INDUSTRIAL ROBOTICS
UNIT 7

UNIT I INTRODUCTION

- Definition of a Robot - Basic Concepts - Robot configurations - Types of Robot drives - Basic robot motions -Point to point control - Continuous path control.

Definition of a Robot

- A machine that looks and acts like a human being.
- An efficient but insensitive person
- An automatic apparatus.
  - Something guided by automatic controls.

  E.g. remote control
- A computer whose main function is to produce motion.

Law's of Robotics

Asimov proposed three "Laws of Robotics"

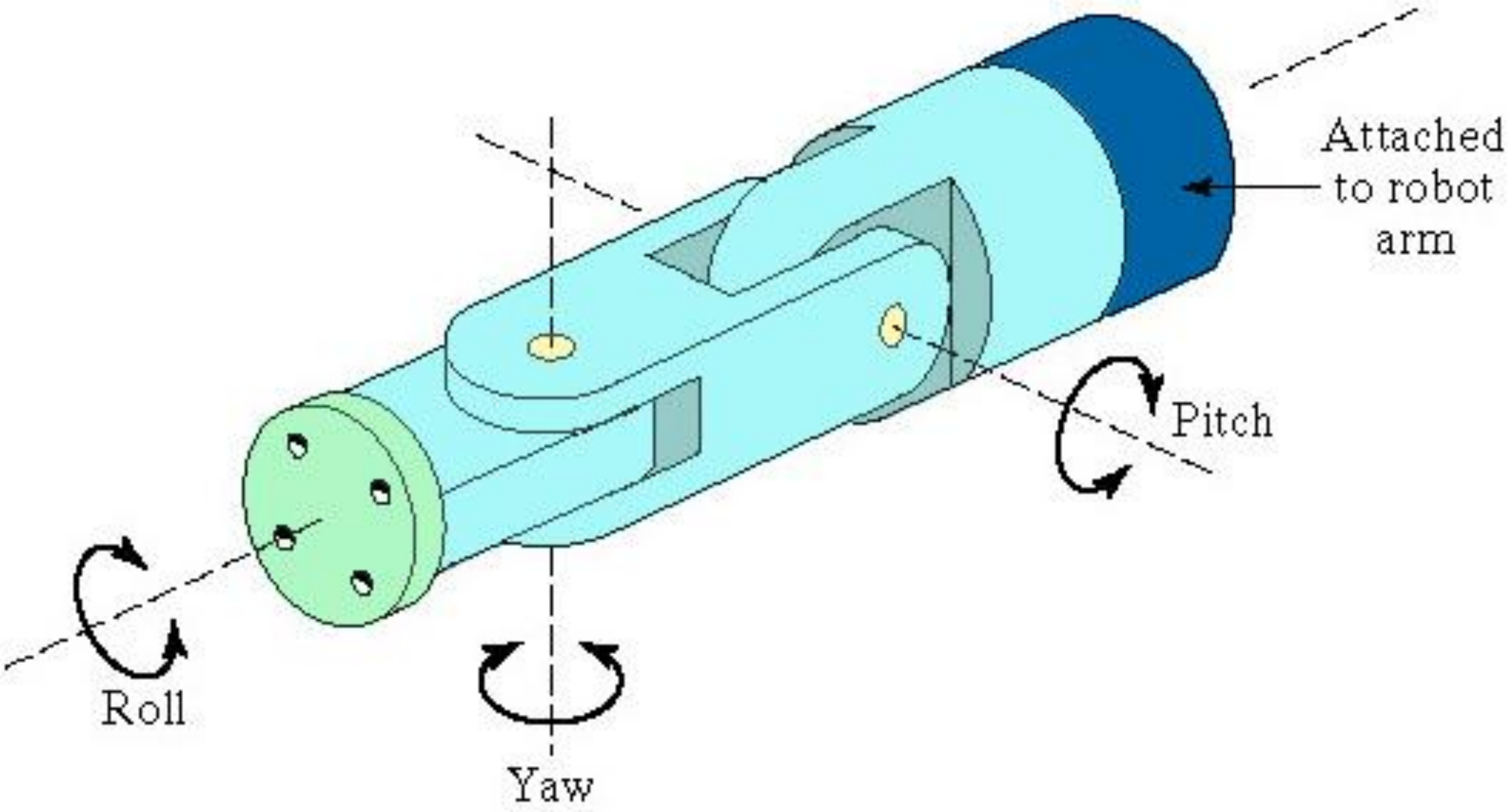
- Law 1: A robot may not injure a human being or through inaction, allow a human being to come to harm
- Law 2: A robot must obey orders given to it by human beings, except where such orders would conflict with a higher order law
- Law 3: A robot must protect its own existence as long as such protection does not conflict with a higher order law

Robot anatomy

- Robot manipulator consists of two sections:
  - Body-and-arm – for positioning of objects in the robot's work volume
  - Wrist assembly – for orientation of objects

WRIST

- Wrist assembly is attached to end-of-arm
- End effector is attached to wrist assembly
- Function of wrist assembly is to orient end effector
  - Body-and-arm determines global position of end effector
- Two or three degrees of freedom:
  - Roll
  - Pitch
  - Yaw



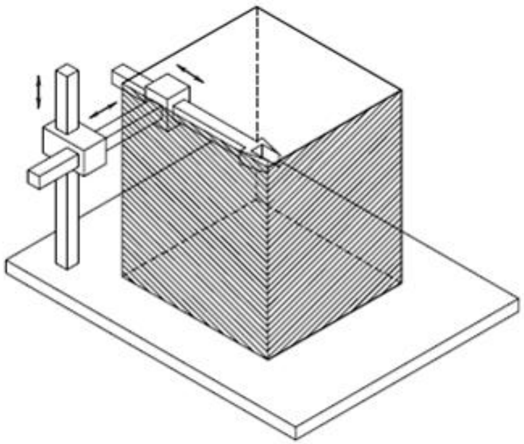
Attached
to robot
arm
Pitch
Roll
Yaw

Robot configurations

- Rectangular (or) Cartesian
- Cylindrical (or) Post-type
- Spherical (or) Polar
- SCARA (Selective Compliance Assembly Robot Arm)

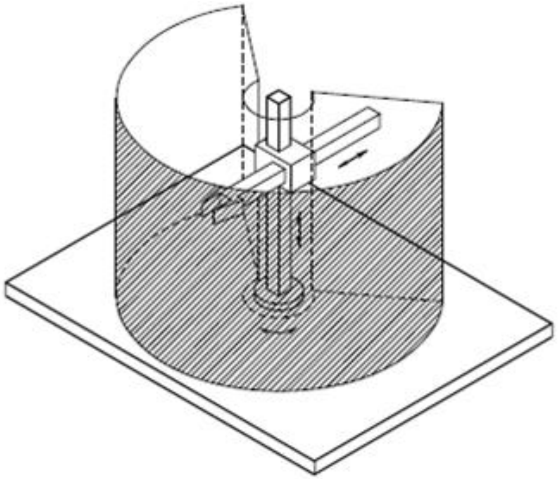
Cartesian/Rectangular Manipulator

- straight, or linear motion along three axes:
  - in and out, (x)
  - back and forth (y)
  - up and down (z)



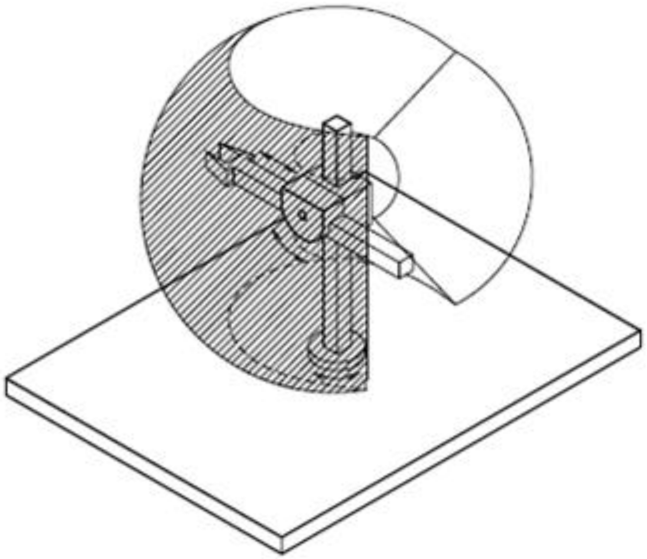
Cylindrical Manipulator

- Rotation about the base or shoulder. (θ)
- up and down (z)
- in and out (R)



Polar or Spherical Manipulator

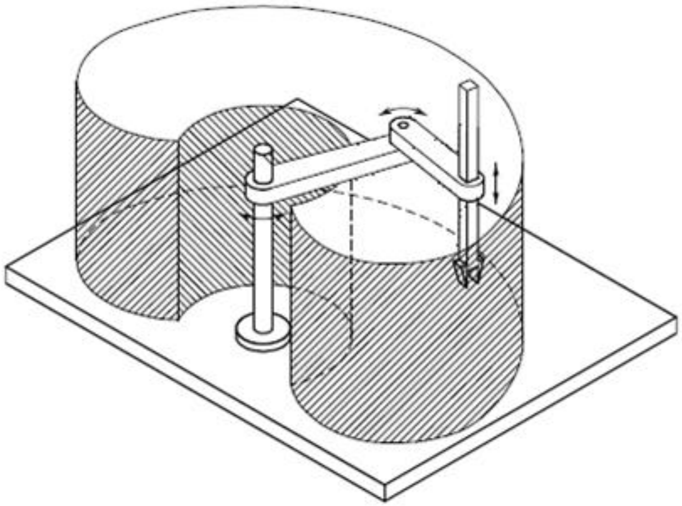
- rotation about the base
- Rotation about an axis in the vertical plane to raise and lower it.
- reaches in and out.



Spherical manipulator and its workspace

SCARA Robot

- Selective Compliance Assembly Robot Arm
  - the same work area as a cylindrical-coordinates robot.
  - the reach axis includes a rotational joint in a plane parallel to the floor.



Types of Robot drives

Electric: All robots use electricity as the primary source of energy.

- Electricity turns the pumps that provide hydraulic and pneumatic pressure.
- It also powers the robot controller and all the electronic components and peripheral devices.
- In all electric robots, the drive actuators, as well as the controller, are electrically powered.
- Because electric robots do not require a hydraulic power unit, they conserve floor space and decrease factory noise.
- No energy conversion is required.

Pneumatic: these are generally found in relatively low-cost manipulators with low load carrying capacity.

- Pneumatic drives have been used for many years for powering simple stop-to-stop motions.
- It is inherently light weight, particularly when operating pressures are moderate.

- **Hydraulic**: are either linear position actuators or a rotary vane configuration.
- Hydraulic actuators provide a large amount of power for a given actuator.
- The high power-to-weight ratio makes the hydraulic actuator an attractive choice for moving moderate to high loads at reasonable speeds and moderate noise level.
- Hydraulic motors usually provide a more efficient way of energy to achieve a better performance, but they are expensive and generally less accurate.

Basic Robot motions

A robot manipulator can make four types of motion in travelling from one point to another in the workplace:

- **Slew motion** : simplest type of motion. Robot is commanded to travel from one point to another at default speed.
- **Joint-interpolated motion**: requires the robot controller to calculate the time it will take each joint to reach its destination at the commanded speed.
- **Straight-line interpolation motion**: requires the end of the end effector to travel along a straight path determine in rectangular coordinates.
- Useful in applications such as arc welding, inserting pins into holes, or laying material along a straight path.
- **Circular interpolation motion**: requires the robot controller to define the points of a circle in the workplace based on a minimum of three specified positions.
- Circular interpolation produces a linear approximation of the circle and is more readily available using a programming language rather than manual or teach pendant techniques.

Point to point control

Point-To-Point: These robots are most common and can move from one specified point to another but cannot stop at arbitrary points not previously designated.

- All Axes start and end simultaneously
- All Geometry is computed for targets and relevant Joint changes which are then forced to be followed during program execution
- Only the end points are programmed, the path used to connect the end points are computed by the controller
- user can control velocity, and may permit linear or piece wise linear motion
- Feedback control is used during motion to ascertain that individual joints have achieved desired location
- Often used hydraulic drives, recent trend towards servomotors
- loads up to 500lb and large reach

Applications

- pick and place type operations
- palletizing
- machine loading

Continuous path control

Continuous Path:

- It is an extension of the point-to-point method. this involves the utilization of more points and its path can be arc, a circle, or a straight line.
- Because of the large number of points, the robot is capable of producing smooth movements that give the appearance of continuous or contour movement.
- In addition to the control over the endpoints, the path taken by the end effector can be controlled
- Path is controlled by manipulating the joints throughout the entire motion, via closed loop control.

Applications

- spray painting
- polishing
- grinding
- arc welding

CONTROLLED PATH

Controlled Path: It is a specialized control method that is a part of general category of a point-to-point robot but with more precise control.

- The controlled path robot ensures that the robot will describe the right segment between two taught points.
- Controlled-path is a calculated method and is desired when the manipulator must move in the perfect path motion.

UNIT II COMPONENTS & OPERATIONS

- Basic control system concepts - control system analysis - robot actuation and fed back, Manipulators – direct and inverse kinematics, Coordinate transformation - Brief Robot dynamics. Types of Robot and effectors -Grippers - Tools as end effectors - Robot/End - effort interface.

Basic control system concepts

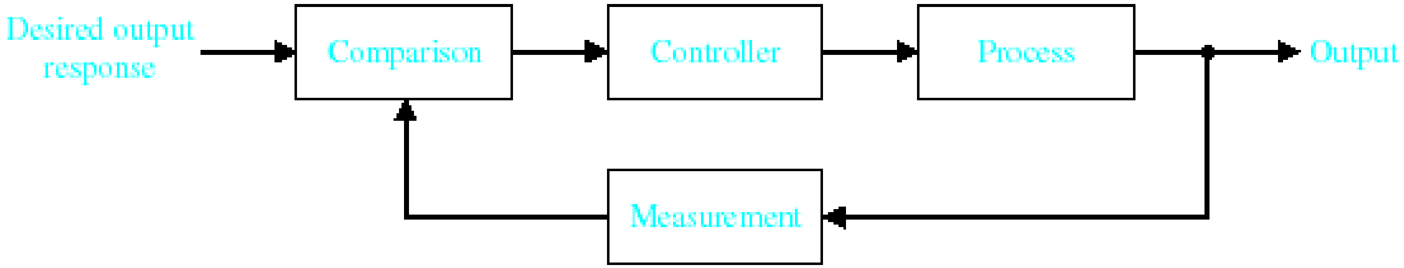
- **Open-Loop Control Systems**
- **Closed-Loop Control Systems**
- **Multivariable Control Systems**

OPEN-LOOP CONTROL SYSTEMS

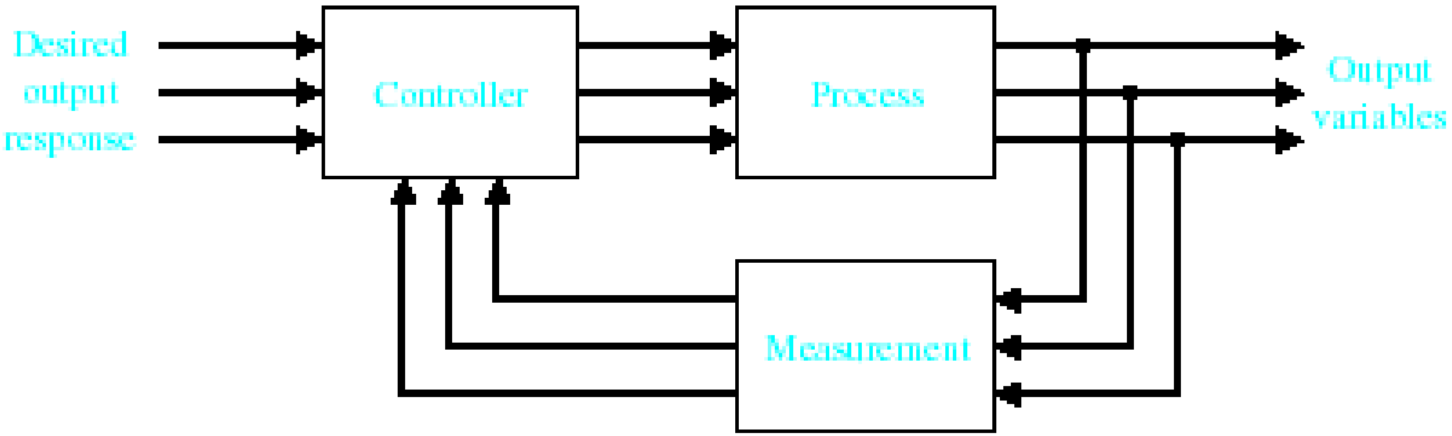
- **Open-Loop Control Systems** utilize a controller or control actuator to obtain the desired response.

Closed-Loop Control Systems

- **Closed-Loop Control Systems** utilizes feedback to compare the actual output to the desired output response



MULTIVARIABLE CONTROL SYSTEMS



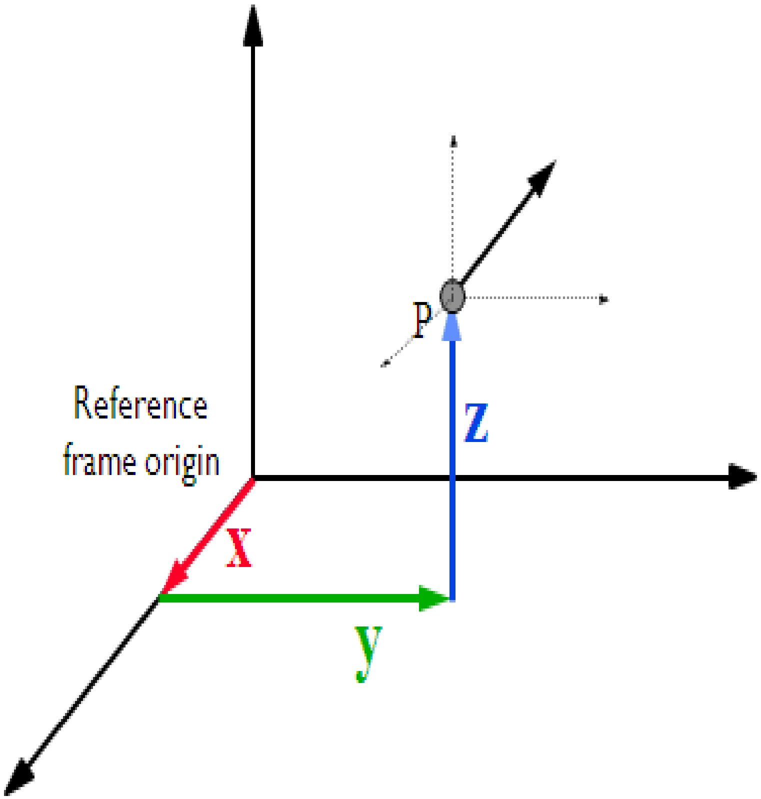
MANIPULATORS

- Manipulator consists of joints and links
  - Joints provide relative motion
  - Links are rigid members between joints
  - Various joint types: linear and rotary
  - Each joint provides a “degree-of-freedom”
  - Most robots possess five or six degrees-of-freedom

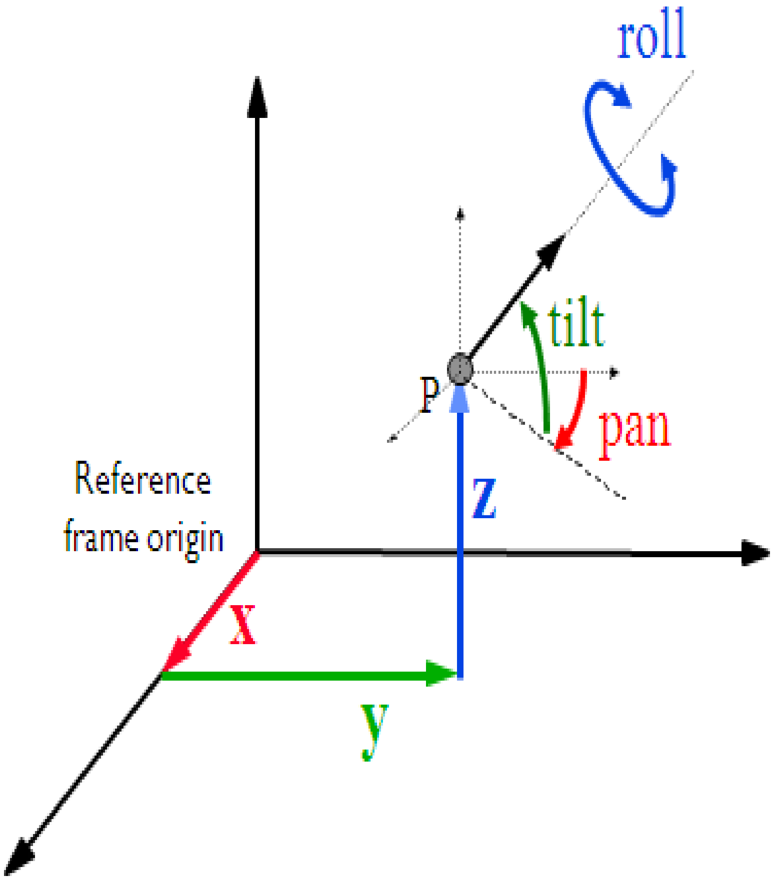
DEGREES OF FREEDOM

- Degree of Freedom is the number of independent relative motion in the form of translation and rotation
- The body in space has got the maximum of 6 degrees of motion(3 translatory & 3 rotary motions)
- Each Translatory has 1 DOF and each Rotary has 1 DOF

POSITIONING



ORIENTING



KINEMATICS

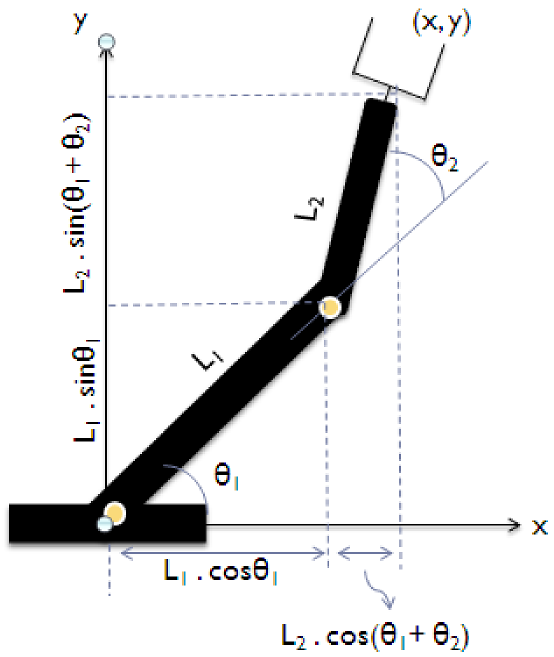
- It is the branch of dynamics which deals with the relative motion existing between members.

Forward Kinematics (angles to position)

- What you are given:
  - The length of each link
  - The angle of each joint
- What you can find:
  - The position of any point (i.e. it's (x, y, z) coordinates
- Forward Kinematics of 2 link manipulator

$$x = L_1 \cdot \cos\theta_1 + L_2 \cdot \cos(\theta_1 + \theta_2)$$

$$y = L_1 \cdot \sin\theta_1 + L_2 \cdot \sin(\theta_1 + \theta_2)$$



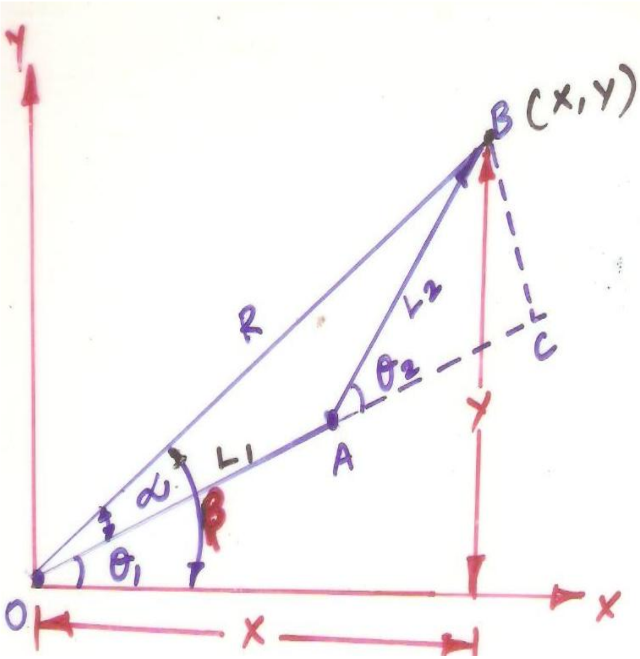
Inverse Kinematics (Position to Angles)

- What you are given:
  - The length of each link
  - The angle of each joint
- What you can find:
  - The angles of each joint needed to obtain that position
- Inverse kinematics of 2 link manipulator

$$BC = L_2 \sin\theta_2$$
$$AC = L_2 \cos\theta_2$$

$$\tan\alpha = \frac{L_2 \sin\theta_2}{L_1 + L_2\cos\theta_2} \quad (1)$$

$$\tan\beta = \frac{y}{x} \quad (2)$$



$$x = [L_1\cos\theta_1 + L_2\cos(\theta_1+\theta_2)] \quad - (3)$$
$$y = [L_1\sin\theta_1 + L_2\sin(\theta_1+\theta_2)] \quad - (4)$$

Squaring on both sides and adding

$$x^2 + y^2 = L_1^2 + L_2^2 + 2L_1L_2\cos\theta_2$$

or

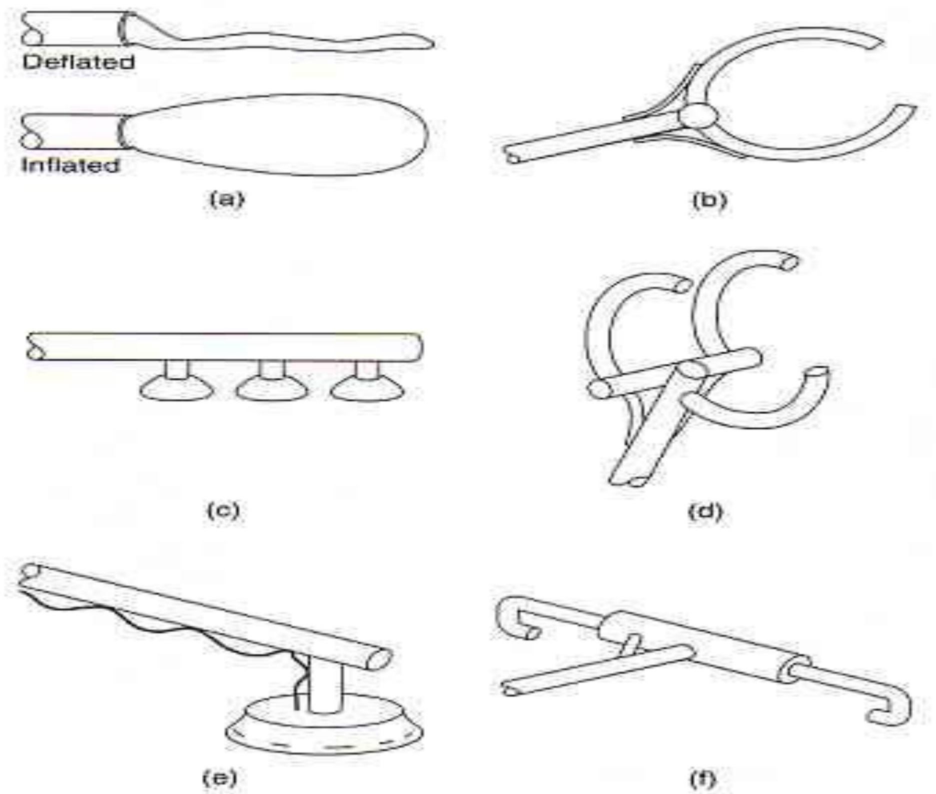
$$\boxed{\cos\theta_2 = \frac{x^2+y^2-L_1^2-L_2^2}{2L_1L_2}}$$

$$\beta - \alpha = \theta_1$$
$$\tan(\beta-\alpha) = \tan\theta_1$$
$$\frac{\tan\beta - \tan\alpha}{1+\tan\beta\tan\alpha} = \tan\theta_1$$

$$\tan\theta_1 = \frac{y[L_1+L_2\cos\theta_2] - xL_2\sin\theta_2}{x[L_1+L_2\cos\theta_2] + yL_2\sin\theta_2}$$

TYPES OF ROBOT END EFFECTORS

- Inflatable bladder
- Two-finger clamp
- Vaccum cups
- Three-fingers clamp
- Magnet head
- Tubing pickup device

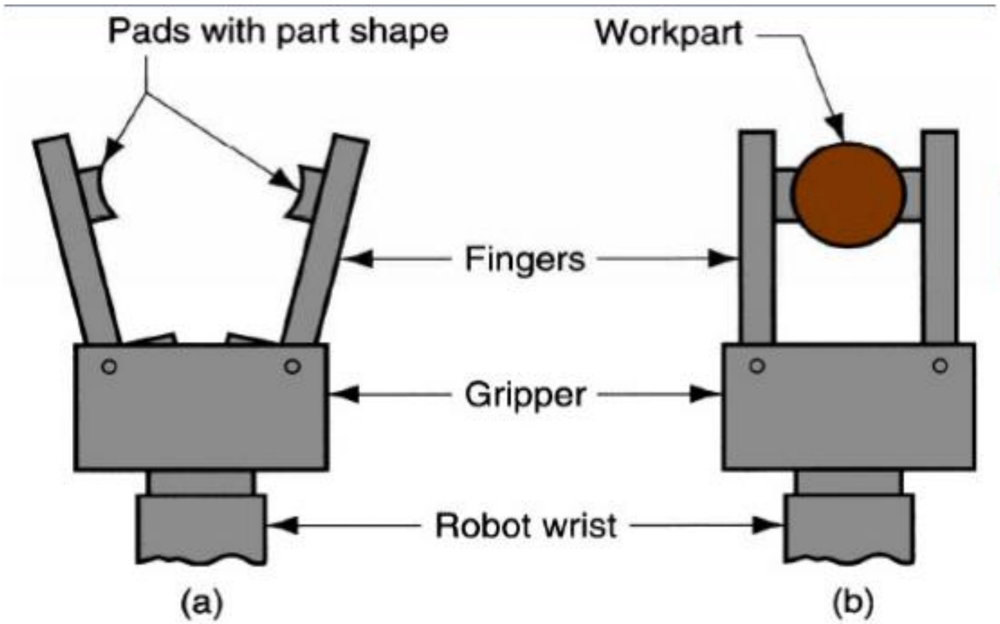


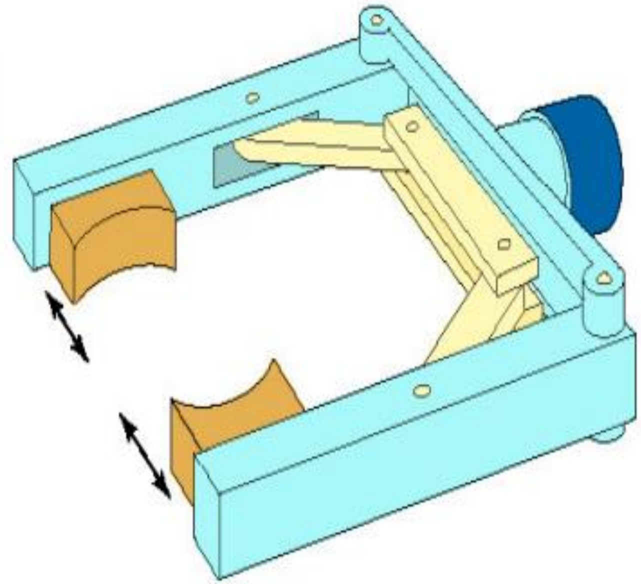
End-of-Arm-Tooling

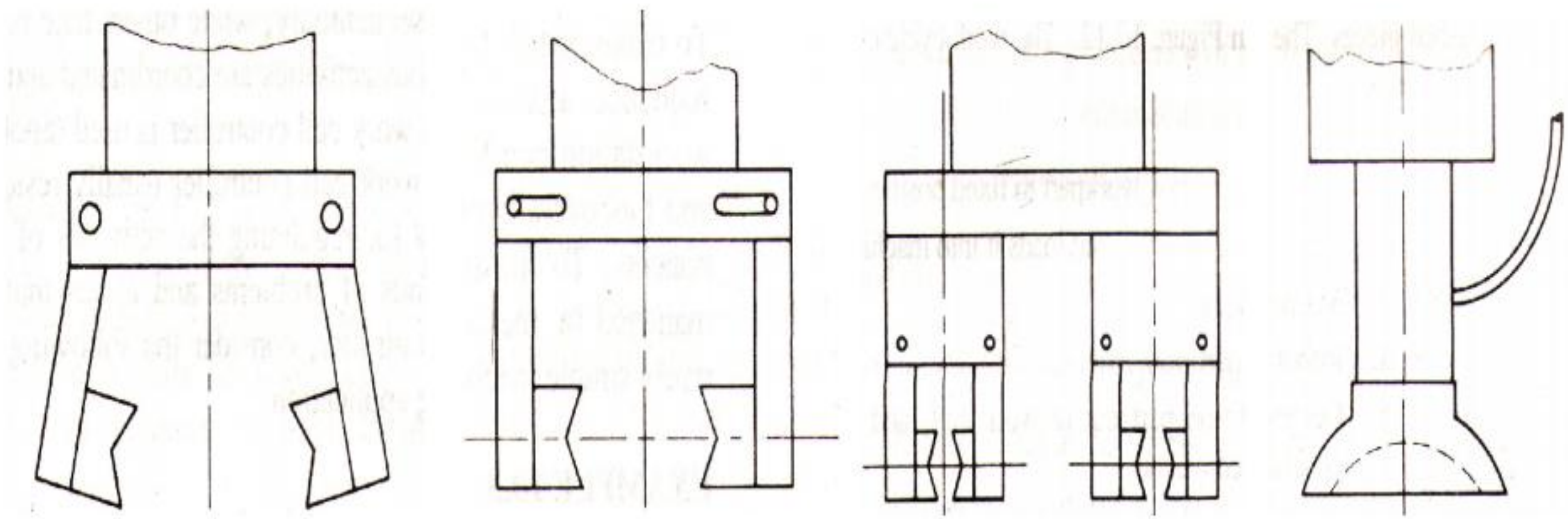
- This general class of devices is also called end-of-arm tooling (EOAT).
- Robot end-of-arm tooling is not limited to various kinds of gripping devices.
- Grippers not available by default in general-purpose robots
- In some situations, a robot must change its gripper during its task. If so, the robot's wrist must be fitted with a quick-disconnect device.

GRIPPERS

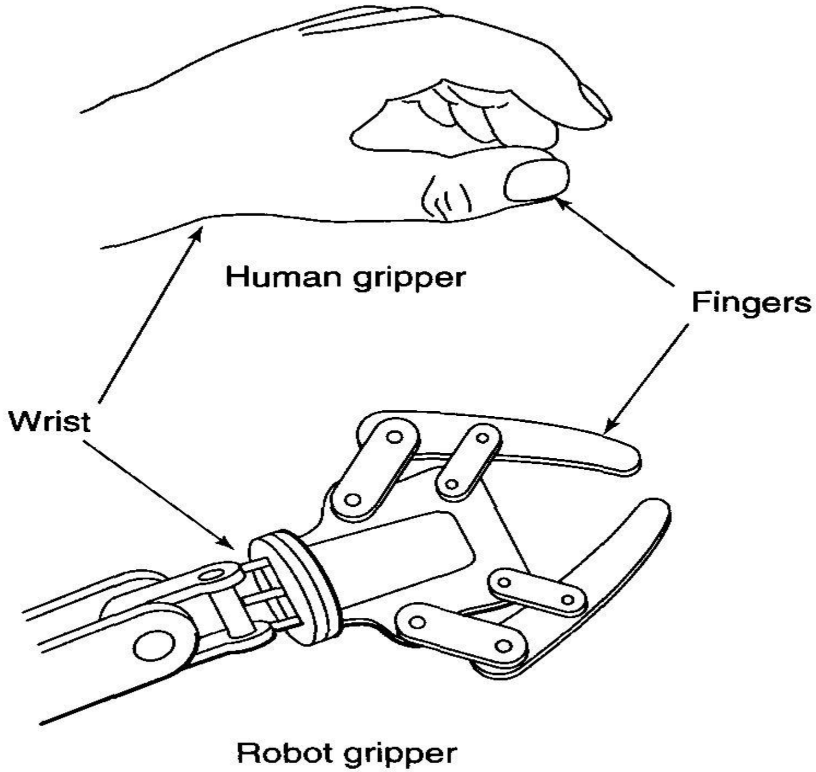
- Grippers are end effectors used to grasp and manipulate objects.
- Just like a hand, a gripper enables holding, tightening, handling and releasing of an object.
- A gripper can be attached to a robot or it can be part of a fixed automation system


Pads with part shape
Workpart
Fingers
Gripper
Robot wrist
(a)
(b)

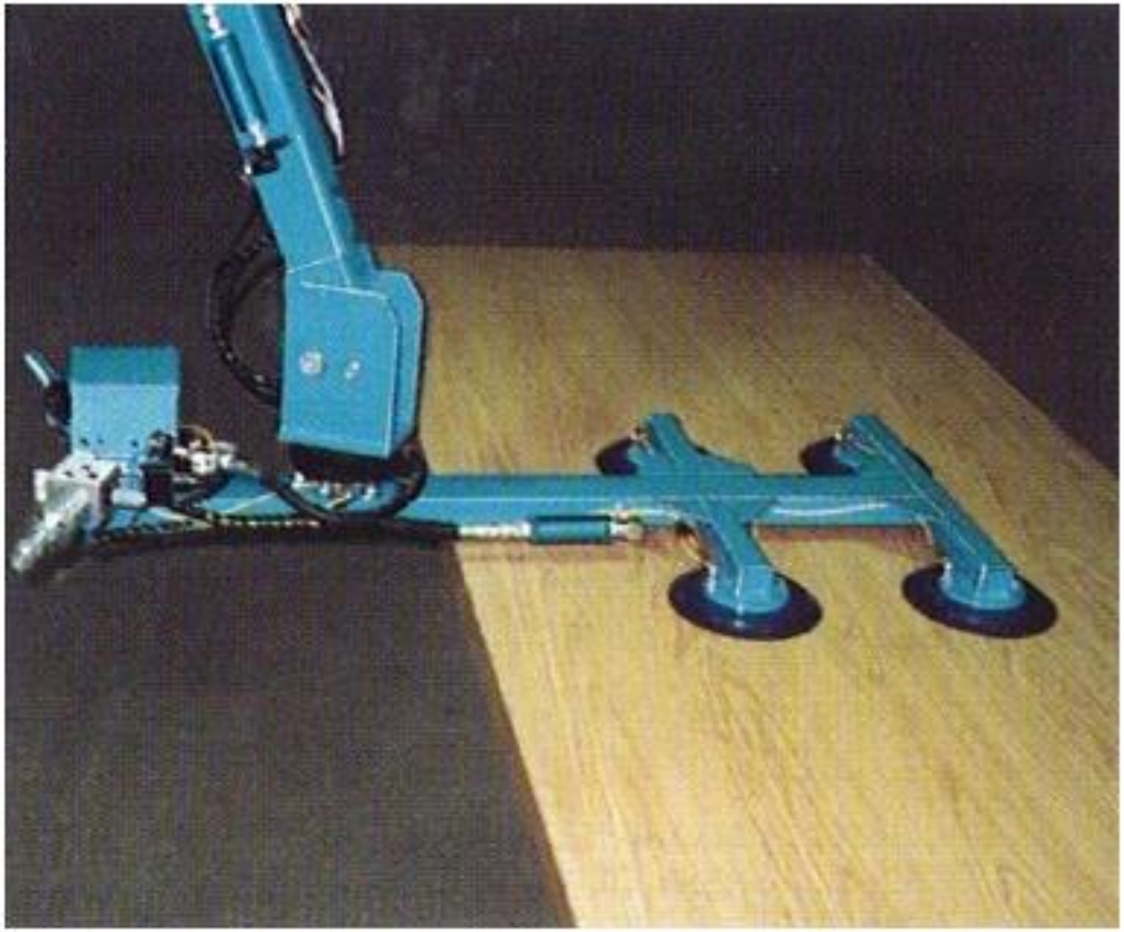




Mechanical Gripper



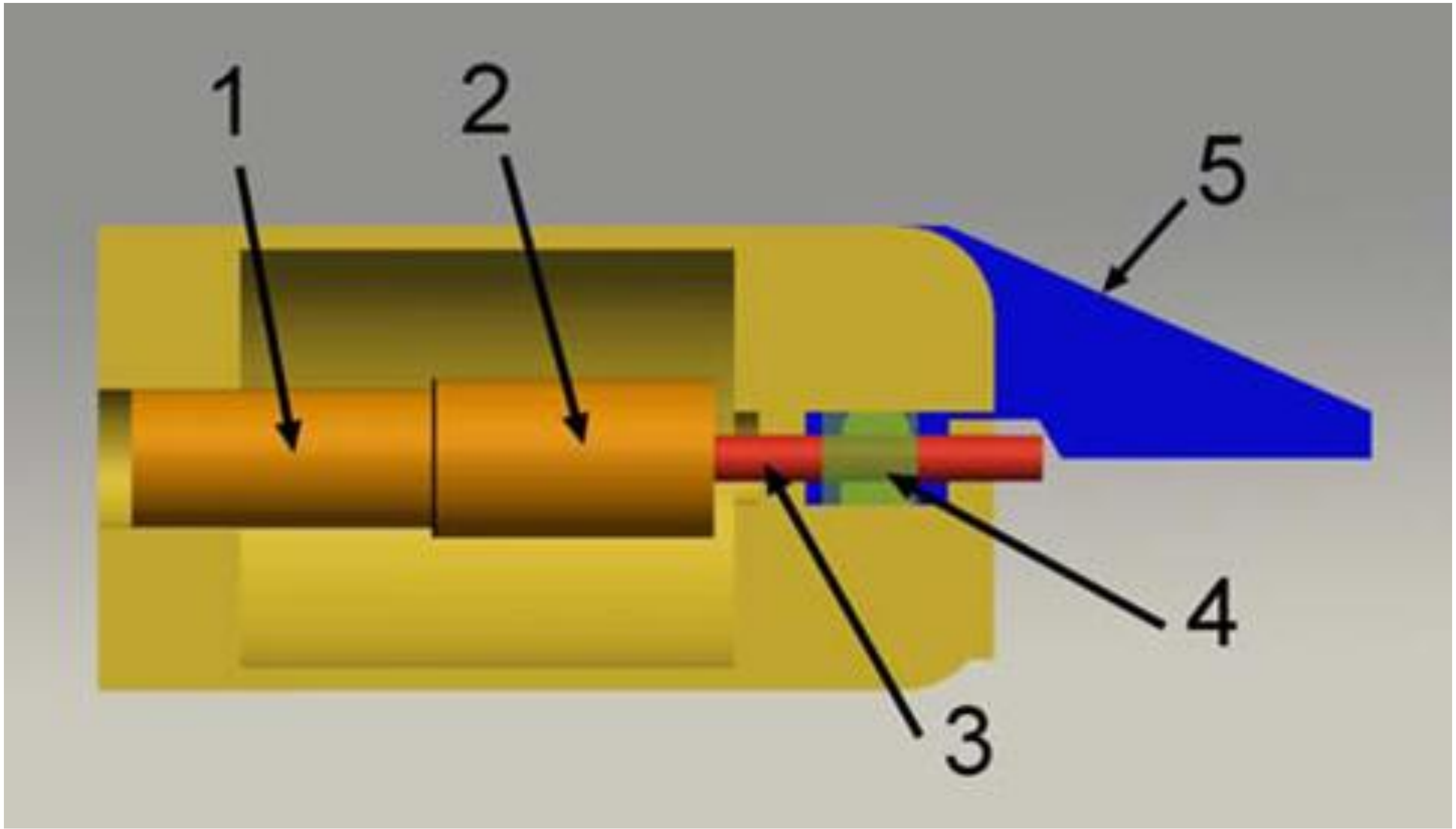
Vacuum Gripper



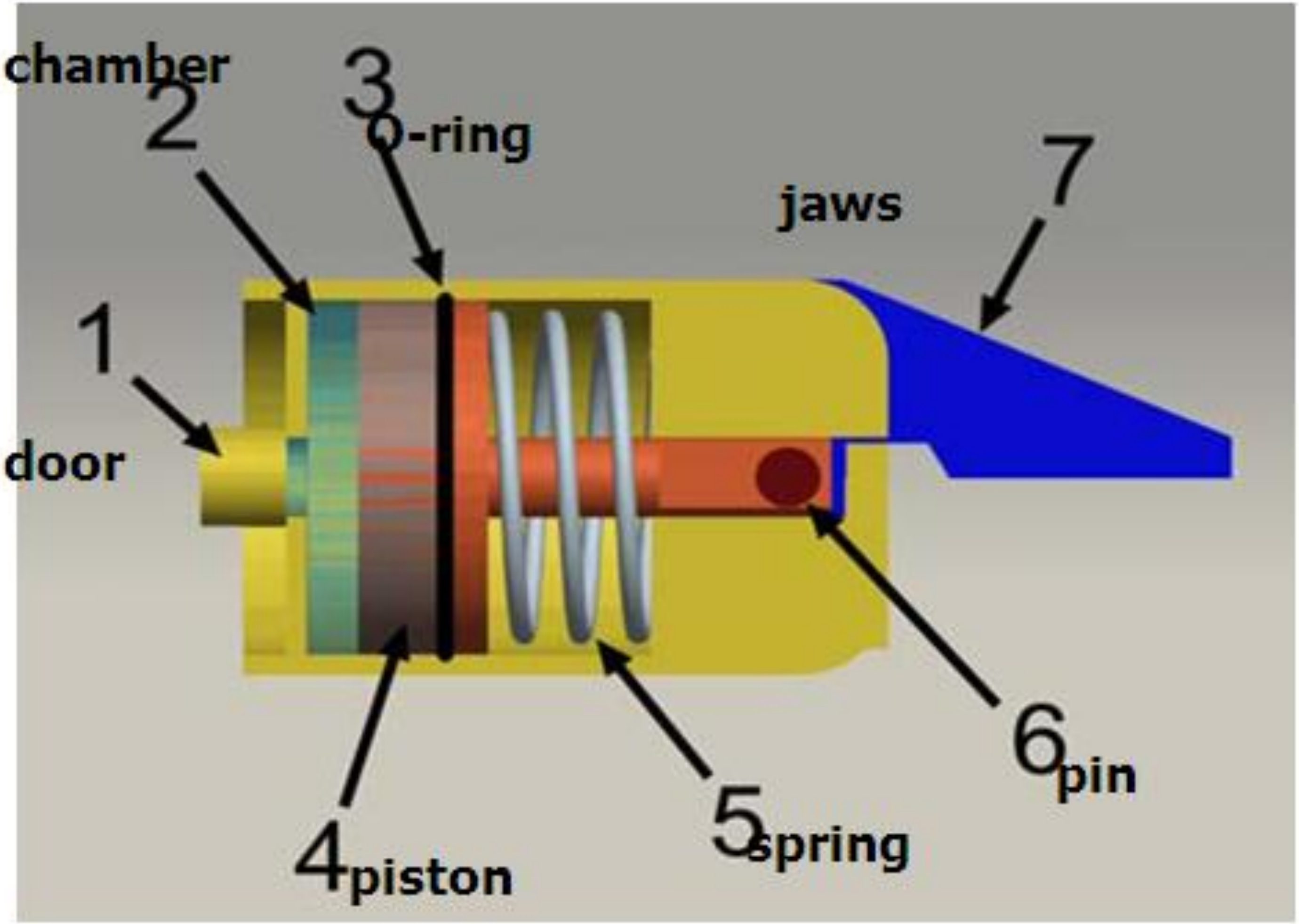
Gripper Actuation

- Manual: Actuated by hand crank, wheel, levers, or other manual or mechanical means.
- Electric: Grippers fingers or jaws actuated by electric motor, solenoid, etc.
- Pneumatic: Gripper is actuated by compressed air acting on a cylinder or vanes.
- Hydraulic: Gripper is actuated by hydraulic fluid acting on a cylinder or vanes.

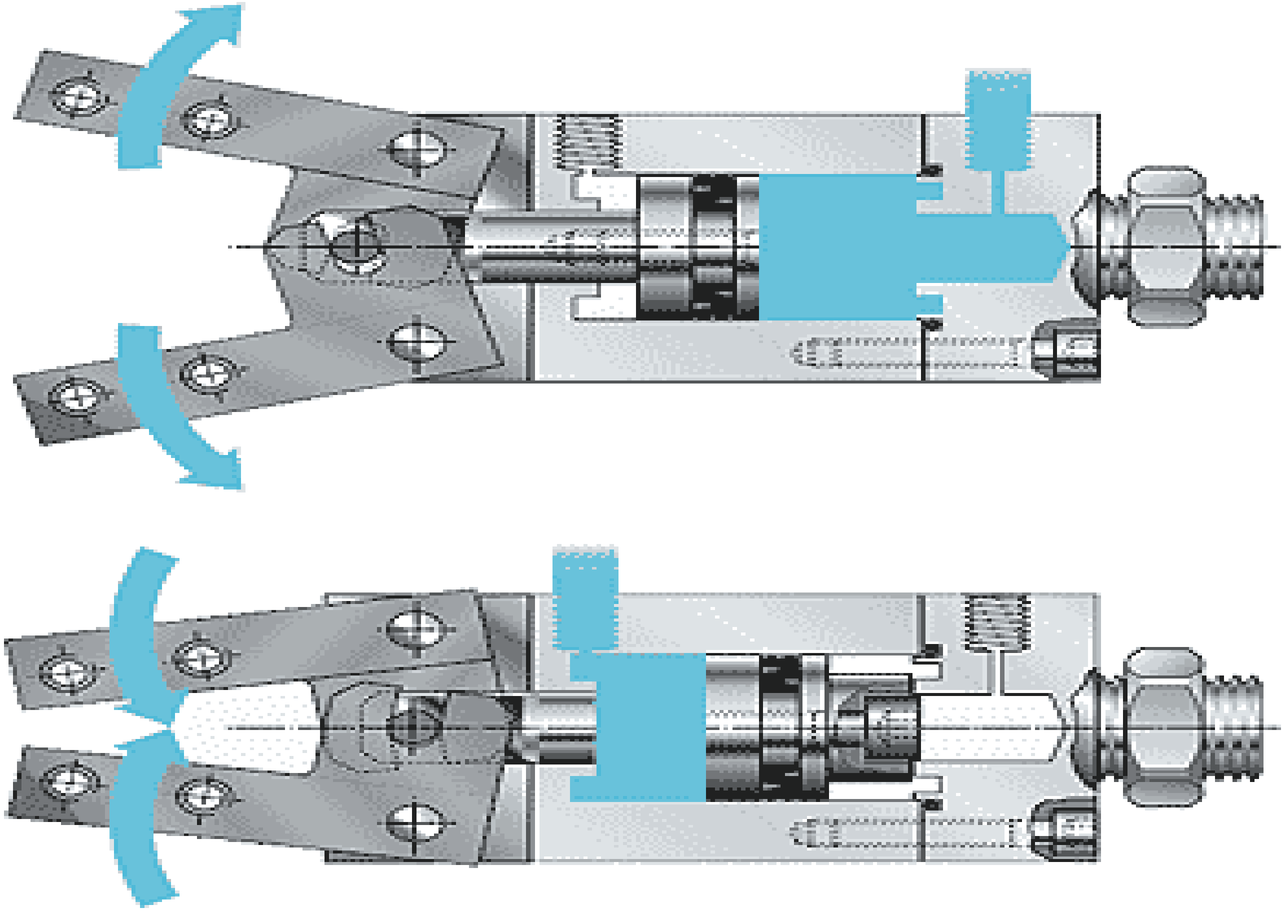
Electric gripper



Hydraulic Gripper



PNEUMATIC GRIPPER



REQUIREMENTS FOR AN EFFECTIVE GRIPPER

- Parts or items must be grasped and held without damage
- Parts must be positioned firmly or rigidly while being operated on.
- Hands or grippers must accommodate parts of differing sizes or even of varying sizes
- Self-aligning jaws are required to ensure that the load stays centered in the jaws
- Grippers or end effectors must not damage the part being handled.
- Jaws or grippers must make contact at a minimum of two points to ensure that the part doesn’t rotate while being positioned.

UNIT III SENSING AND MACHINE VISION

- Range sensing - Proximity sensing - Touch sensing - Force and Torque sensing. Introduction to Machine vision - Sensing and digitizing - Image processing and analysis.

Sensor

- Sensor is a basic component of transducer.
- The purpose of a sensor is to respond to some kind of an input physical property and to convert it into an electrical signal which is compatible with electronic circuits.
- The sensor output signal may be in the form of voltage, current, or charge .

SENSOR TYPES

A. Based on power requirement:

1. **Active**: require external power, called excitation signal, for the operation
2. **Passive**: directly generate electrical signal in response to the external stimulus

B. Based on sensor placement:

1. Contact sensors
2. Non-contact sensors

Why do Robots need sensors?

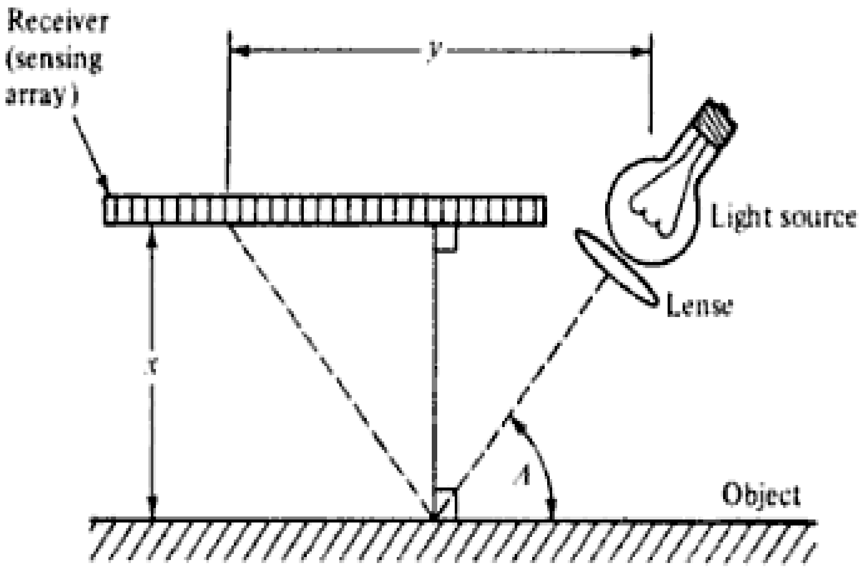
- Provides “awareness” of surroundings
  - What’s ahead, around, “out there”?
- Allows interaction with environment
  - Robot lawn mower can “see” cut grass
- Protection & Self-Preservation
  - Safety, Damage Prevention, Stairwell sensor
- Gives the robot capability to goal-seek
  - Find colorful objects, seek goals
- Makes robots “interesting”

What can be sensed?

- Light
  - Presence, color, intensity, content (mod), direction
- Sound
  - Presence, frequency, intensity, content (mod), direction
- Heat
  - Temperature, wavelength, magnitude, direction
- Chemicals
  - Presence, concentration, identity, etc.
- Object Proximity
  - Presence/absence, distance, bearing, color, etc.
- Physical orientation/attitude/position
  - Magnitude, pitch, roll, yaw, coordinates, etc.
- Magnetic & Electric Fields
  - Presence, magnitude, orientation, content (mod)
- Resistance (electrical, indirectly via V/I)
  - Presence, magnitude, etc.
- Capacitance (via excitation/oscillation)
  - Presence, magnitude, etc.
- Inductance (via excitation/oscillation)
  - Presence, magnitude, etc.

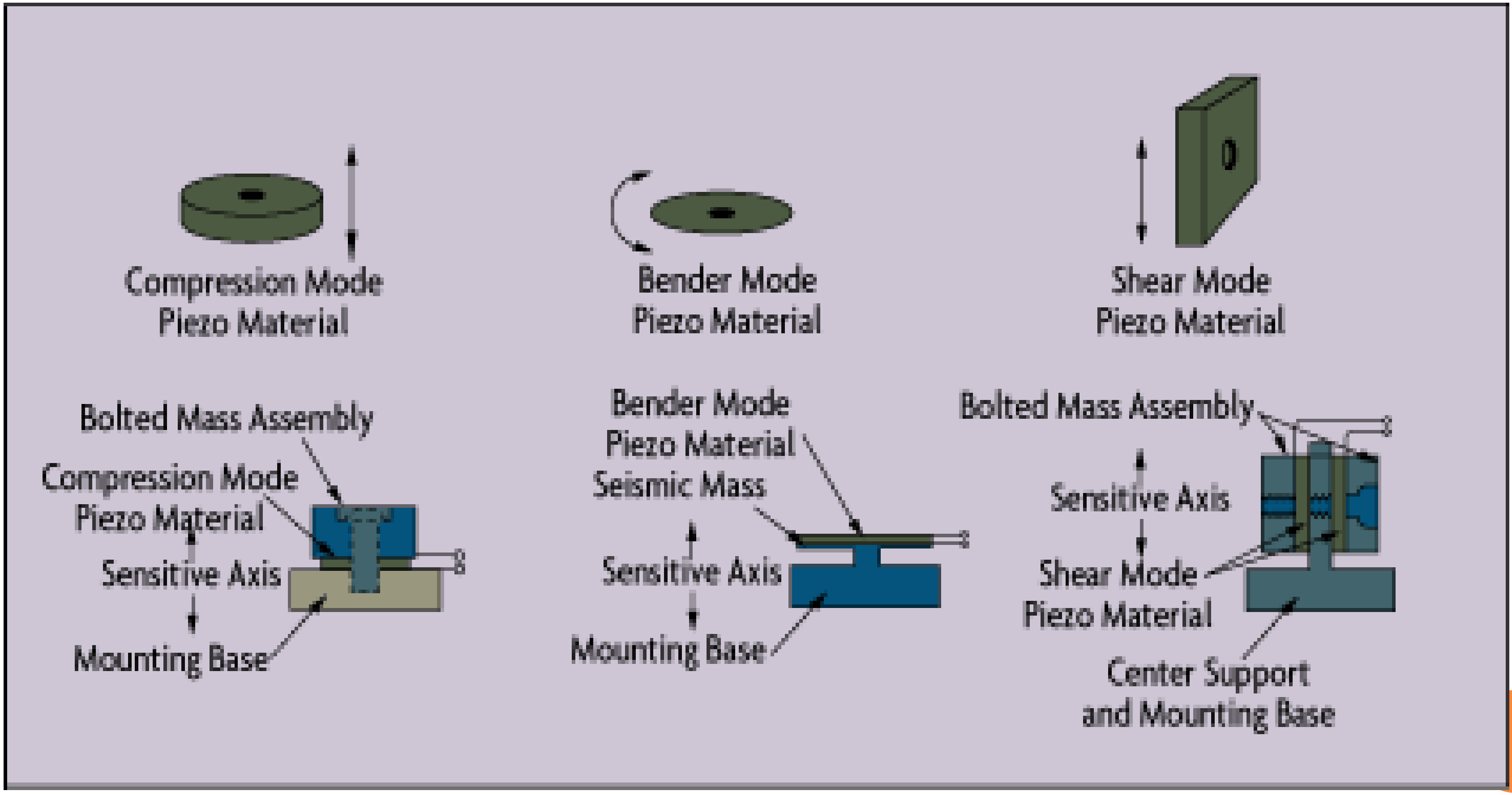
PROXIMITY SENSOR

- Proximity sensors are devices that indicate when one object is close to another object.
- The distances can be several millimeters and feet.
- Widely used in general industrial automation
- – Conveyor lines (counting, jam detection, etc)
- – Machine tools (safety interlock, sequencing)
- Usually digital (on/off) sensors detecting the presence or absence of an object



Force Sensor

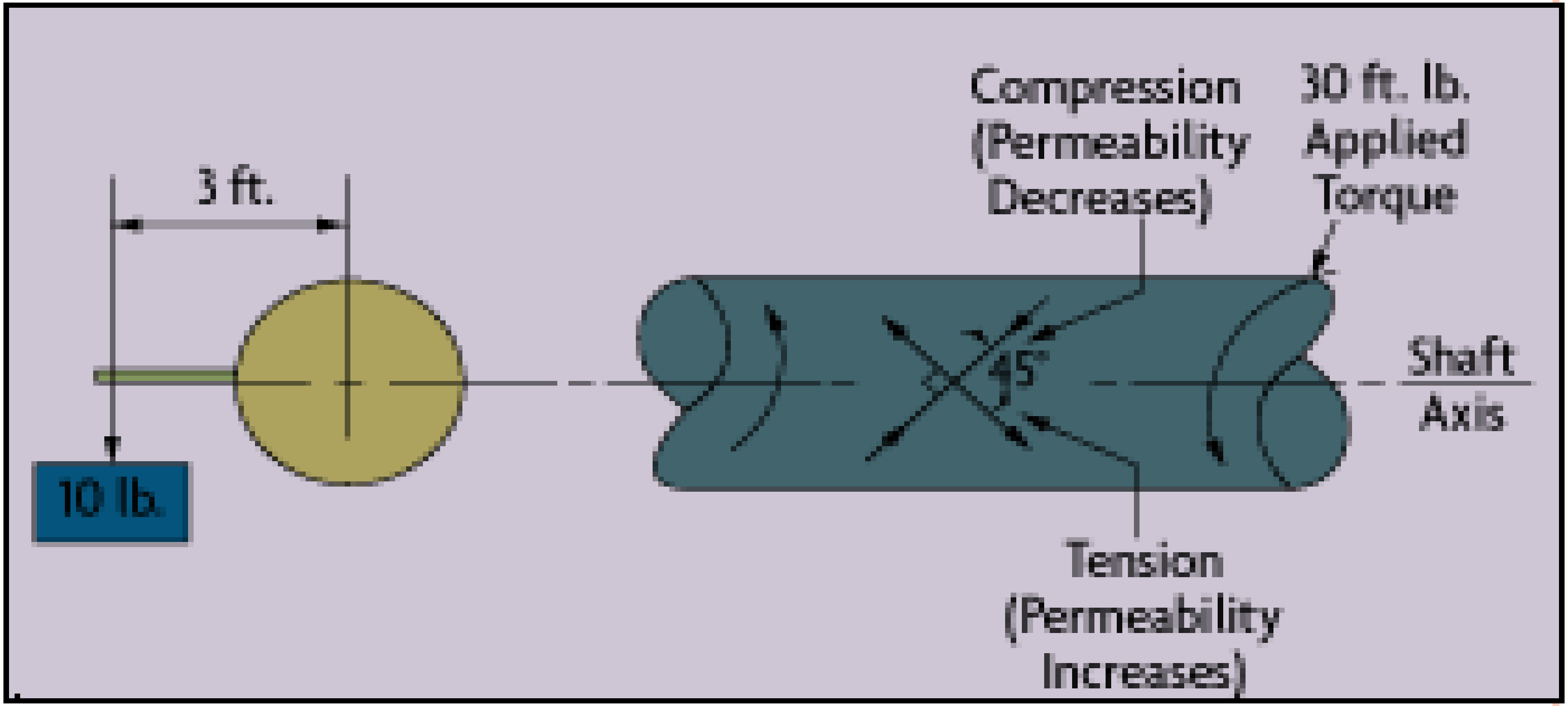
- The fundamental operating principles of force, acceleration, and torque instrumentation are closely allied to the piezoelectric and strain gage devices used to measure static and dynamic pressures.
- Piezoelectric sensor produces a voltage when it is "squeezed" by a force that is proportional to the force applied.
- Difference between these devices and static force detection devices such as strain gages is that the electrical signal generated by the crystal decays rapidly after the application of force.
- The high impedance electrical signal generated by the piezoelectric crystal is converted to a low impedance signal suitable for such an instrument as a digital storage oscilloscope.
- Depending on the application requirements, dynamic force can be measured as either compression, tensile, or torque force.
- Applications may include the measurement of spring or sliding friction forces, chain tensions, clutch release forces.



Compression Mode
Piezo Material
Bender Mode
Piezo Material
Shear Mode
Piezo Material
Bolted Mass Assembly
Compression Mode
Piezo Material
Sensitive Axis
Mounting Base
Bender Mode
Piezo Material
Seismic Mass
Sensitive Axis
Mounting Base
Bolted Mass Assembly
Sensitive Axis
Shear Mode
Piezo Material
Center Support
and Mounting Base

TORQUE SENSORS

- Torque is measured by either sensing the actual shaft deflection caused by a twisting force, or by detecting the effects of this deflection.
- The surface of a shaft under torque will experience compression and tension, as shown in Figure.
- To measure torque, strain gage elements usually are mounted in pairs on the shaft, one gauge measuring the increase in length (in the direction in which the surface is under tension), the other measuring the decrease in length in the other direction.



3 ft.
10 lb.
Compression
(Permeability
Decreases)
30 ft. lb.
Applied
Torque
45°
Shaft
Axis
Tension
(Permeability
Increases)

Tactile Sensor

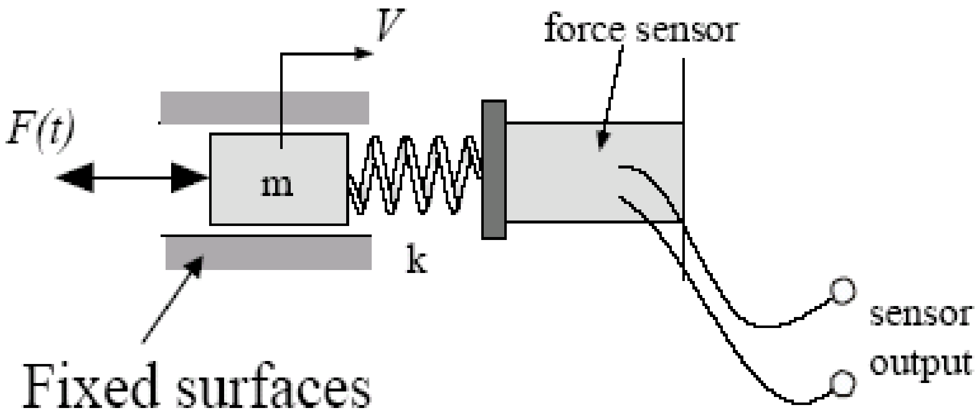
- Tactile sensor are devices which measures the parameters of a contact between the sensor and an object.
- A tactile sensor consists of an array of touch sensitive sites, the sites may be capable of measuring more than one property.
- The contact forces measured by a sensor are able to convey a large amount of information about the state of a grip.
- Texture, slip, impact and other contact conditions generate force and position signatures, that can be used to identify the state of a manipulation.

Force/Torque Measurement

- Force and torque measurement finds application in many practical and experimental studies as well as in control applications.
- Force-motion causality. When measuring force, it can be critical to understand whether force is the input or output to the sensor.
- Design of a force sensors relies on deflection, so measurement of motion or displacement can be used to measure force, and in this way the two are intimately related.

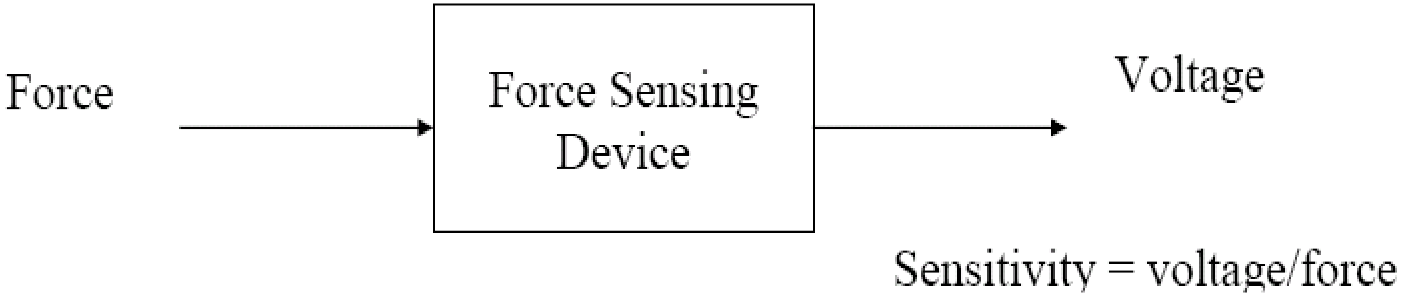
Design of a Force Sensor

- Consider a simple sensor that is to be developed to measure a reaction force at the base of a spring, as shown below.



Sensor Mechanisms for Force

- In the force sensor design given, no specific sensing mechanism was implied. The constraint placed on the stiffness exists for any type of force sensor.
- It is clear, however, that the force sensor will have to respond to a force and provide an output voltage. This can be done in different ways.



Sensing Mechanisms

- To measure force, it is usually necessary to design a mechanical structure that determines the stiffness. This structure may itself be a sensing material.
- Force will induce stress, leading to strain which can be

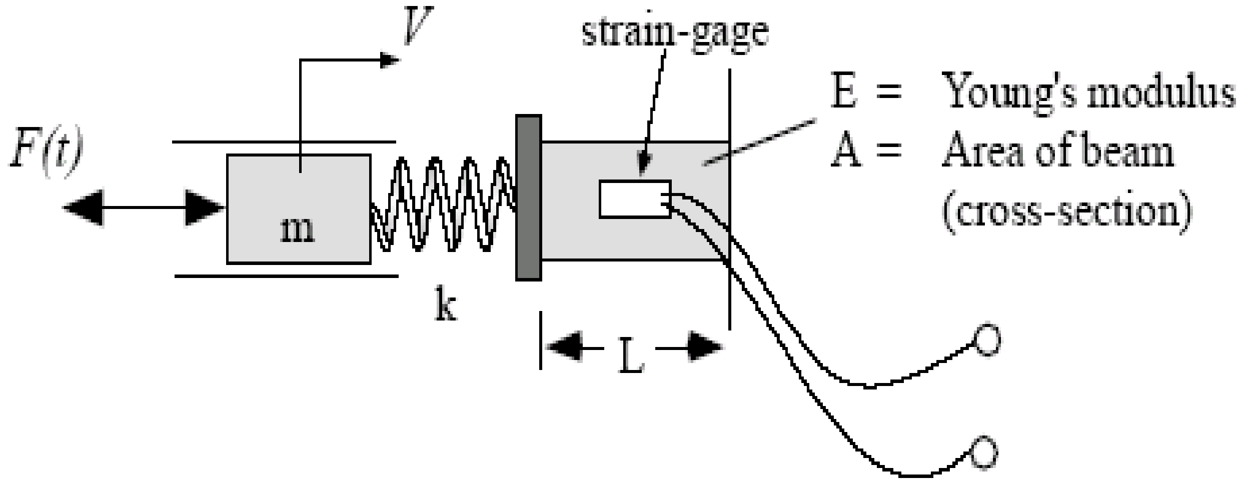
  detected, most commonly, by

  – strain gages (via piezoresistive effect)

  – some crystals or ceramics (via piezoelectric effect)
- Force can also be detected using a displacement sensor, such as an LVDT.

STRAIN-GAGE FORCE SENSOR DESIGN

- Let's consider now the force sensor studied earlier, and consider a design that will use one strain gage on an axially loaded material.



STRAIN GUAGES

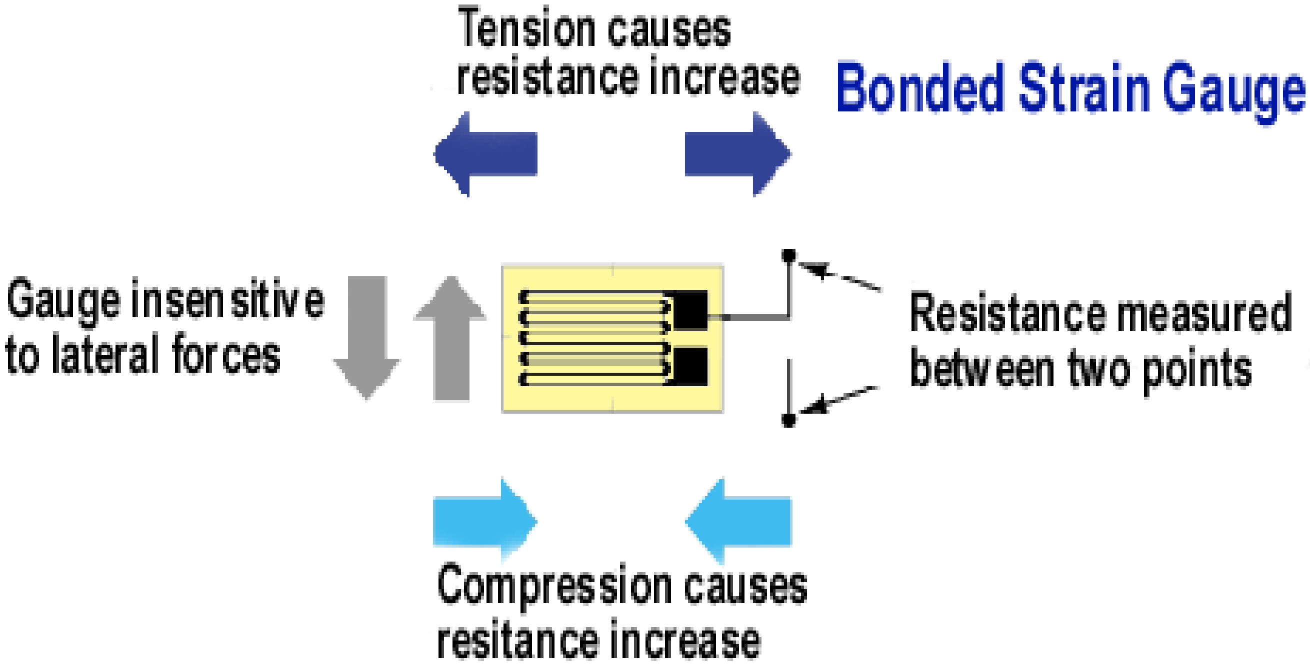
- Many types of force\torque sensors are based on strain gage measurements.
- The measurements can be directly related to stress and force and may be used to measure other types of variables including displacement and acceleration

WHAT'S A STRAIN GAUGE?

- The electrical resistance of a length of wire varies in direct proportion to the change in any strain applied to it. That's the principle upon which the strain gauge works.
- The most accurate way to measure this change in resistance is by using the wheatstone bridge.
- The majority of strain gauges are foil types, available in a wide choice of shapes and sizes to suit a variety of applications.
- They consist of a pattern of resistive foil which is mounted on a backing material.

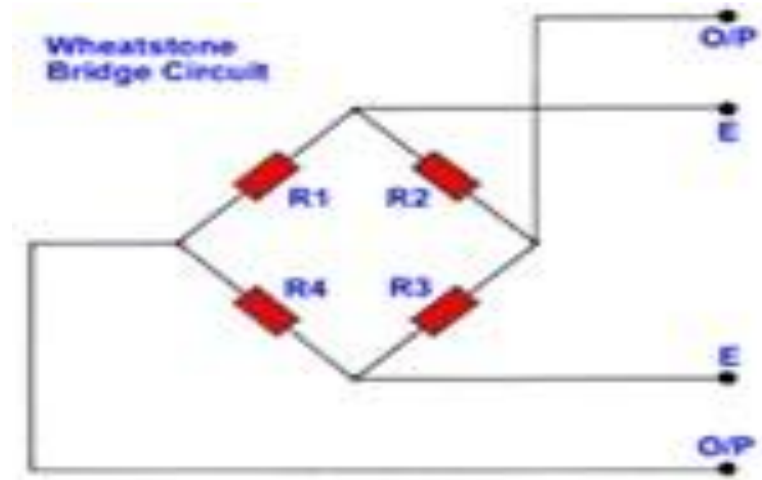
STRAIN GAUGE CONTD..

- They operate on the principle that as the foil is subjected to stress, the resistance of the foil changes in a defined way.



STRAIN GAUGE CONFIGURATION

- The strain gauge is connected into a wheatstone Bridge circuit with a combination of four active gauges(full bridge),two guages (half bridge) or,less commonly, a single gauge (quarter bridge).



Output DC voltage

$$v_o = \left[\frac{R_1 R_4 - R_2 R_3}{(R_1 + R_2)(R_3 + R_4)} \right] \cdot V_s$$

GUAGE FACTOR

- A fundamental parameter of the strain guage is its sensitivity to strain, expressed quantitatively as the guage factor (GF).

- Guage factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain).

STRAIN GUAGE CONTD..

- The complete wheatstone brigde is excited with a stabilized DC supply.
- As stress is applied to the bonded strain guage, a resistive change takes place and unbalances the wheatstone bridge which results in signal output with respect to stress value.
- As the signal value is small the signal conditioning electronics provides amplification to increase the signal.

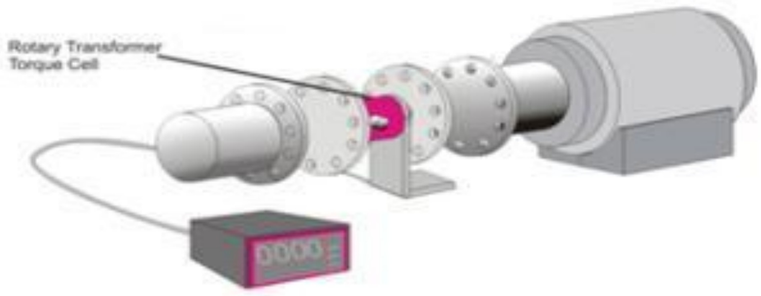
TORQUE SENSOR

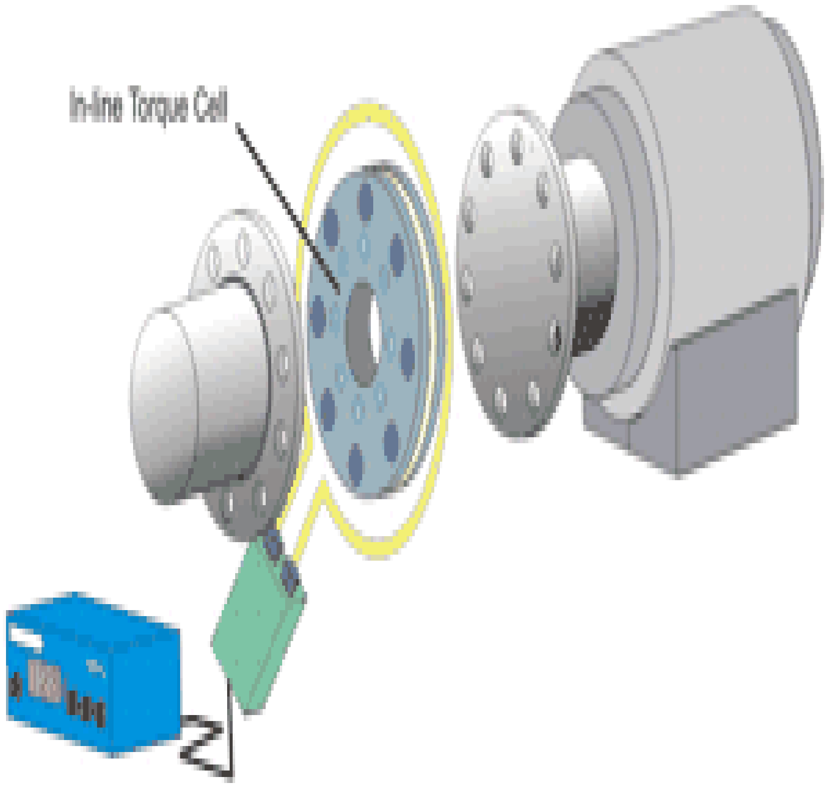
- Torque is a measure of the forces that causes an object to rotate.
- Reaction torque sensors measure static and dynamic torque with a stationary or non-rotating transducer.
- Rotary torque sensors use rotary transducers to measure torque.

TECHNOLOGY

- Magnetoelastic : A magnetoelastic torque sensor detects changes in permeability by measuring changes in its own magnetic field.
- Piezoelectric : A piezoelectric material is compressed and generates a charge, which is measured by a charge amplifier.
- Strain guage : To measure torque,strain guage elements usually are mounted in pairs on the shaft,one guage measuring the increase in length the other measuring the decrease in the other direction.

FIGURES SHOWING TORQUE SENSORS





TORQUE MEASUREMENT

- The need for torque measurements has led to several methods of acquiring reliable data from objects moving. A torque sensor, or transducer, converts torque into an electrical signal.
- The most common transducer is a strain guage that converts torque into a change in electrical resistance.
- The strain guage is bonded to a beam or structural member that deforms when a torque or force is applied.

TORQUE MEASUREMENT CONTD..

- Deflection induces a stress that changes its resistance. A wheatstone bridge converts the resistance change into a calibrated output signal.
- The design of a reaction torque cell seeks to eliminate side loading (bending) and axial loading, and is sensitive only to torque loading.
- The sensor's output is a function of force and distance, and is usually expressed in inch-pounds, foot-pounds or Newton-meters.

Classification of torque sensors

- Torques can be divided into two major categories, either static or dynamic.
- The methods used to measure torque can be further divided into two more categories, either reaction or in-line.
- A dynamic force involves acceleration, were a static force does not.

CLASSIFICATION OF TORQUE SENSORS CONTD..

- In reaction method the dynamic torque produced by an engine would be measured by placing an inline torque sensor between the crankshaft and the flywheel, avoiding the rotational inertia of the flywheel and any losses from the transmission.
- In-line torque measurements are made by inserting a torque sensor between torque carrying components, much like inserting an excitation between a socket and a socket wrench.

TECHNICAL OBSTACLES

- Getting power to the gages over the stationary/rotating gap and getting the signal back.

- The methods to bridge the gap are either contact or non-contact.

CONTACT/NON-CONTACT METHODS

- Contact: slip rings are used in contact-type torque sensors to apply power to and retrive the signal from strain gages mounted on the rotating shaft.

- Non-contact: the rotary transformer couples the strain gages for power and signal return. The rotary transformer works on the same principle as any conventional transformer except either the primary or secondary coils rotate.

APPLICATIONS OF FORCE/TORQUE SENSORS

- In robotic tactile and manufacturing applications
- In control systems when motion feedback is employed.
- In process testing, monitoring and diagnostics applications.
- In measurement of power transmitted through a rotating device.
- In controlling complex non-linear mechanical systems.

Tactile sensors

- Tactile and touch sensor are devices which measures the parameters of a contact between the sensor and an object.
- Def: This is the detection and measurement of the spatial distribution of forces perpendicular to a predetermined sensory area, and the subsequent interpretation of the spatial information.
- used to sense a diverse range of stimulus ranging from detecting the presence or absence of a grasped object to a complete tactile image.

TACTILE SENSORS CONTD...

- A tactile sensor consists of an array of touch sensitive sites, the sites may be capable of measuring more than one property.
- The contact forces measured by a sensor are able to convey a large amount of information about the state of a grip.
- Texture, slip, impact and other contact conditions generate force and position signatures, that can be used to identify the state of a manipulation.
- This information can be determined by examination of the frequency domain .

DESIRABLE CHARACTERISTICS OF A TACTILE SENSOR

- A touch sensor should ideally be a single-point contact, though the sensory area can be any size. In practice, an area of 1-2 mm2 is considered a satisfactory.
- The sensitivity of the touch sensor is dependent on a number of variables determined by the sensor's basic physical characteristic.
- A sensitivity within the range 0.4 to 10N, is considered satisfactory for most industrial applications.
- A minimum sensor bandwidth is of 100 Hz.

- The sensor’s characteristics must be stable and repeatable with low hysteresis. A linear response is not absolutely necessary, as information processing techniques can be used to compensate for any moderate non-linearities.
- As the touch sensor will be used in an industrial application, it will need to be robust and protected from environmental damage.
- If a tactile array is being considered, the majority of application can be undertaken by an array 10-20 sensors square, with a spatial resolution of 1-2 mm.

TACTILE SENSOR TECHNOLOGY

- Many physical principles have been exploited in the development of tactile sensors. As the technologies involved are very diverse, in most cases, the developments in tactile sensing technologies are application driven.
- Conventional sensors can be modified to operate with non-rigid materials.

- Mechanically based sensors
- Resistive based sensors
- Force sensing resistor

- Capacitive based sensors
- Magnetic based sensor
- Optical Sensors
- Optical fibre based sensors
- Piezoelectric sensors
- Strain gauges in tactile sensors
- Silicon based sensors
- Multi-stimuli Touch Sensors

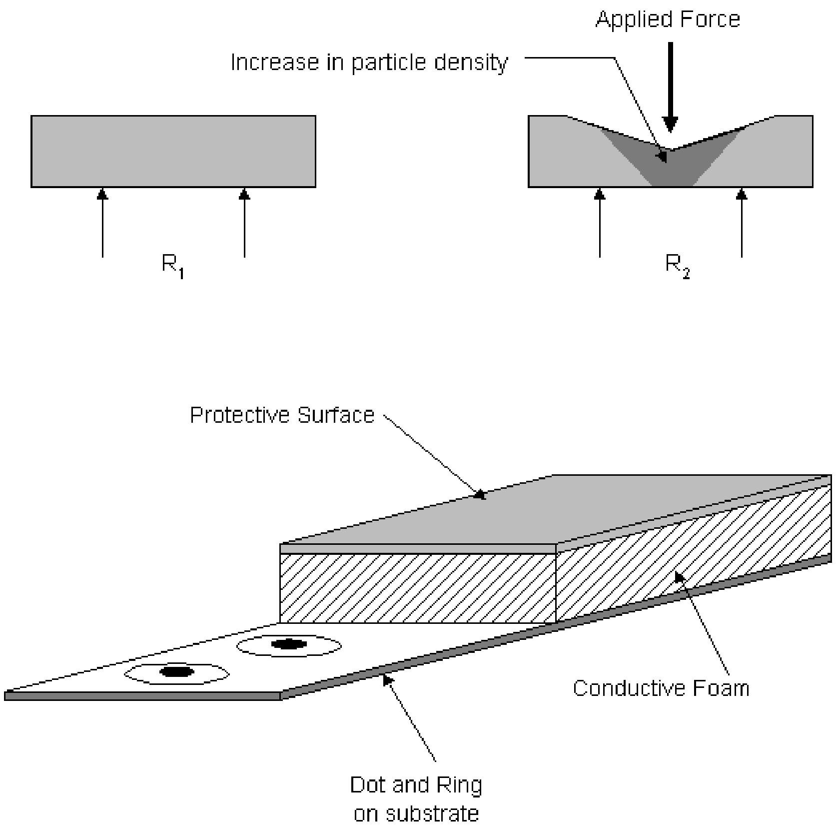
MECHANICALLY BASED SENSORS

- The simplest form of touch sensor is one where the applied force is applied to a conventional mechanical micro-switch to form a binary touch sensor.
- The force required to operate the switch will be determined by its actuating characteristics and any external constraints.
- Other approaches are based on a mechanical movement activating a secondary device such as a potentiometer or displacement transducer.

RESISTIVE BASED SENSORS

- The majority of industrial analogue touch or tactile sensors that have been used are based on the principle of resistive sensing. This is due to the simplicity of their design and interface to the robotic system.
- The use of compliant materials that have a defined force-resistance characteristics have received considerable attention in touch and tactile sensor research.
- The basic principle of this type of sensor is the measurement of the resistance of a conductive elastomer or foam between two points.
- The majority of the sensors use an elastomer that consists of a carbon doped rubber.

- In adjacent sensor the resistance of the elastomer changes with the application of force, resulting from the deformation of the elastomer altering the particle density.



RESISTIVE SENSORS CONTD..

- If the resistance measurement is taken between opposing surfaces of the elastomer, the upper contacts have to be made using a flexible printed circuit to allow movement under the applied force.
- Measurement from one side can easily be achieved by using a dot-and-ring arrangement on the substrate.
- Resistive sensors have also been developed using elastomer cords laid in a grid pattern, with the resistance measurements being taken at the points of intersection.
- Arrays with 256-elements have been constructed. This type of sensor easily allows the construction of a tactile image of good resolution.

DISADVANTAGES OF THE CONDUCTIVE ELASTOMER OR FOAM BASED SENSOR :

- An elastomer has a long nonlinear time constant. In addition the time constant of the elastomer, when force is applied, is different from the time constant when the applied force is removed.
- The force-resistance characteristic of elastomer based sensors are highly nonlinear, requiring the use of signal processing algorithms.
- Due to the cyclic application of forces experience by a tactile sensor, the resistive medium within the elastomer will migrates over a period of time.
- Additionally, the elastomer will become permanently deformed and fatigue leading to permanent deformation of the sensor. This will give the sensor a poor long-term stability and will require replacement after an extended period of use.

Machine Vision

- It is the process of applying a range of technologies and methods to provide imaging-based automatic inspection, process control and robot guidance in industrial applications.
- The primary uses for machine vision are automatic inspection and robot guidance. Common MV applications include quality assurance, sorting, material handling, robot guidance, and optical gauging.
- creates a model of the real world from images

recovers useful information about a scene from its two dimensional projections

STAGES OF MACHINE VISION:

Image Acquisition	*Analog to digital conversion*
Image Processing	*Remove noise, improve contrast…*
Image Segmentation	*Find regions (objects) in the image*
Image Analysis	*Take measurements of objects/relationships*
Pattern Recognition	*Match the description with similar description of known objects (models)*

Image formation

- Perspective Projection
- Orthographic projection

Image Processing

- Filtering, Smoothing, Thinning , Expending ,Shrinking ,Compressing

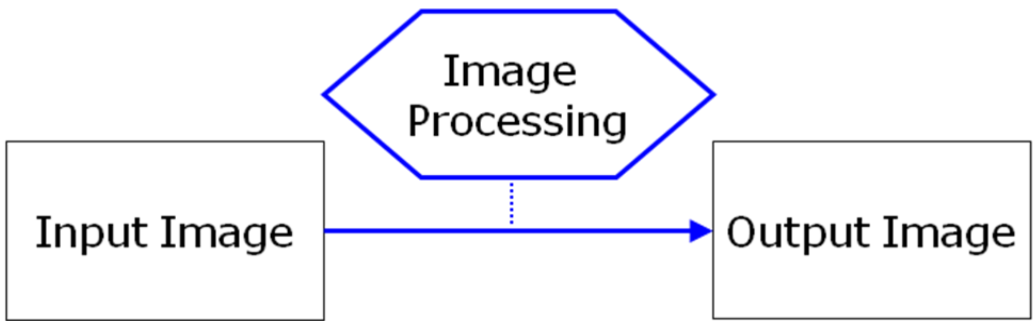


Image Segmentation

- Classify pixels into groups having similar characteristics

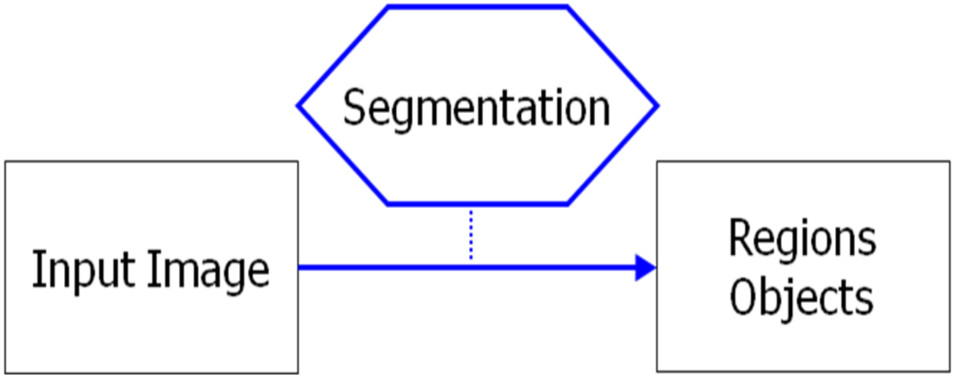
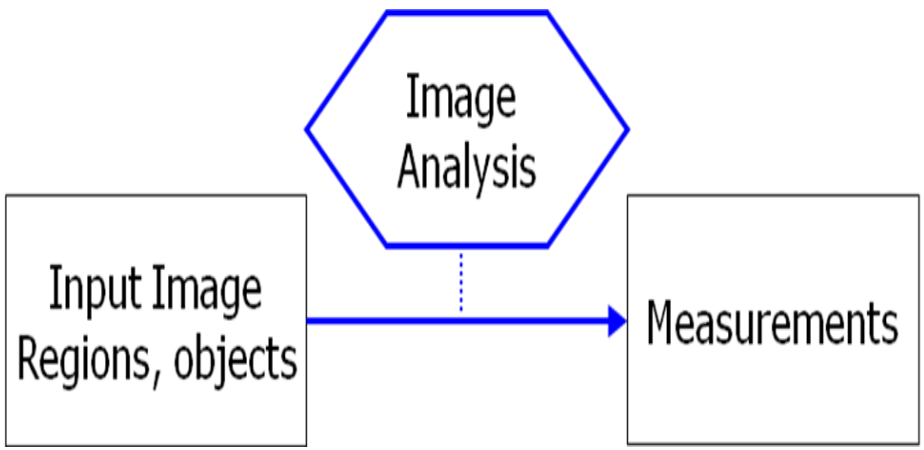


IMAGE ANALYSIS

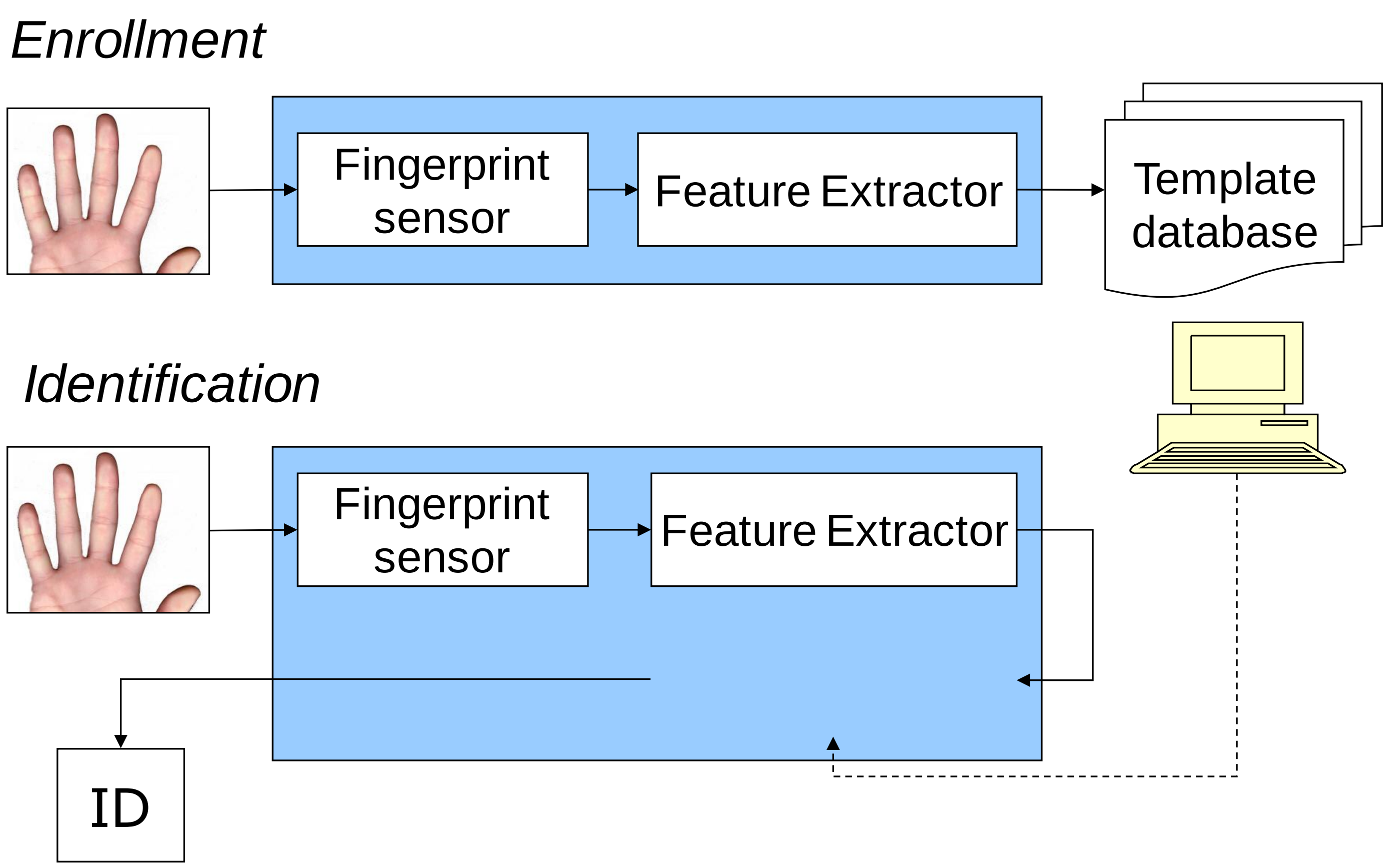
- Measurements: Size, Position, Orientation, Spatial relationship, Gray scale or color intensity

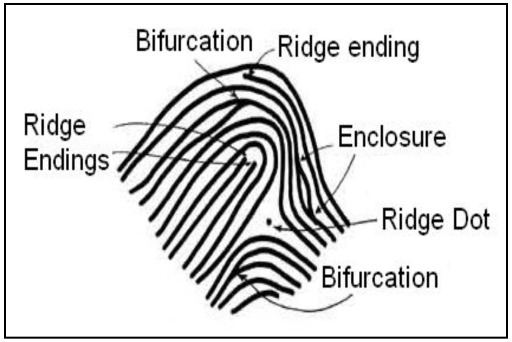


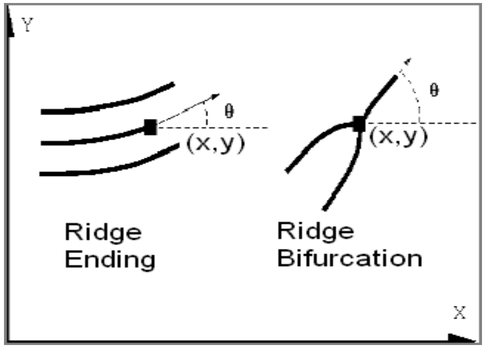
SENSING AND DIGITIZING

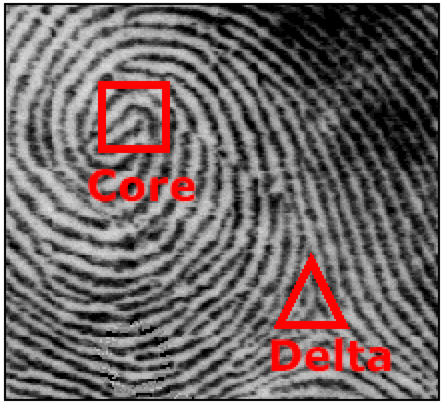
- Image sensing requires some type of image formation device such as camera and a digitizer which stores a video frame in the computer memory. We divide the sensing and digitizing into several steps. The initial step involves capturing the image of the scene with the vision camera. The image consists of relative light intensities corresponding to the various portions of the scene. These light intensities are continuous analog values which must be sampled and converted into digital form.
- The second step of digitixing is achieved by an analog –to –digital converter. The A/D converter is either a part of a digital video camera or the front end of a frame grabber. The choice is dependent on the type of hardware system. The frame grabber, representing the third step is an image storage and computation device which stores a given pixel array.

Image processing and analysis

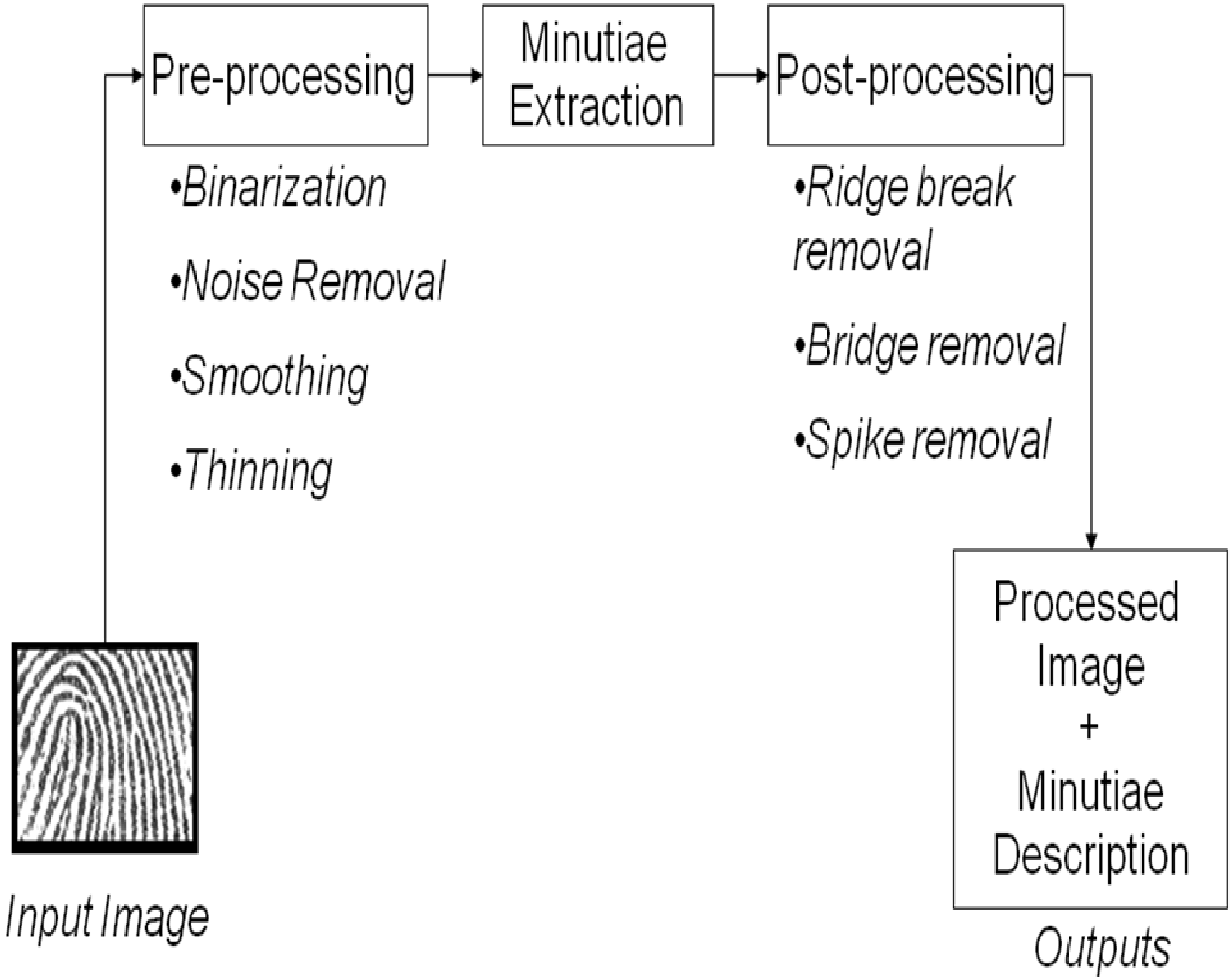








Arch Loop Whorl


Pre-processing
Minutiae Extraction
Post-processing
•Binarization
•Noise Removal
•Smoothing
•Thinning
•Ridge break removal
•Bridge removal
•Spike removal
Processed Image + Minutiae Description
Input Image
Outputs

UNIT IV ROBOT PROGRAMMING

- Robot Programming methods - languages - Capabilities and limitation - Artificial intelligence - Knowledge representation – Search techniques - A1 and Robotics.

ROBOT PROGRAMMING METHODS

- Manual method
- Walkthrough method
- Lead through method
- Off-line programming

Robot Programming Languages

- The VALTM Language
- The VAL language was developed for PUMA robot
- Monitor command are set of administrative instructions that direct the operation of the
- robot system. Some of the functions of Monitor commands are
- Preparing the system for the user to write programs for PUMA
- Defining points in space
- Commanding the PUMA to execute a program
- Listing program on the CRT
- Examples for monitor commands are: EDIT, EXECUTE, SPEED, HERE etc.

THE MCL LANGUAGE

- MCL stands for Machine Control Language developed by Douglas.
- The language is based on the APT and NC language. Designed control complete
- manufacturing cell.
- MCL is enhancement of APT which possesses additional options and features needed
- to do off-line programming of robotic work cell.
- Additional vocabulary words were developed to provide the supplementary
- capabilities intended to be covered by the MCL. These capability include Vision,
- Inspection and Control of signals
- MCL also permits the user to define MACROS like statement that would be
- convenient to use for specialized applications.
- MCL program is needed to compile to produce CLFILE.
- Some commands of MCL programming languages are DEVICE, SEND, RECEIV,
- WORKPT, ABORT, TASK, REGION, LOCATE etc.

- Robot motion programming commands
-
- MOVE P1
- HERE P1 -used during leadthrough of manipulator
- MOVES P1
- DMOVE(4, 125)
- APPROACH P1, 40 MM
- DEPART 40 MM
- DEFINE PATH123 = PATH(P1, P2, P3)
- MOVE PATH123
- SPEED 75
-
- Input interlock:
- WAIT 20, ON
- Output interlock:
- SIGNAL 10, ON
- SIGNAL 10, 6.0
- Interlock for continuous monitoring:
- REACT 25, SAFESTOP
-
- Gripper
- OPEN
- CLOSE
- Sensor and servo-controlled hands
- CLOSE 25 MM

What is Intelligence?

- Intelligence:
  - "the capacity to learn and solve problems" (Websters dictionary)
  - in particular,
    - the ability to solve novel problems
    - the ability to act rationally
- the ability to act like humans.
- Artificial Intelligence
  - build and understand intelligent entities or agents
  - 2 main approaches: "engineering" versus "cognitive modeling"

WHAT'S INVOLVED IN INTELLIGENCE?

- Ability to interact with the real world
  - to perceive, understand, and act
  - e.g., speech recognition and understanding and synthesis
  - e.g., image understanding
  - e.g., ability to take actions, have an effect
- Reasoning and Planning
  - modeling the external world, given input
  - solving new problems, planning, and making decisions
  - ability to deal with unexpected problems, uncertainties
- Learning and Adaptation
  - we are continuously learning and adapting
  - our internal models are always being "updated"
    - e.g., a baby learning to categorize and recognize animals

GOALS OF AI RESEARCH

- **Artificial intelligence** (**AI**) is technology and a branch of computer science that studies and develops intelligent machines and software.
- Deduction, reasoning, problem solving
- Knowledge representation
- Planning
- Learning
- Natural language processing
- Motion and manipulation
- Perception
- Social intelligence
- Creativity
- General intelligence

Knowledge Representation

- **Knowledge representation** (KR) is an area of artificial intelligence research aimed at representing knowledge in symbols to facilitate inferencing from those knowledge elements, creating new elements of knowledge. The KR can be made to be independent of the underlying knowledge model or knowledge base system (KBS) such as a semantic network

Some issues that arise in knowledge representation from an AI perspective are:

- How do people represent knowledge?
  What is the nature of knowledge?
  Should a representation scheme deal with a particular domain or should it be general purpose?
  How expressive is a representation scheme or formal language?
  Should the scheme be declarative or procedural?

VARIOUS TECHNIQUES USED IN REPRESENTING KNOWLEDGE

- Lists
- Trees
- Semantic networks
- Schemas Scripts (Schank and Abelson)
- Rule-based representations (Newell and Simon)
- Logic-based representations

SEARCH TECHNIQUES

- 1. **Exhaustive search techniques**
  - **a. Depth-first search (DFS)**
  - **b. Breadth-first search**

Applications of AI and Robotics

- Industrial Automation
- Services for the Disabled
- Vision Systems
- Planetary Exploration
- Mine Site Clearing
- Law Enforcement

UNIT V INDUSTRIAL APPLICATIONS

- Application of robots in machining - Welding - Assembly - Material handling - Loading and unloading – CIM - Hostile and remote environments.

ROBOT APPLICATIONS

- Work environment hazardous for human beings
- Repetitive tasks
- Boring and unpleasant tasks
- Multi shift operations
- Infrequent changeovers
- Performing at a steady pace
- Operating for long hours without rest
- Responding in automated operations
- Minimizing variation

Industrial Robot Applications

- Material-handling applications:
  - Involve the movement of material or parts from one location to another.
  - It includes part placement, palletizing and/or de-palletizing, machine loading and unloading.
- Processing Operations:
  - Requires the robot to manipulate a special process tool as the end effectors.
  - The application include spot welding, arc welding, riveting, spray painting, machining, metal cutting, de-burring, polishing.
- Assembly Applications:
  - Involve part-handling manipulations of a special tools and other automatic tasks and operations.
- Inspection Operations:
  - Require the robot to position a work part to an inspection device.
  - Involve the robot to manipulate a device or sensor to perform the inspection.

Material Handling Applications

- This category includes the following:
- Part Placement
- Palletizing and/or depalletizing
- Machine loading and/or unloading
- Stacking and insertion operations

PART PLACEMENT

- The basic operation in this category is the relatively simple pick-and-place operation.
- This application needs a low-technology robot of the cylindrical coordinate type.
- Only two, three, or four joints are required for most of the applications.
- Pneumatically powered robots are often utilized.

Palletizing and/or Depalletizing

- The applications require robot to stack parts one on top of the other, that is to palletize them, or to unstack parts by removing from the top one by one, that is depalletize them.
- Example: process of taking parts from the assembly line and stacking them on a pallet or vice versa.

Machine loading and/or unloading

- Robot transfers parts into and/or from a production machine.
- There are three possible cases:

Machine loading in which the robot loads parts into a production machine, but the parts are unloaded by some other means.

- Example: a press working operation, where the robot feeds sheet blanks into the press, but the finished parts drop out of the press by gravity.

Machine loading in which the raw materials are fed into the machine without robot assistance. The robot unloads the part from the machine assisted by vision or no vision.

- Example: bin picking, die casting, and plastic moulding.

Machine loading and unloading that involves both loading and unloading of the work parts by the robot. The robot loads a raw work part into the process ad unloads a finished part.

- Example: Machine operation difficulties
- Difference in cycle time between the robot and the production machine. The cycle time of the machine may be relatively long compared to the robot’s cycle time.

Stacking and Insertion Operation

- In the stacking process the robot places flat parts on top of each other, where the vertical location of the drop-off position is continuously changing with cycle time.
- In the insertion process robot inserts parts into the compartments of a divided carton.
- The robot must have following features to facilitate material handling:

• The manipulator must be able to lift the parts safely.

• The robot must have the reach needed.

• The robot must have cylindrical coordinate type.

• The robot's controller must have a large enough memory to store all the programmed points so that the robot can move from one location to another.

• The robot must have the speed necessary for meeting the transfer cycle of the operation.

PROCESSING OPERATIONS

- Robot performs a processing procedure on the part.
- The robot is equipped with some type of process tooling as its end effector.
- Manipulates the tooling relative to the working part during the cycle.
- Industrial robot applications in the processing operations include:

  Spot welding

  Continuous arc welding

  Spray painting

  Metal cutting and deburring operations

  Various machining operations like drilling, grinding, laser and water jet cutting, and riveting.

  Rotating and spindle operations

  Adhesives and sealant dispensing

ASSEMBLY OPERATIONS

- The applications involve both material-handling and the manipulation of a tool.
- They typically include components to build the product and to perform material handling operations.
- Are traditionally labor-intensive activities in industry and are highly repetitive and boring. Hence are logical candidates for robotic applications.
- These are classified as:

  Batch assembly: As many as one million products might be assembled.

  The assembly operation has long production runs.

  Low-volume: In this a sample run of ten thousand or less products might be made.

  The assembly robot cell should be a modular cell.

  One of the well suited areas for robotics assembly is the insertion of odd electronic components.

INSPECTION OPERATION

- Some inspection operation requires parts to be manipulated, and other applications require that an inspection tool be manipulated.
- Inspection work requires high precision and patience, and human judgment is often needed to determine whether a product is within quality specifications or not.
- Inspection tasks that are performed by industrial robots can usually be divided into the following three techniques:

  By using a feeler gauge or a linear displacement transducer known as a linear variable differential transformer (LVDT), the part being measured will come in physical contact with the instrument or by means of air pressure, which will cause it to ride above the surface being measured.

  By utilizing robotic vision, matrix video cameras are used to obtain an image of the area of interest, which is digitized and compared to a similar image with specified tolerance.

  By involving the use of optics and light, usually a laser or infrared source is used to illustrate the area of interest.
- The robot may be in active or passive role.

  In active role robot is responsible for determining whether the part is good or bad.

  In the passive role the robot feeds a gauging station with the part. While the gauging station is determining whether the part meets the specification, the robot waits for the process to finish.

THE GENERAL CONSIDERATIONS IN ROBOT MATERIAL HANDLING

- Part positioning orientation
- Gripper design
- Minimum distance moved
- Robot work volume
- Robot weight capacity
- Accuracy and repeatability
- Robot configuration, Degree of Freedom and Control
- Machine utilization problems

Accuracy and Precision

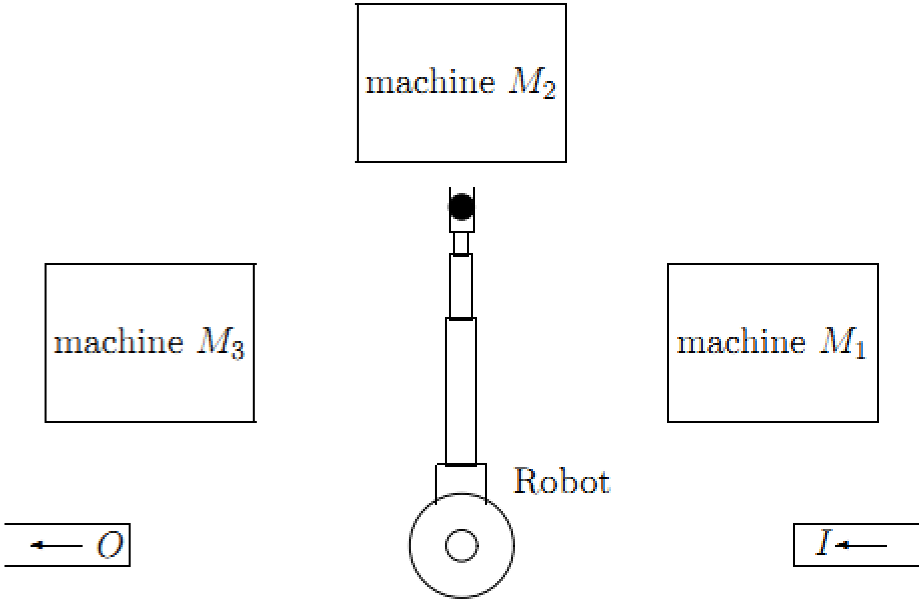
	Accuracy	Precision
Definition:	The degree of closeness to true value.	The degree to which an instrument or process will repeat the same value.
Measurements:	Single factor or measurement	Multiple measurements or factors are needed
About:	A term used in measuring a process or device.	A term used in measuring a process or device.
Uses:	Physics, chemistry, engineering, statistics and so on.	Physics, chemistry, engineering, statistics and so on.

BOWL FEEDERS

- Common devices used to feed individual component parts for assembly on industrial production lines. They are used when a randomly sorted bulk package of small components must be fed into another machine one-by-one, oriented in a particular direction

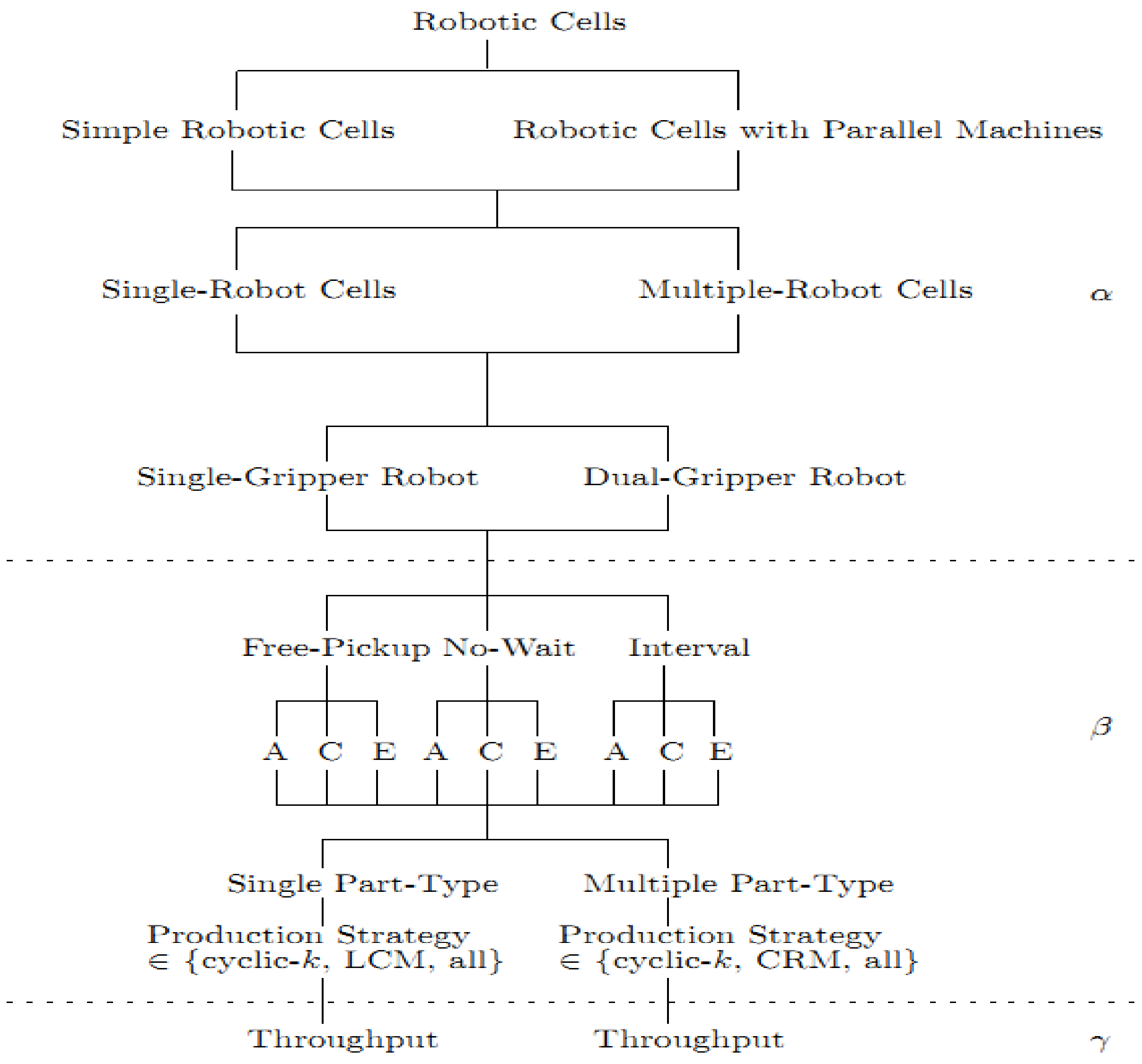
TYPES OF ROBOT CELL LAYOUTS

- Robot- centered cell
- In-line robot cell
- Mobile robot cell



A Three-Machine Simple Robotic Cell.

A Classification Scheme for Robotic Cells and Notation



A, C, E denote Additive, Constant, Euclidean Travel Time, respectively

Advantages of Robots

- Robotics and automation can, in many situation, increase productivity, safety, efficiency, quality, and consistency of Products
- Robots can work in hazardous environments
- Robots need no environmental comfort
- Robots work continuously without any humanity needs and illnesses
- Robots have repeatable precision at all times
- Robots can be much more accurate than humans, they may have milli or micro inch accuracy.
- Robots and their sensors can have capabilities beyond that of humans.
- Robots can process multiple stimuli or tasks simultaneously, humans can only one.
- Robots replace human workers who can create economic problems.

Disadvantages of Robots

- Robots lack capability to respond in emergencies, this can cause:
  - Inappropriate and wrong responses
  - A lack of decision-making power
  - A loss of power
  - Damage to the robot and other devices
  - Human injuries
- Robots may have limited capabilities in
  - Degrees of Freedom
  - Dexterity
  - Sensors
  - Vision systems
  - Real-time Response
- Robots are costly, due to
  - Initial cost of equipment
  - Installation Costs
  - Need for peripherals
  - Need for training
  - Need for Programming

Summary of Robot Applications

- 1. Hazardous work environment for humans
- 2. Repetitive work cycle
- 3. Difficult handling task for humans
- 4. Multi shift operations
- 5. Infrequent changeovers
- 6. Part position and orientation are established in the work cell