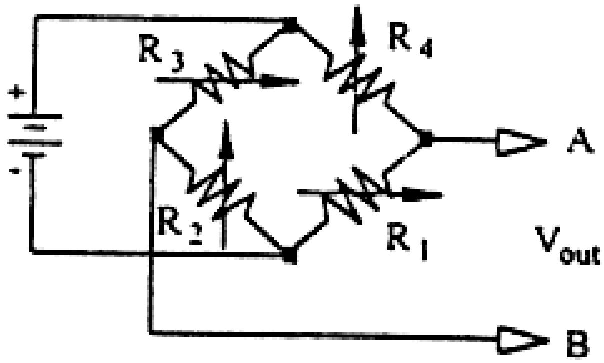
Force & Torque Sensors

Force transducers are often based oı displacement principles. There various type force and torque transducer available commercially



A force-measuring device based on a compression spring and LDVT.



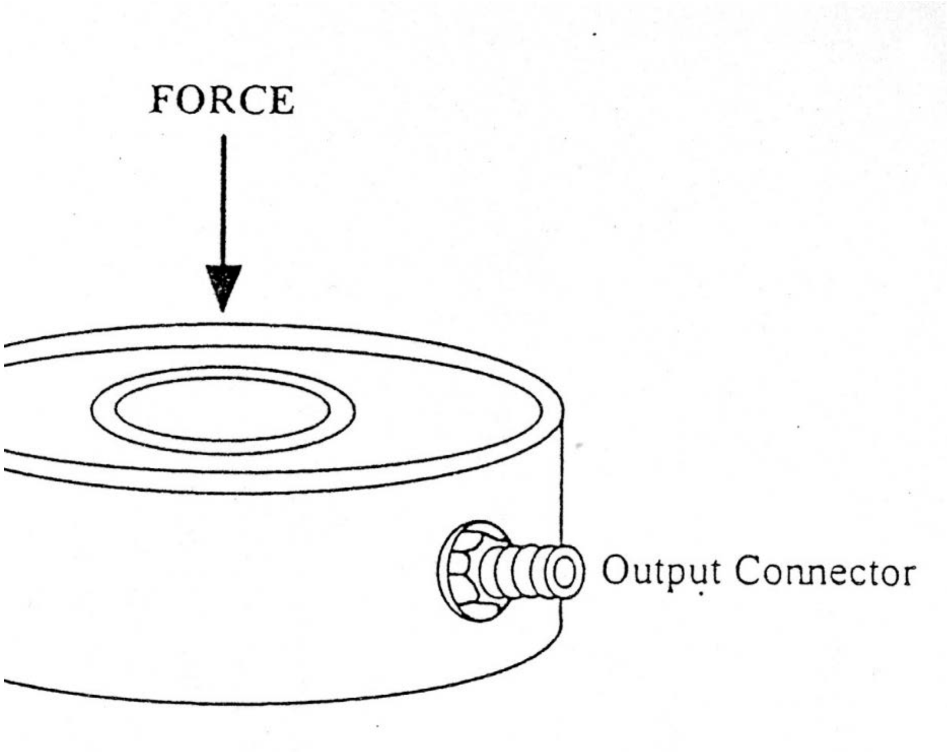


This figure illustrate a tension load cell.

It can be used to measure the force

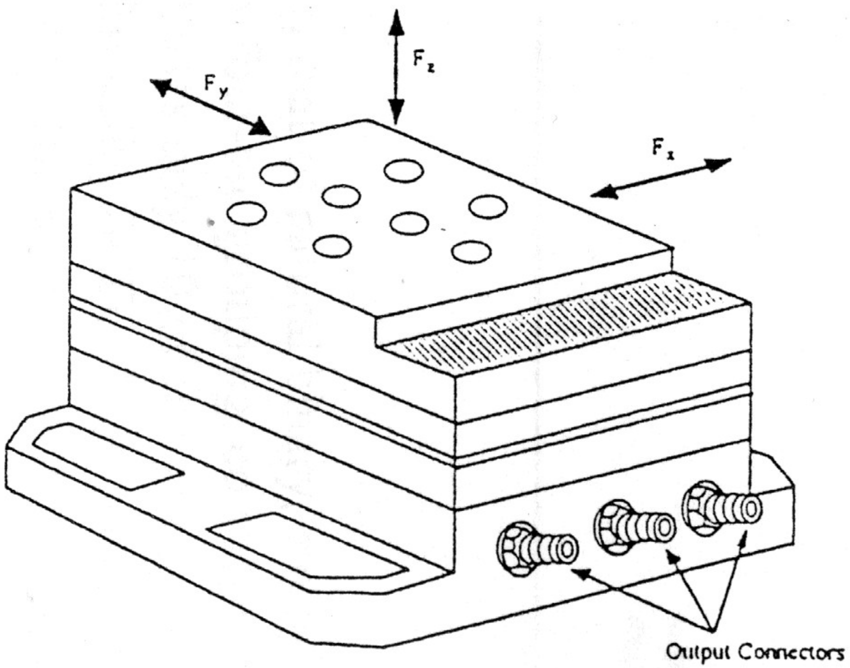
required to pick up heavy load in industry

Force & Torque Sensors



- Force can be measured using piezoelectric principle.
- Figure shows a load washer type piezoelectric force transducer. It is designed to measure axial forces. It is preloaded when manufactured and can measure both tensile and compressive forces.

Force & Torque Sensors



- Measured using piezoelectric principle.
- Figure shows a three-component dynamometer type piezoelectric force transducer that measures three orthogonal components of force.

Inertial Sensors

- **Gyroscopes**
  - Measure the rate of rotation independent of the coordinate frame
  - Common applications:
    - Heading sensors, Full Inertial Navigation systems (INS)
- **Accelerometers**
  - Measure accelerations with respect to an inertial frame
  - Common applications:
    - Tilt sensor in static applications, Vibration Analysis, Full INS Systems

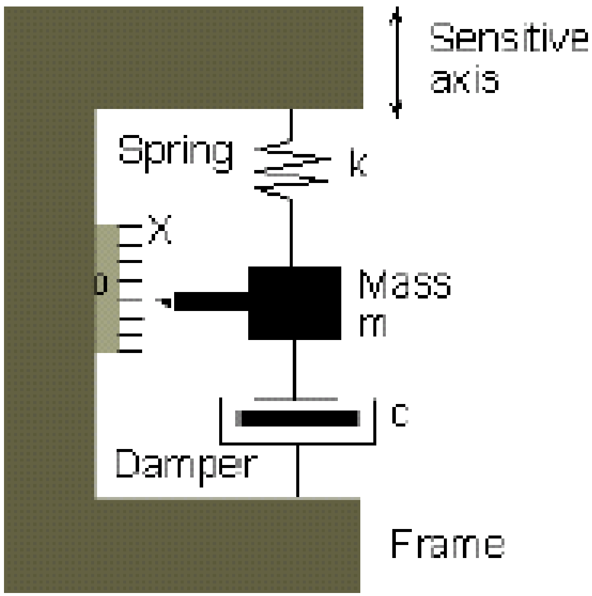
Accelerometers

- They measure the inertia force generated when a mass is affected by a change in velocity.
- This force may change
  - The tension of a string
  - The deflection of a beam
  - The vibrating frequency of a mass

Accelerometer

- Main elements of an accelerometer:

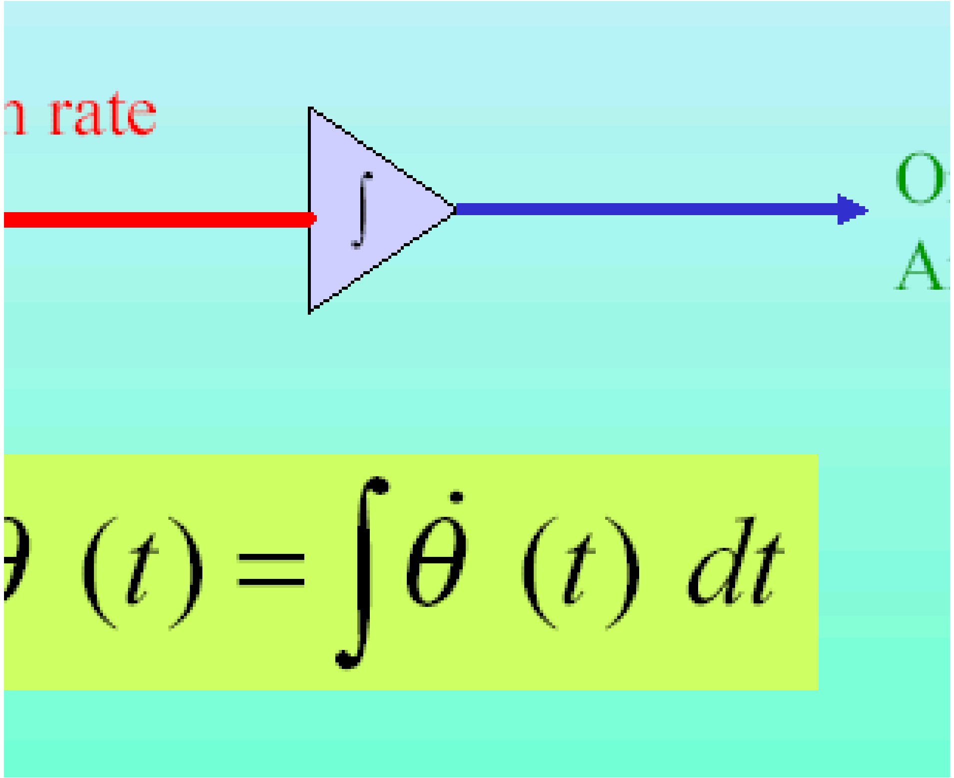
1. Mass 2. Suspension mechanism 3. Sensing element



$$F = m\frac{d^2x}{d^2t} + c\frac{dx}{dt} + kx$$

High quality accelerometers include a servo loop to improve the linearity of the sensor.

Gyroscopes

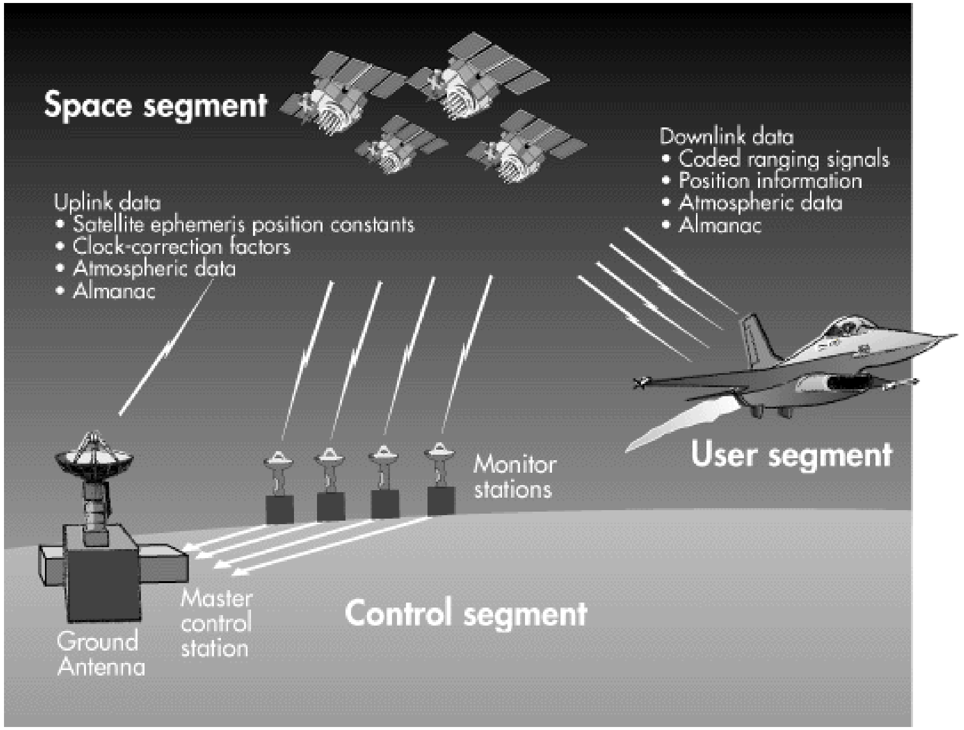


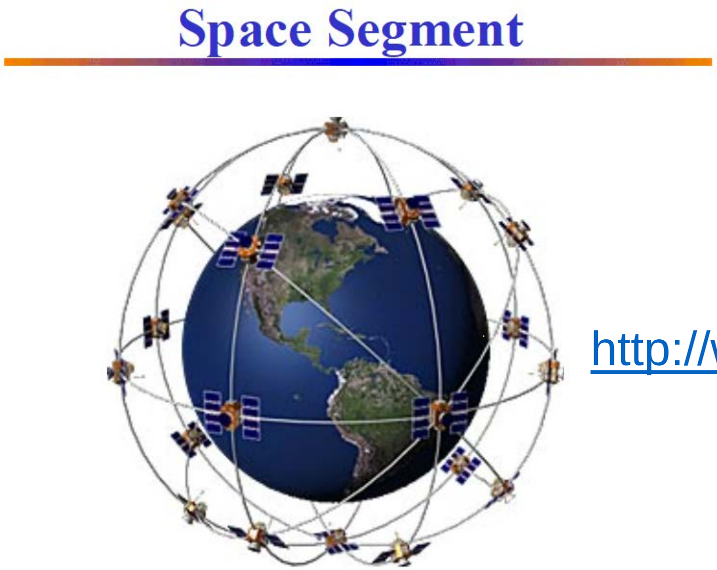
- These devices return a signal proportional to the rotational velocity.
- There is a large variety of gyroscopes that are based on different principles

Global Positioning System (GPS)

24 satellites (+several spares)

broadcast time, identity, orbital parameters (latitude, longitude, altitude)





http://www.cnde.iastate.edu/staff/swormley/gps/gps.html

Noise Issues

- Real sensors are noisy
- Origins: natural phenomena + less-than-ideal engineering
- Consequences: limited accuracy and precision of measurements
- Filtering:
  - software: averaging, signal processing algorithm
  - hardware tricky: capacitor

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Questions

- What are the defining features of Industry 4.0, and how does it differ from the previous industrial revolutions?
- Describe the role of a cyber-physical system (CPS) in Industry 4.0.
- How does a decentralized control system (DCS) improve industrial operations compared to a centralized control architecture?
- What is the Safety Integrated Level (SIL), and why is it important in the context of Industry 4.0?
- Explain the concept of 'smart sensors' in industrial applications and how they contribute to the objectives of Industry 4.0.

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