Mct/ROB/200 Robotics, Spring Term 12-13

Lecture 2 – Friday March 8, 2012

Robot Morphology

Objectives

When you have finished this lecture you should be able to:

- Understand what industrial robots are and how they are classified.
- Familiarize with the basic definitions related to industrial robotics.
- Recognize the different geometric configurations of an industrial robot and its main elements.

Outline

- What is an Industrial Robot?
- Basic Definitions
- Geometric Classification
- Elements of Industrial Robot
- Commercial Industrial Robots
- Summary

Outline

- **What is an Industrial Robot?**
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What is an Industrial Robot?

- **Robot Institute of America:** A reprogrammable multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

- **Japanese Industrial Robot Association (JIRA):** A device with degrees of freedom that can be controlled.

- **International Federation of Robotics (IFR):** An automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes.

What is an Industrial Robot?

An industrial robot is an automatically controlled, **reprogrammable, multipurpose** manipulator programmable in three or more axes.

International Organization for Standardization

Key features

Reprogrammability

- Robot's motion is controlled by a program;
- The program can be modified to change significantly the robot's motion

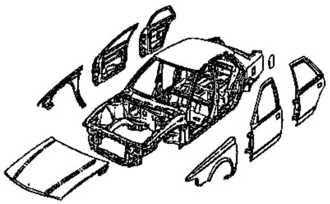
Multifunctionality

A robot could be tooled and programmed in one company to do welding, and in a second company the same type of robot could be used to stack boxed on a palletizer.

What is an Industrial Robot?

Advantages:

- Repeatability
- Tighter quality control
- Waste reduction
- Working in hostile environment
- Increased productivity.



Disadvantages

- high initial costs
- increased dependence on maintenance.

Advantages/ Disadvantages?!

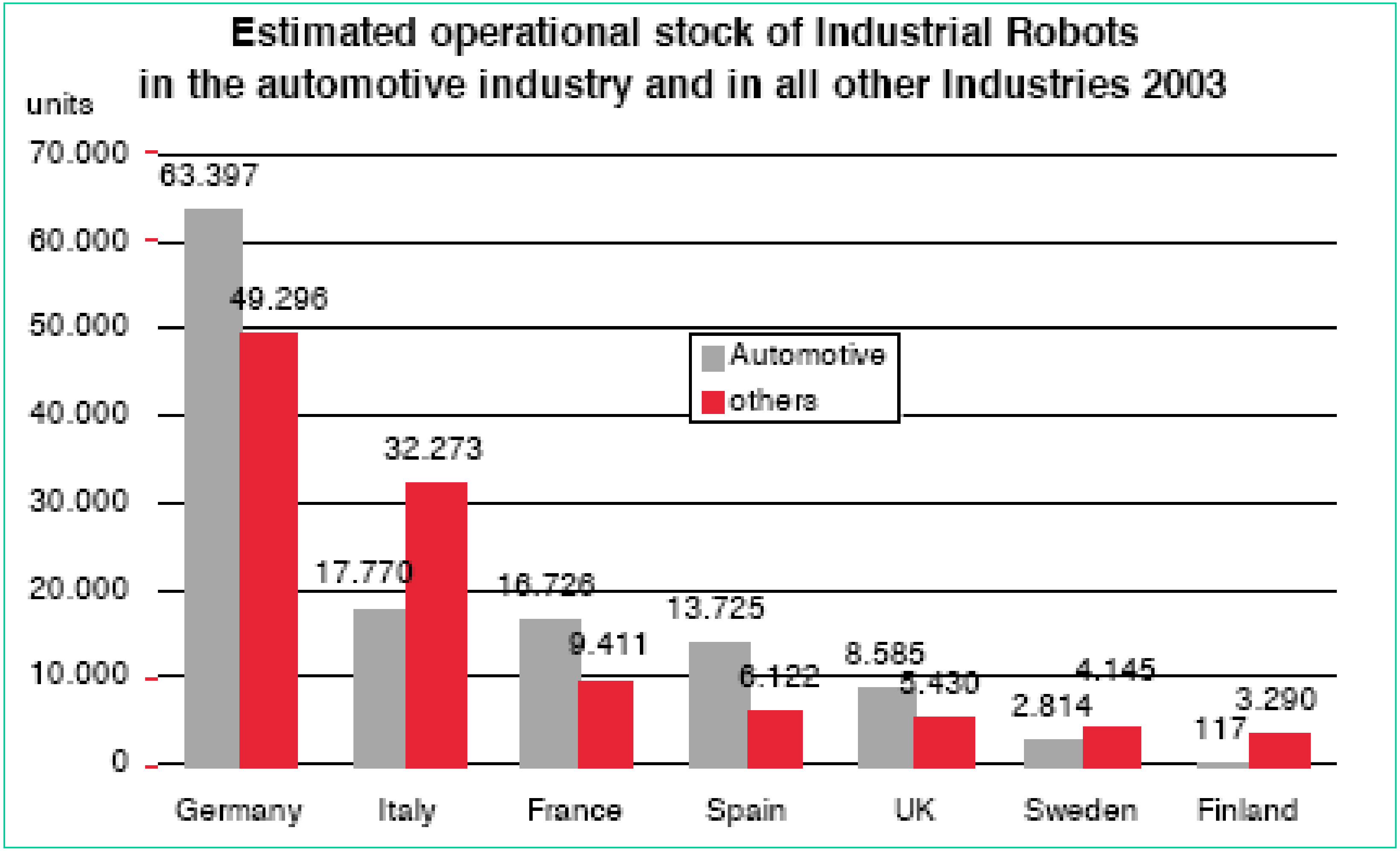
- Impact on employment

Country	Robot Density	Unemployment Rate %
Japan	280	4.7
Germany	135	10.5
Italy	67	11.5
Spain	41	16

IFR, October 2002

What is an Industrial Robot?

- **Industrial Robots in Automotive Industry:**



Source: Industrial Robot Automation. DR.14.1 White paper, European Robotics Network (EURON), 2005.

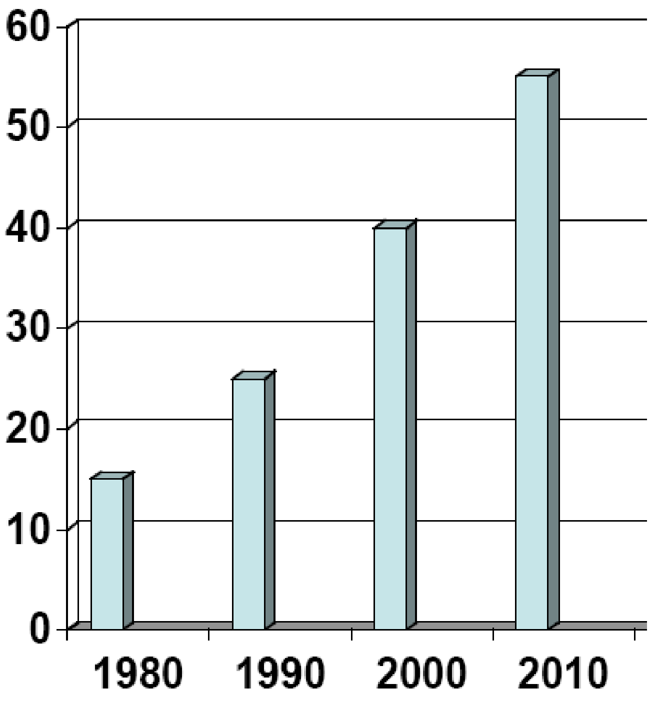
What is an Industrial Robot?

- **Industrial Robots in Automotive Industry:**

Origin of robot supplier in the automotive industry

Robots in the automotive sector			
Make	Japan	Europe	Other
Honda	100 %		
Toyota	100 %		
Nissan	100 %		
Mazda	100 %		
VW	10 %	90 %	
BMW	20 %	80 %	
DC	20 %	80 %	
Renault	50 %	50 %	
PSA	50 %	50 %	
Ford	50 %	50 %	
GM	80 %	20 %	
Korean	60 %	20 %	20 %

Increasing investment portion of robotics by car industry and 1st tier suppliers.



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Outline

- What is an Industrial Robot?
- **<u>Basic Definitions</u>**
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Basic Definitions

- **Manipulator or the rover**

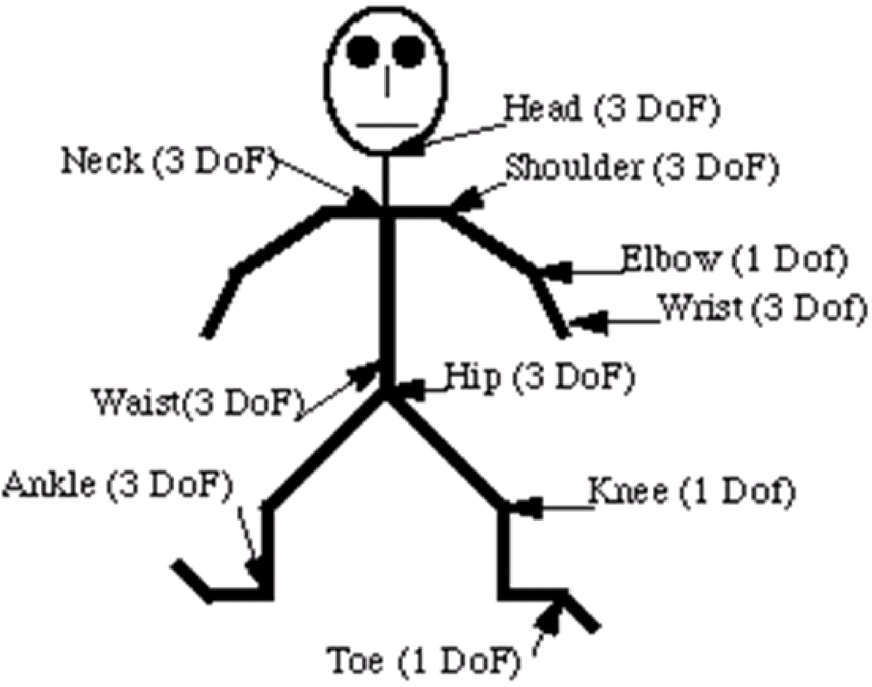
  This is the main body of the robot which consists of the links, the joints, and other structural elements of the robot. Without other elements, the manipulator alone is not a robot.

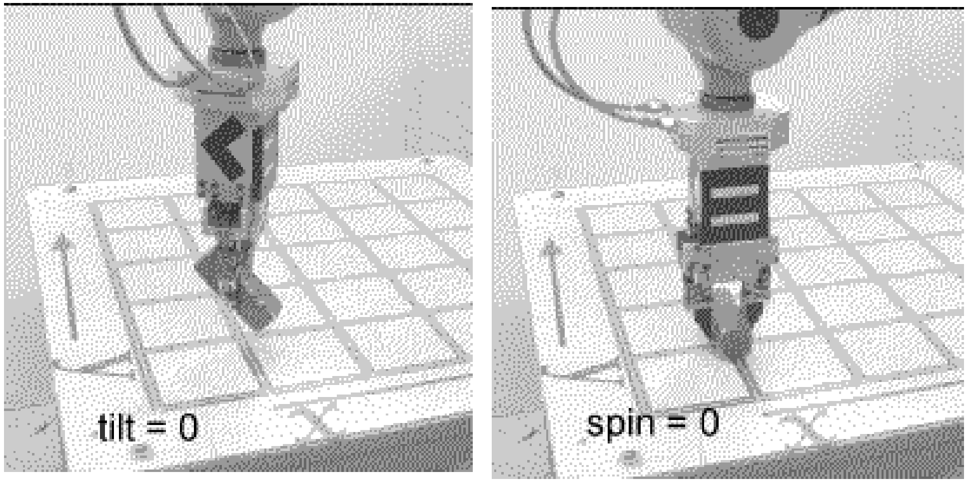
A Fanuc M-410iWW palletizing robotic manipulator with its end effector

Basic Definitions

• **Degrees of Freedom (DOF)**

Every joint or movable axis on the robot is a degree of freedom.

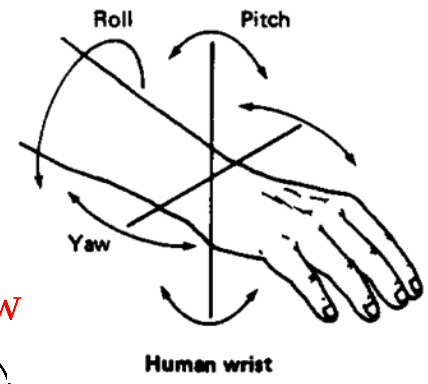


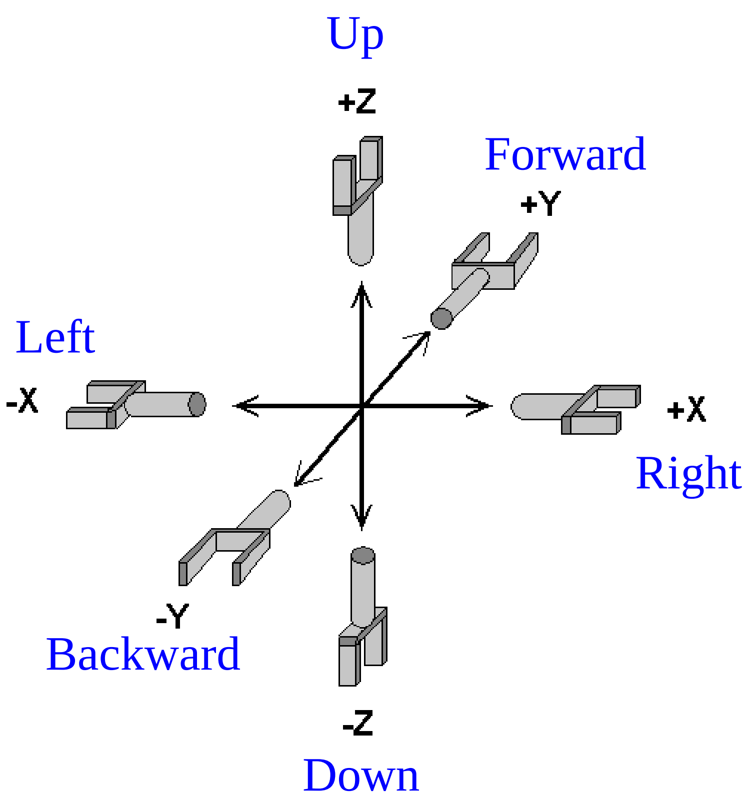


A simple robot arm with 3 degrees of freedom could move in 3 ways: up and down, left and right, forward and backward.

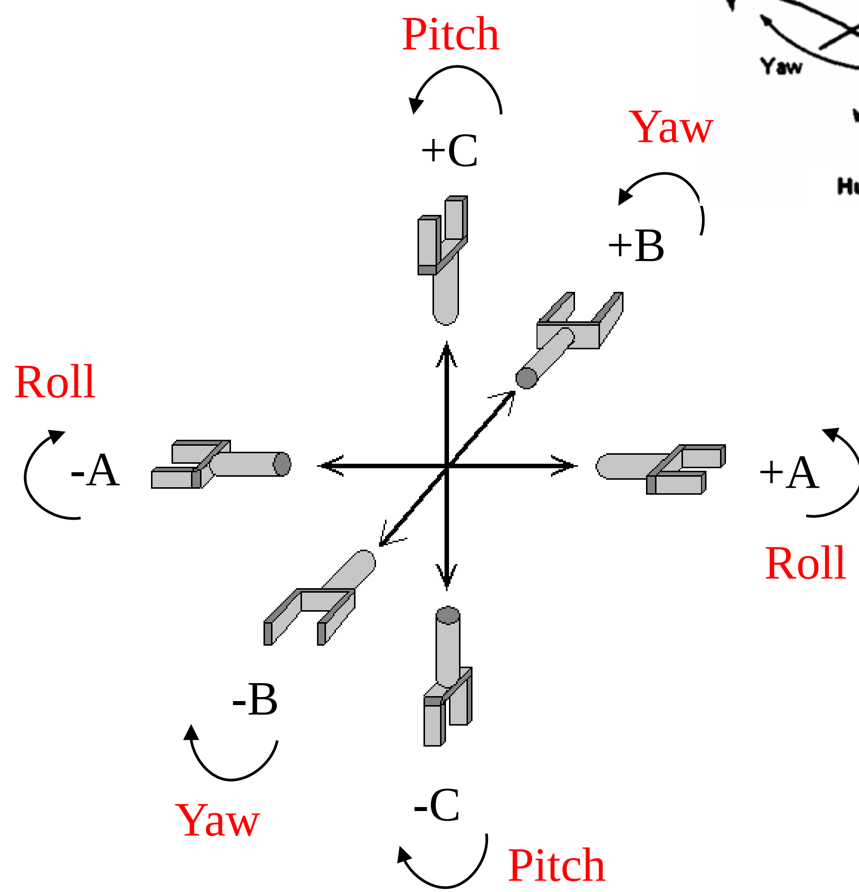
Basic Definitions

- **Degrees of Freedom (DOF)**





3-DOF (Position)



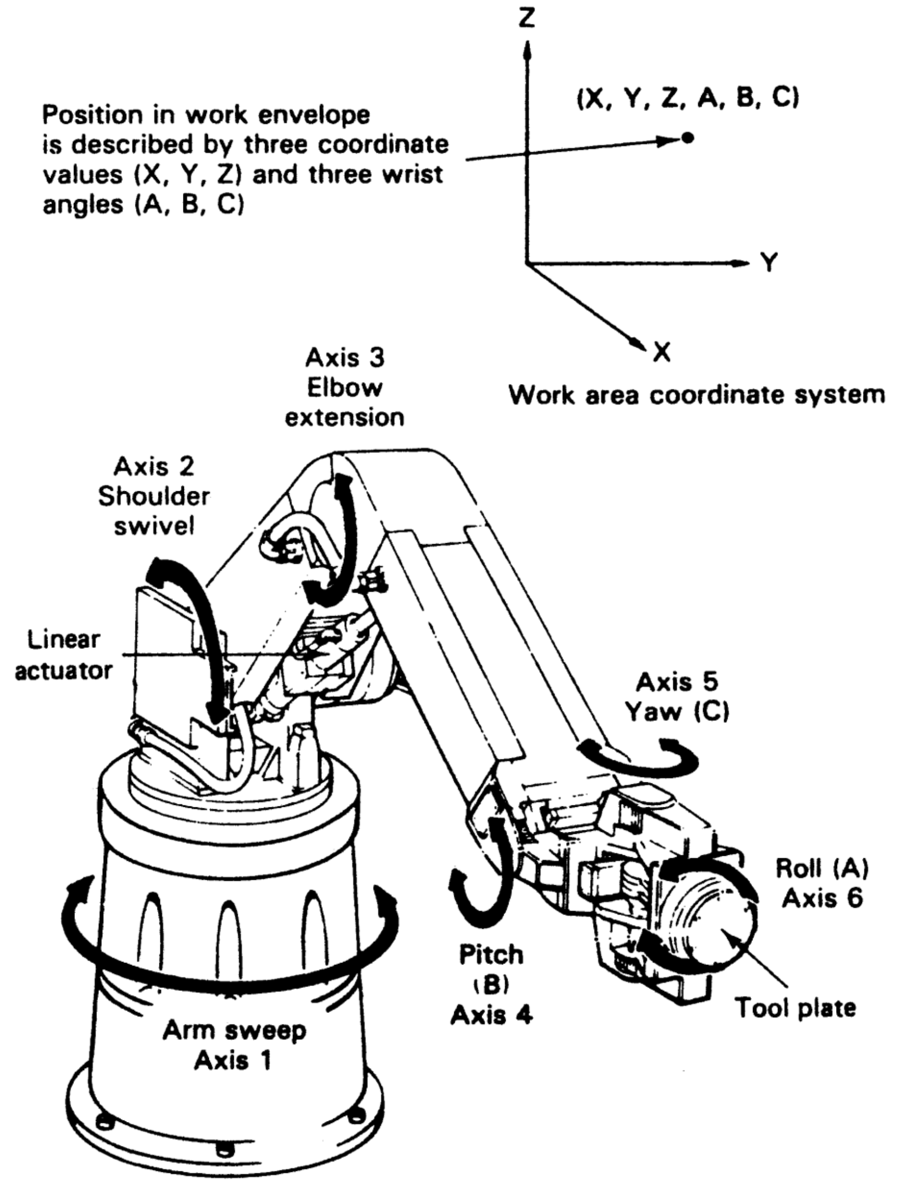
3-DOF (Orientation)

Basic Definitions

- **Degrees of Freedom (DOF)**

  Degree of freedom is the number of independent movements the robot can realize with respect to its base.

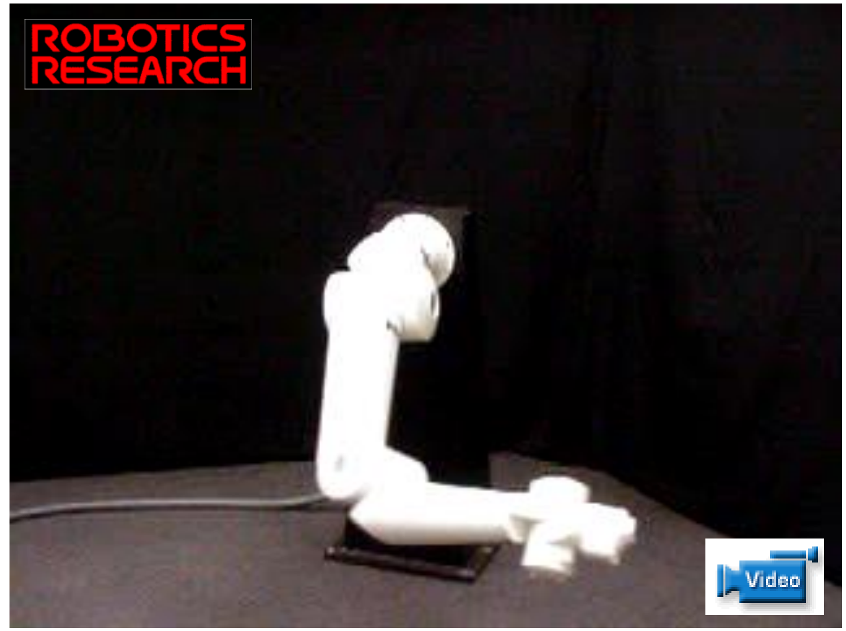
  - 3 DOF is the minimum number (according to robot definition)
  - Most working robots today have 6 degrees of freedom.
  - 7+ DOF – Redundant Robot



Basic Definitions

- **Degrees of Freedom (DOF)**

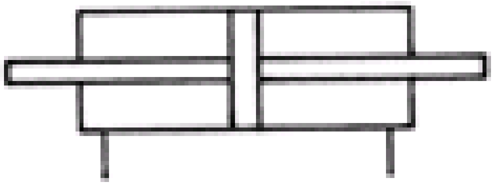
17 DOF



Robot K-1207i
7 GDL

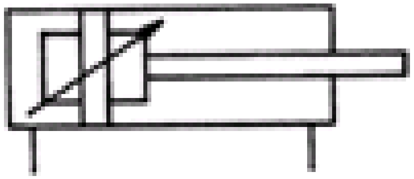
Basic Definitions

- **Partial Degrees of Freedom**
  - There are cases where a joint may have the ability to move, but its movement is **not fully controlled**.
  - For example, consider a linear joint actuated by a pneumatic cylinder, where the arm is fully extended or fully retracted, but no controlled position can be achieved between the two extremes. In this case, the convention is to assign only a ½-degree of freedom to the joint. This means that the joint can only be at specified locations within its limits of movement.



Pneumatic cylinder with double-ended piston rod

½ DOF



Double-acting cylinder with adjustable stroke cushioning at both ends

1-DOF

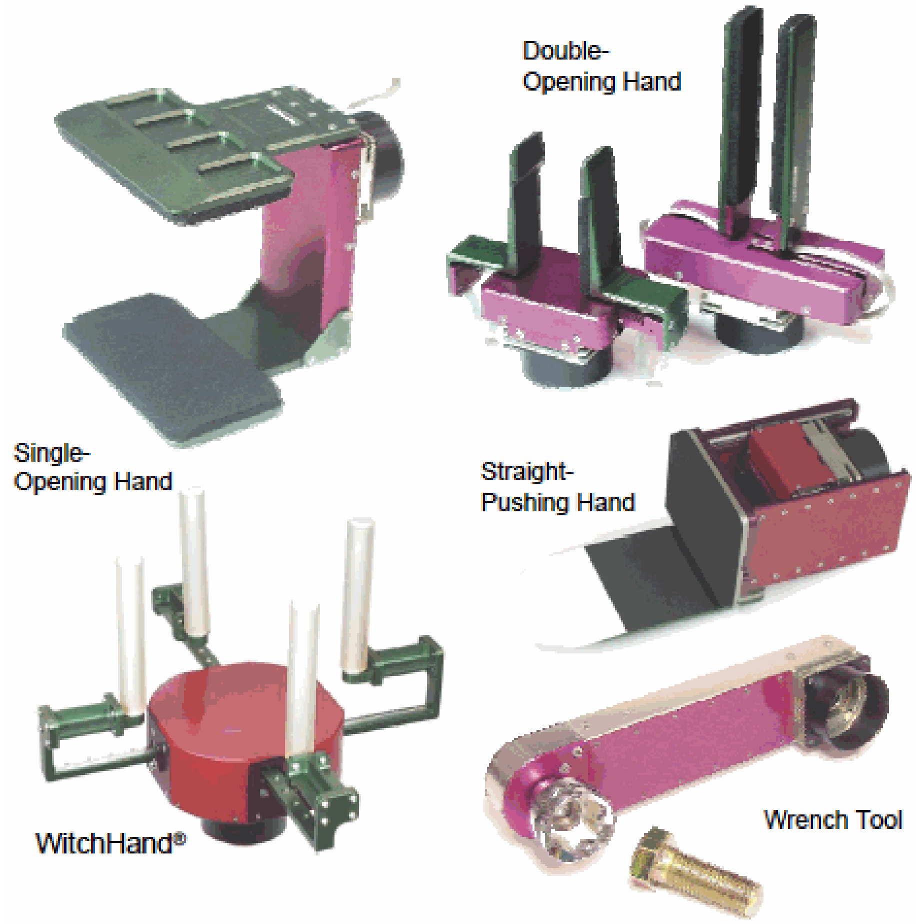
Basic Definitions

- **End-effectors**

  Device at the end of a robot arm that is used to grasp or engage objects.

  Examples include, but are not necessarily limited to:

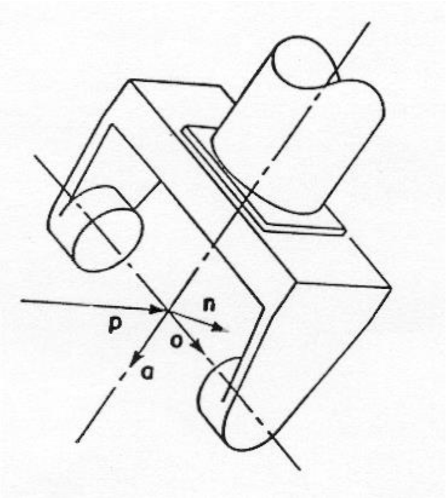
  - Grippers
  - Welding torch
  - Paint spray gun
  - Glue laying device
  - Parts handler



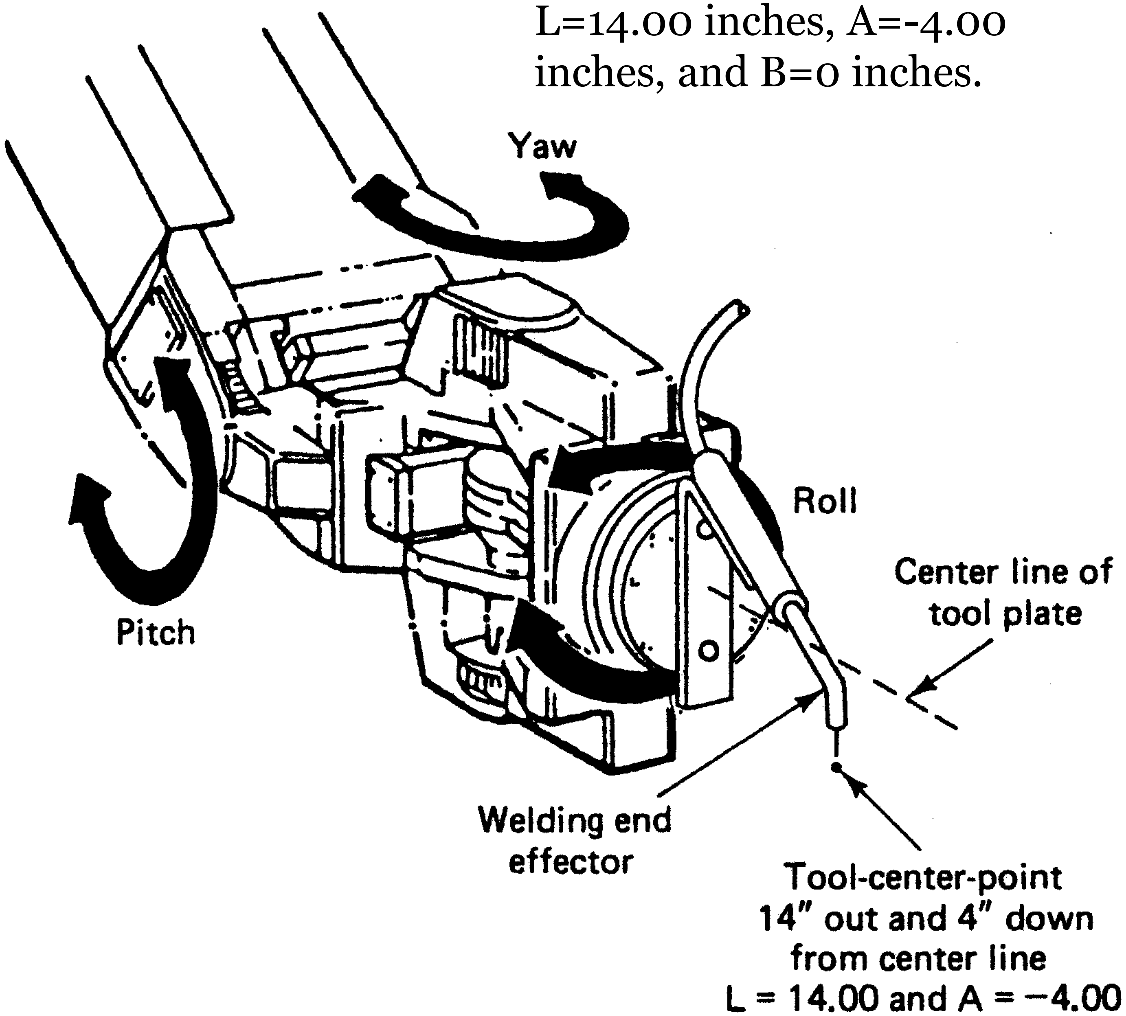
Basic Definitions

- **Offset or TCP (Tool Center Point)**

Offest or TCP (Tool Center Point) is the point of action for the tool mounted to the robot tool plate.



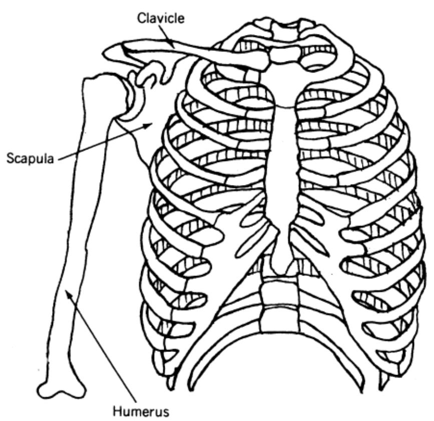
Welding touch with TCP of L=14.00 inches, A=-4.00 inches, and B=0 inches.

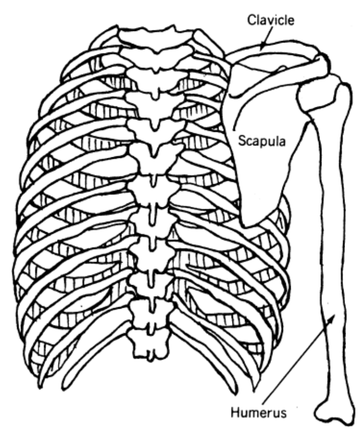


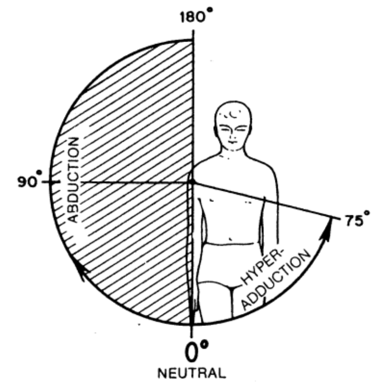
Basic Definitions

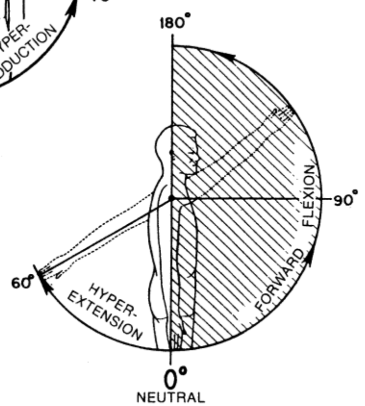
- **Work Envelope/Workspace**

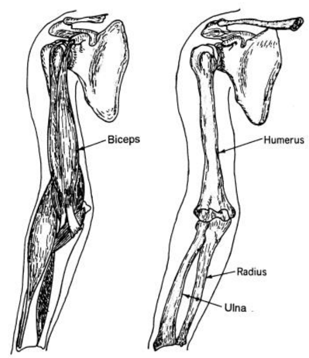
The space in which the robot gripper can move with no limitations in the travel other than those imposed by the joints.

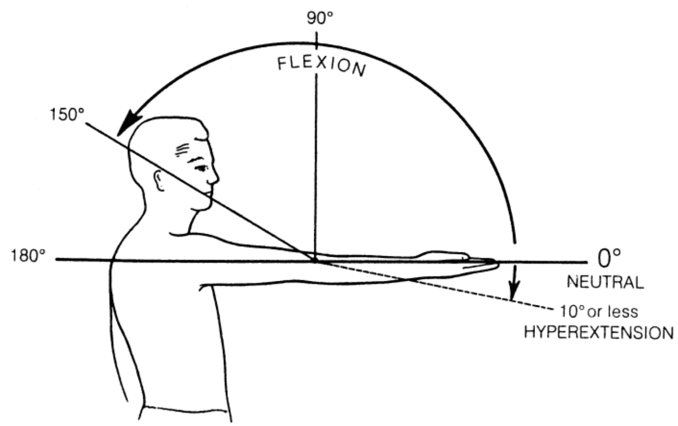


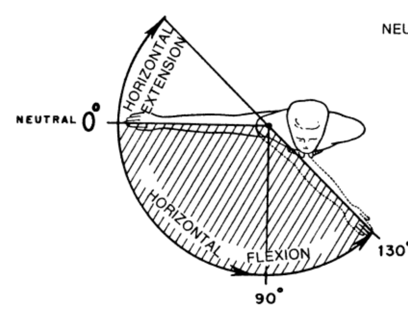












Basic Definitions

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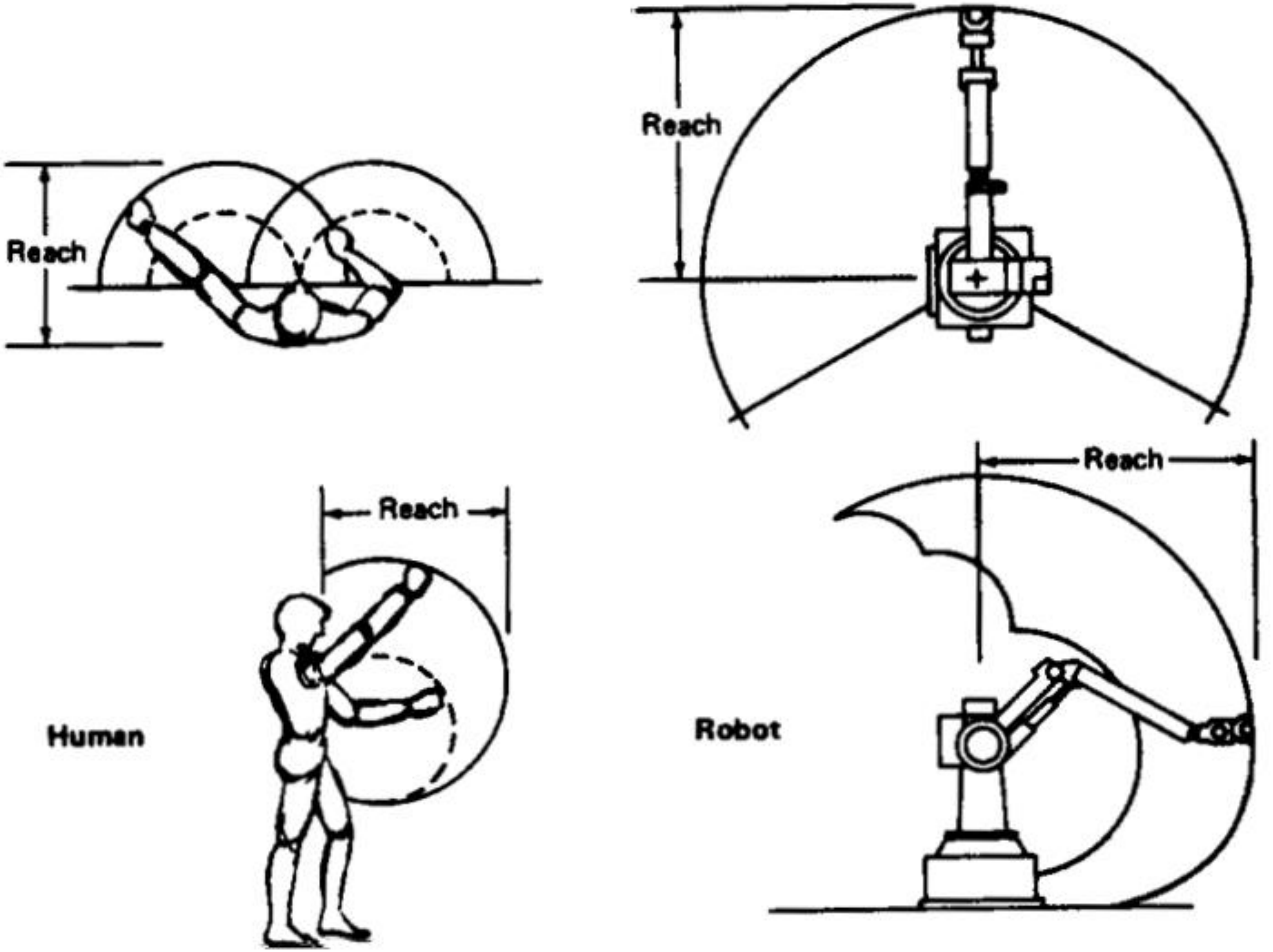

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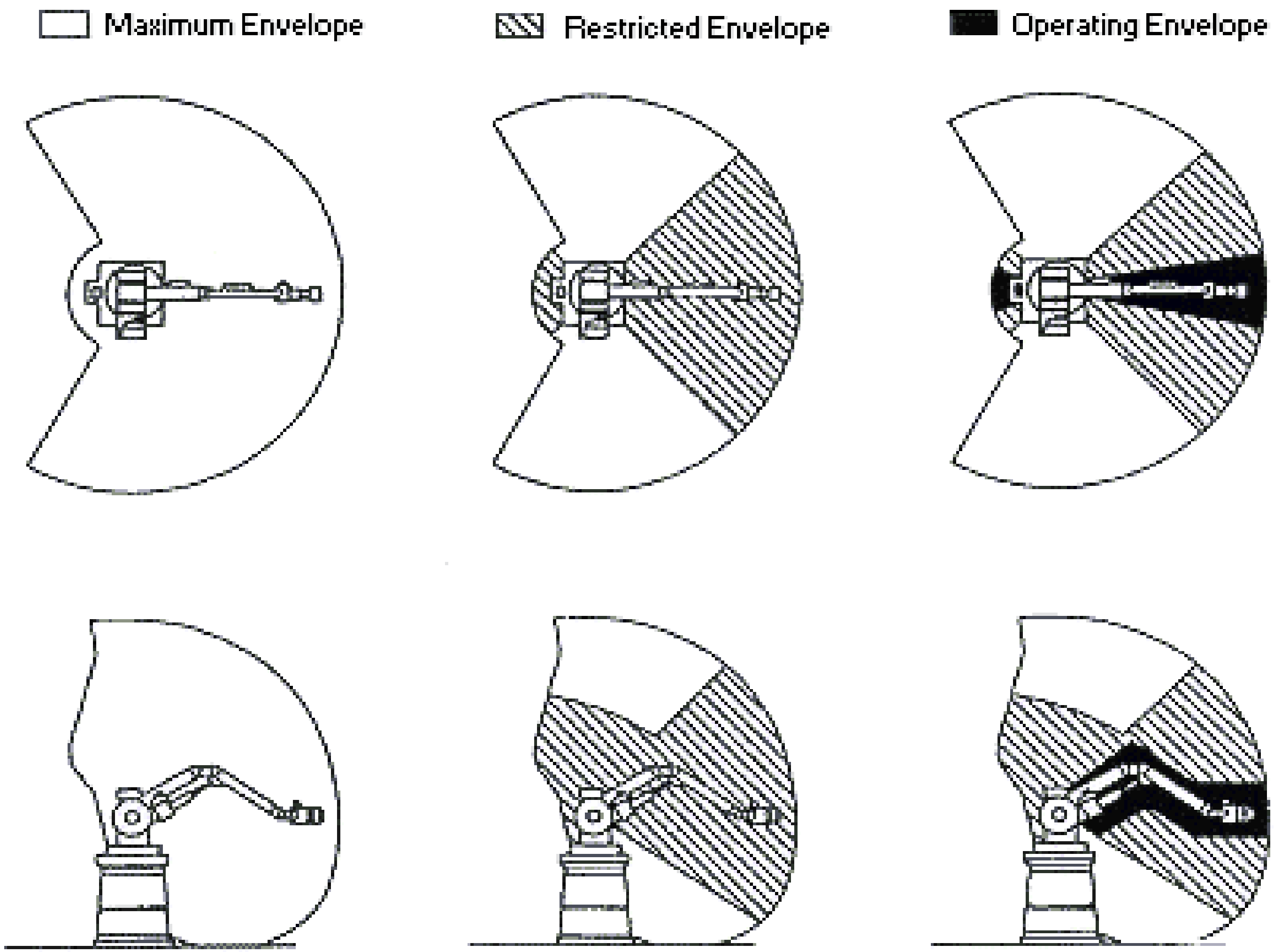

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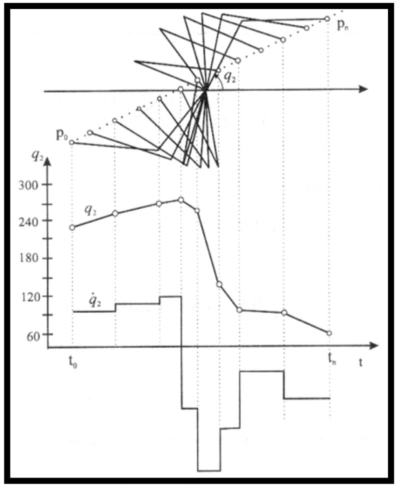
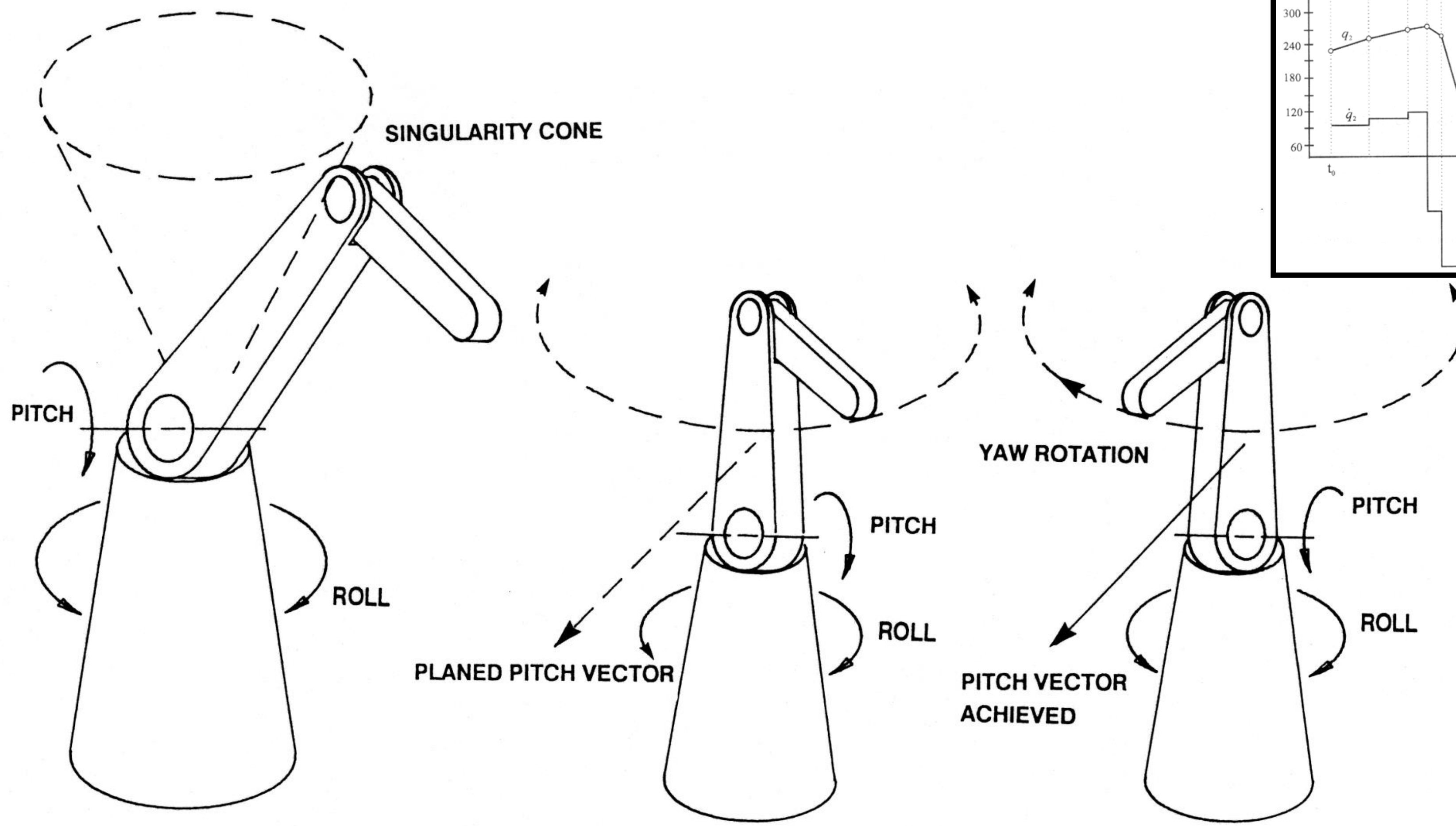




a–Singularity Cone

b–Arm Unable to Move in Pitch Vector

c–Roll Rotation Allows Pitch Vector

Basic Definitions

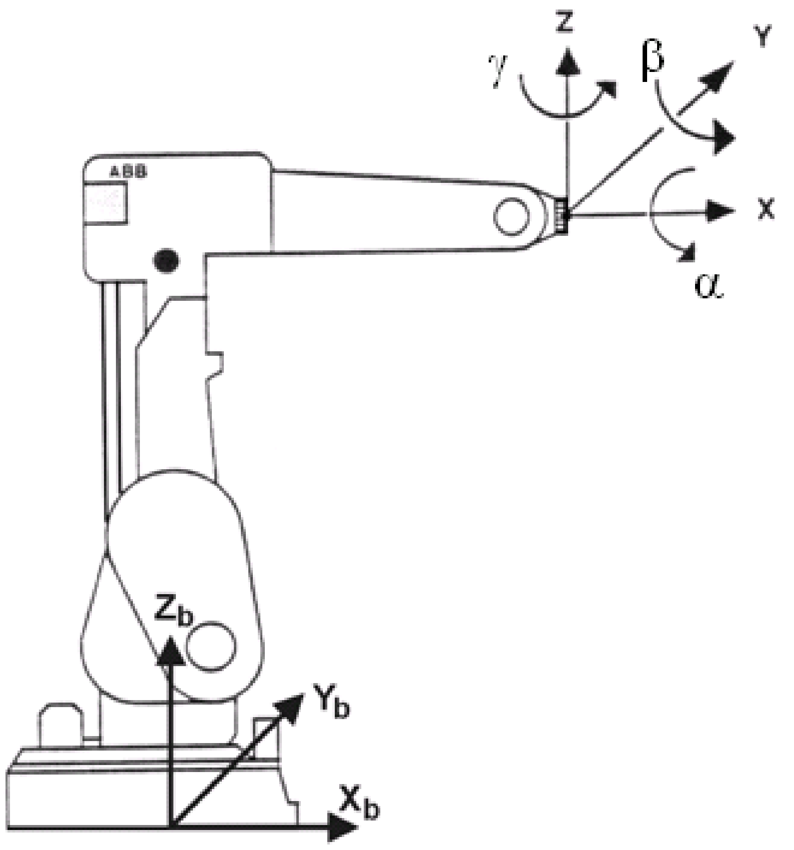
- **Work Envelope/Workspace**
  - The shape of the workspace for each robot is uniquely related to its design. The workspace may be found **mathematically** by writing equations that define the robot's links and joints and that include their limitations such as ranges of motions for each joint*.
  - Alternately, the workspace may be found **empirically** by virtually moving each joint through its range of motions, combining all the space it can reach, and subtracting what it cannot reach.

* Wiitala, Jared M., B. J., Rister, J. P. Schmiedler, "A More Flexible Robotic Wrist," Mechanical Engineering, July 1997, pp. 78–80.

Basic Definitions

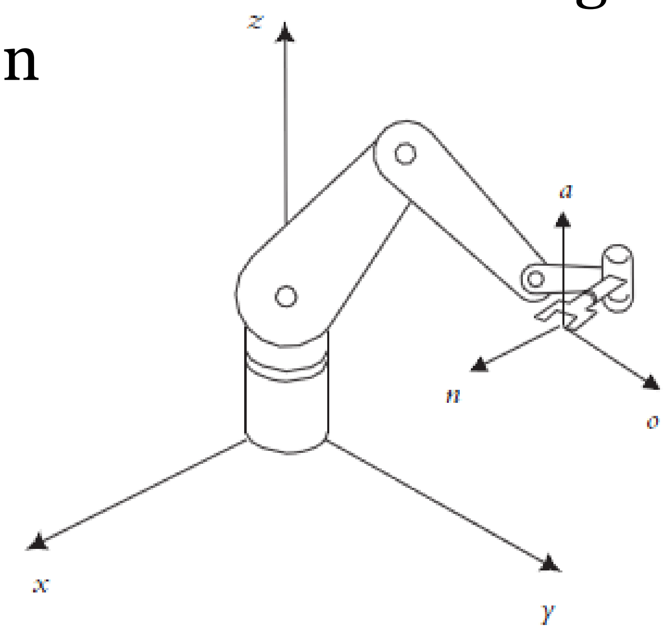
- **Coordinate System**

  All points programmed in the work cell are identified by a base coordinate system that consists of three translation coordinates X, Y, and Z and three rotational coordinates α, β, and γ or A, B, and C.



Basic Definitions

- **Robot Reference Frames**
  - **World Reference Frame:** This is a universal coordinate frame, as defined by the x-,y-, and z-axes. In this case, the joints of the robot move simultaneously in a coordinated manner to create motions along the three major axes. In this frame, no matter where the arm, a positive movement along the x-axis is always in the plus direction of the x-axis, etc. The World reference frame is used to define the motions of the robot relative to other objects, define other parts and machines with which the robot communicates, and define motion trajectories.

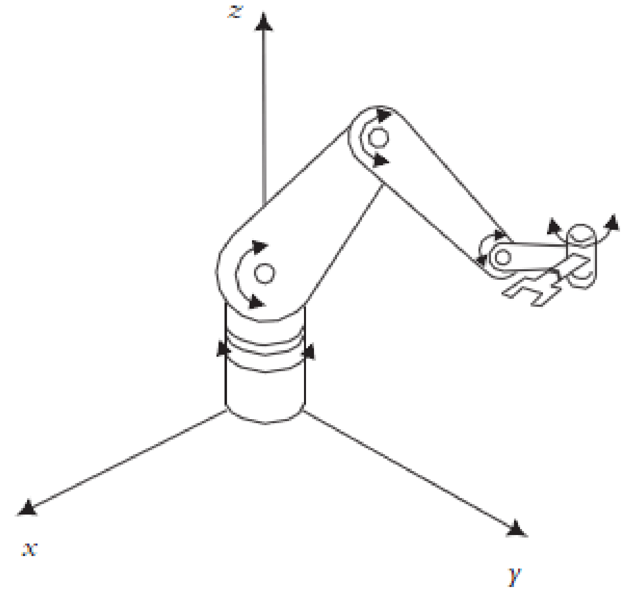


World Reference Frame

Basic Definitions

- **Robot Reference Frames**
  - **Joint Reference Frame:** This is used to specify movements of individual joints of the robot. In this case, each joint is accessed and moved individually; therefore, only one joint moves at a time. Depending on the type of joint used (prismatic, revolute, or spherical), the motion of the robot hand will be different.

For instance, if a revolute joint is moved, the hand will **move on a circle** defined by the joint axis.

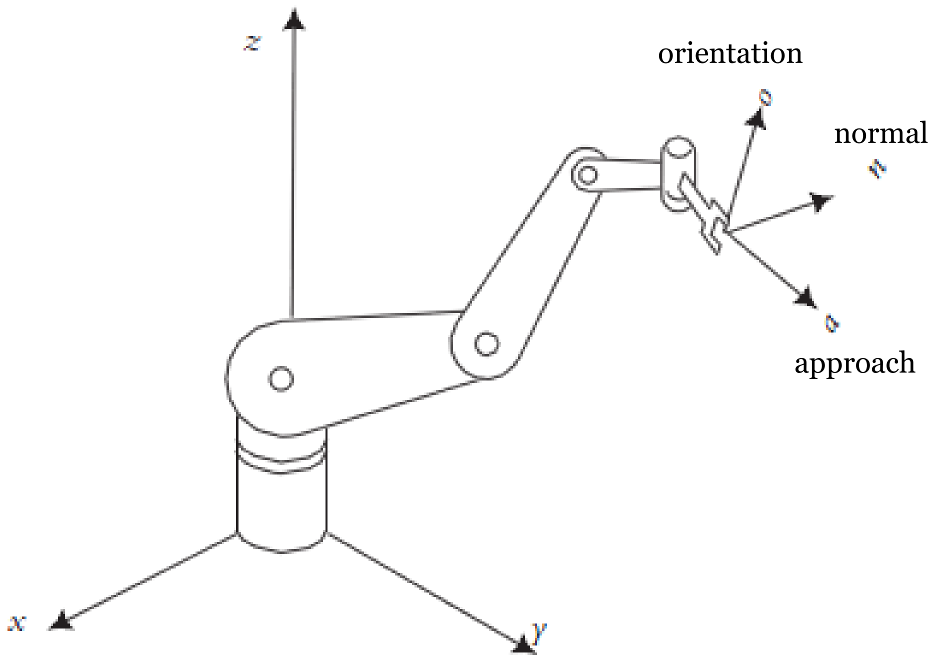


Joint Reference Frame

Basic Definitions

- **Robot Reference Frames**
  - **Tool Reference Frame:** This specifies movements of the robot's hand relative to a frame attached to the hand, and consequently, all motions are relative to this local n,o,a frame. Unlike the universal World frame, the local Tool frame moves with the robot.

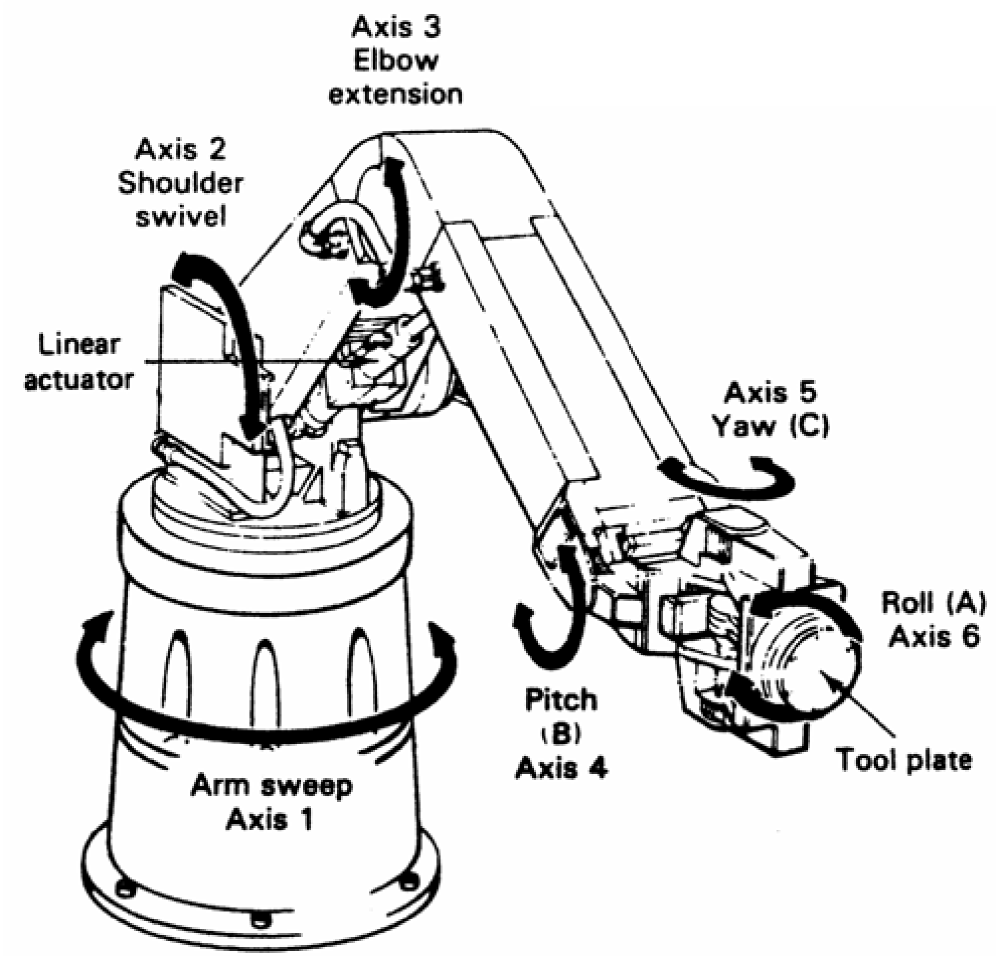
    This reference frame is an extremely useful frame in robotic programming where the robot is to approach and depart from other objects or to assemble parts.



Tool Reference Frame

Basic Definitions

- **Axis Numbering**
  - Start at the robot mounting plate (base).
  - The first axis of motion encountered in labeled axis #1.
  - Progress from the base to the end-effector numbering each axis encountered successively.



Basic Definitions

- **Payload/Load Capacity**

The rated payload is the mass that the robot is designed to manipulate under the manufacturer's specific performance conditions of speed, acceleration-deceleration, and duty cycle over the entire work envelope.

Payload is the weight a robot can carry and still remain within its other specifications.

As an example, a robot's maximum load capacity may be much larger than its specified payload, but at these levels, it may become less accurate, may not follow its intended trajectory accurately, or may have excessive deflections.

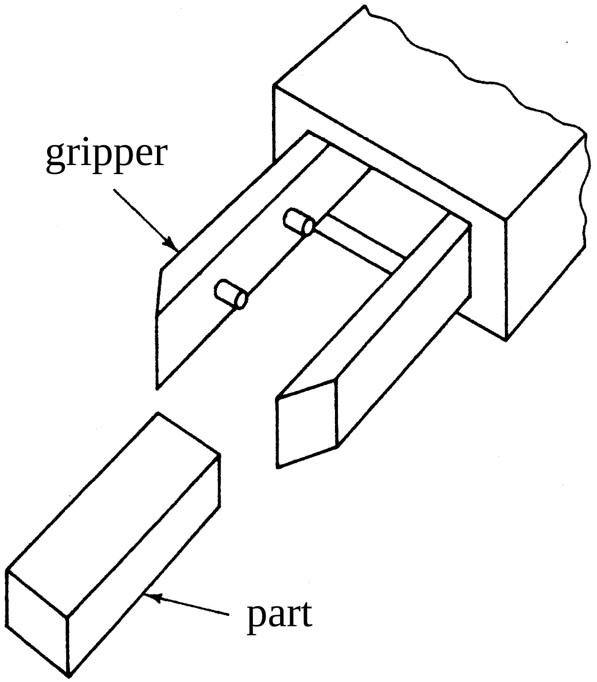
Fanuc Robotics M- 16i robot - mechanical weight=594lb and a payload=35lb

Basic Definitions

- **Maximum Payload**

  The maximum payload is the maximum mass that the robot can manipulate at a specific speed, acceleration-deceleration, center of gravity location (offset), and repeatability under continuous operation over a specific work envelope.

Payload = tooling weight + part weight

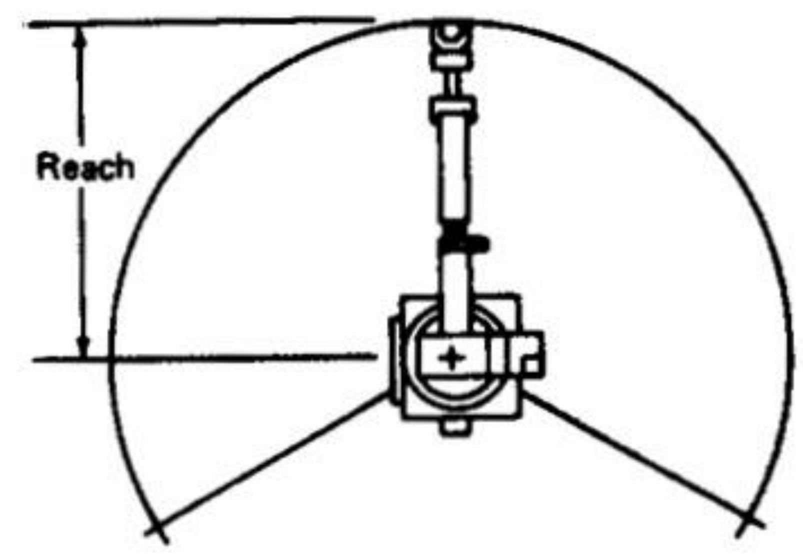


Basic Definitions

- **Reach**

Reach is the **maximum distance** a robot can reach within its work envelope. Many points within the work envelope of the robot may be reached with any desired orientation (called **dexterous**). However, for other points close to the limit of robot's reach capability, orientation cannot be specified as desired (called **nondexterous** point).

Reach is a function of the robot's joints and lengths and its configuration. This is an important specification for industrial robots and must be considered before a robot is selected and installed.



Basic Definitions

- **Accuracy**

  Accuracy is the measure of the difference between the measured value and the actual value.

  Accuracy is defined as the percentage of the true value.

$$\text{percentage of true value} = \frac{\text{measured value} - \text{true value}}{\text{true value}}(100)$$

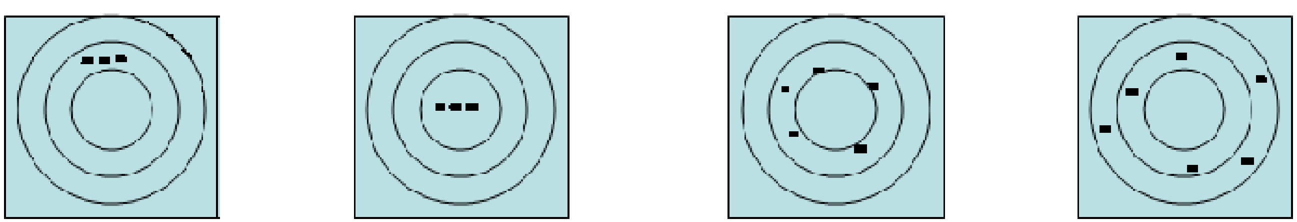
The difference between the measured value and the true value is called bias error

Basic Definitions

- **Precision (validity)**

  Precision is defined as how accurately a specified point can be reached. This is a function of the resolution of the actuators as well as the robot’s feedback devices.

  Most industrial robots can have precision in the **range of 0.001 inches or better**. The precision is a function of how many positions and orientations were used to test the robot, with what load, and at what speed. When the precision is an important specification, it is crucial to investigate these issues.



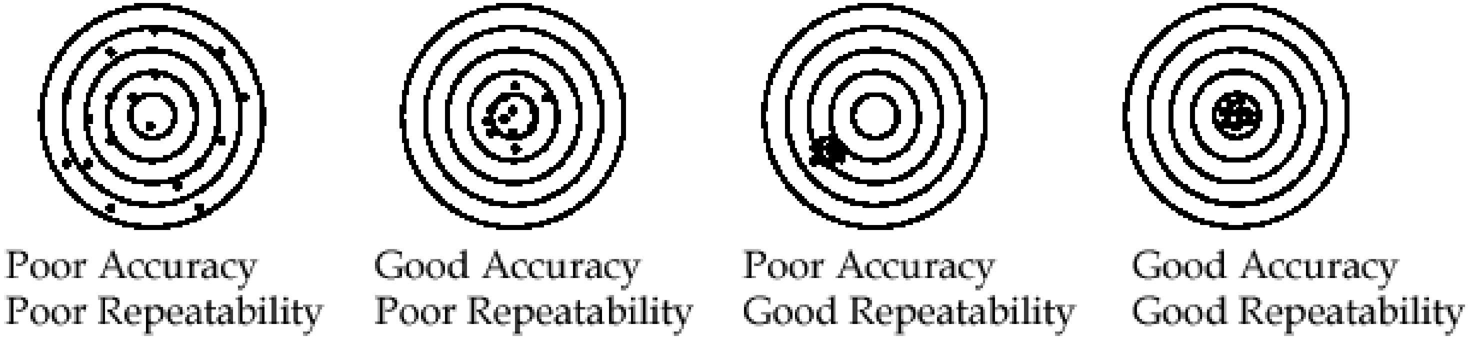
Poor Accuracy High Precision	High Accuracy High Precision	Good Average Accuracy Poor Precision	Poor Accuracy Poor Precision

Basic Definitions

- **Repeatability (variability)**

Repeatability is how accurately the same position can be reached if the motion is repeated many times.

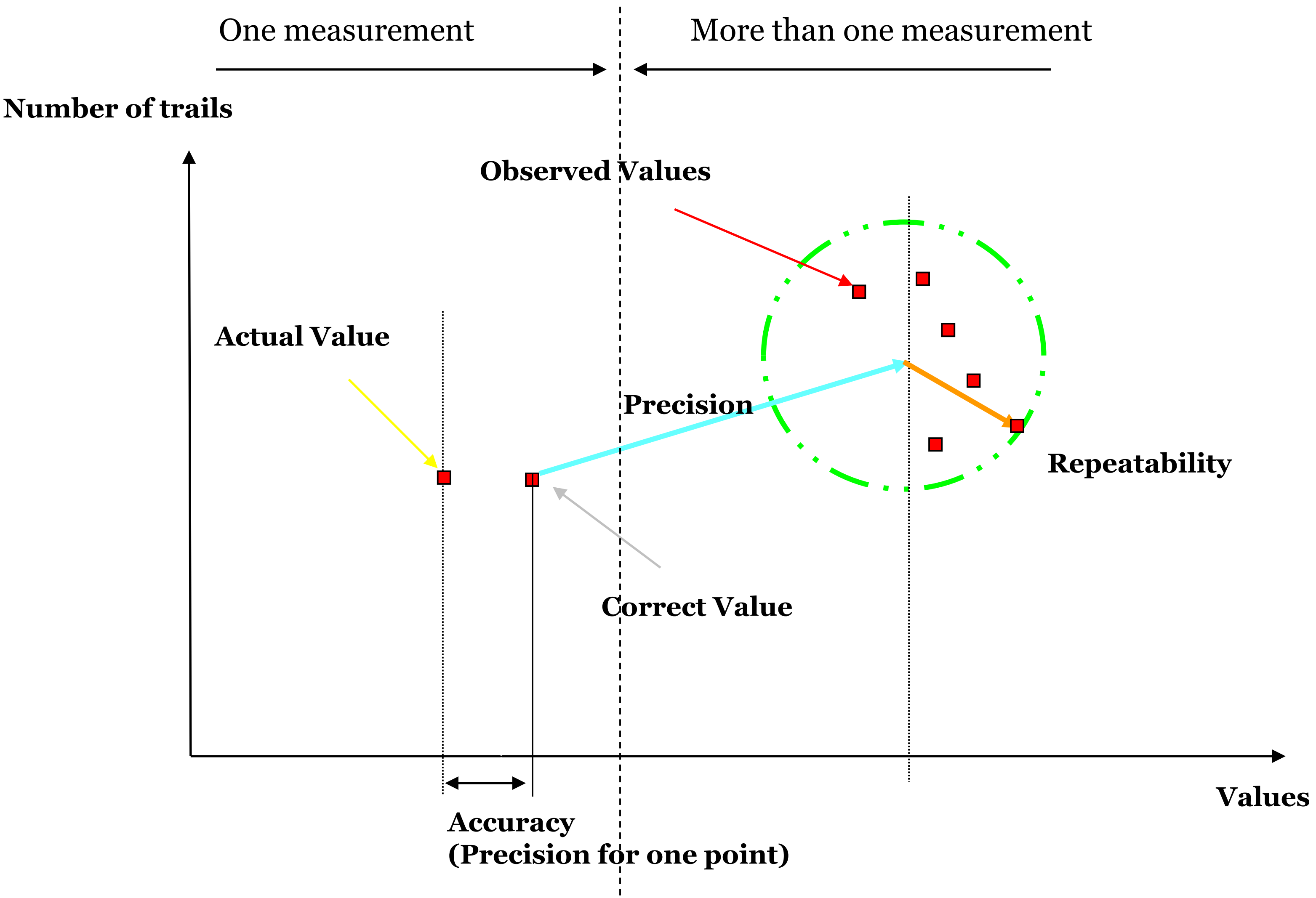
Suppose a robot is driven to the same point 100 times. Since many factors may affect the accuracy of the position, the robot may not reach the same point every time but will be within a certain radius from the desired point. The radius of a circle formed by the repeated motions is called repeatability.



For more info: M. Abderrahim, Alaa Khamis, S. Garrido, L. Moreno, "Accuracy and Calibration Issues of Industrial Manipulators," Chapter in Industrial Robotics: Programming, Simulation and Applications. pp.131-146. ISBN: 3-86611-286-6. Advanced Robotic Systems International & Pro Verlag, 2007.

Basic Definitions

- **Repeatability (variability)**



Basic Definitions

- **Duty Cycle**

  The ratio of run time to total operational time that a robot can continuously work with the rated payload at rated conditions (e.g., speed, acceleration, and temperature) without overheating or degrading the robot specifications.

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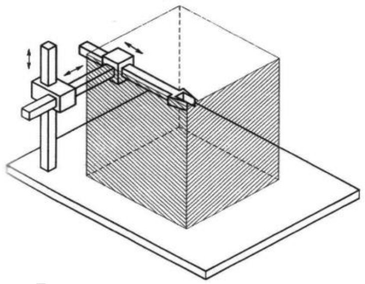
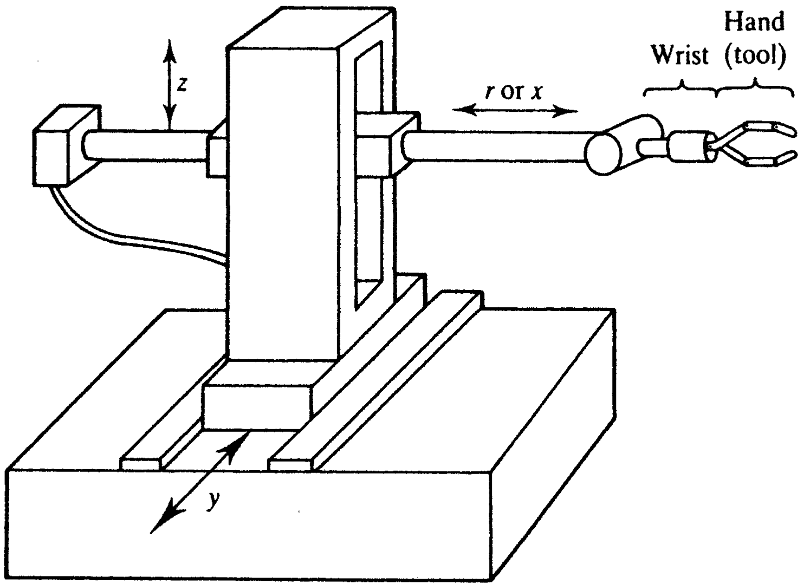
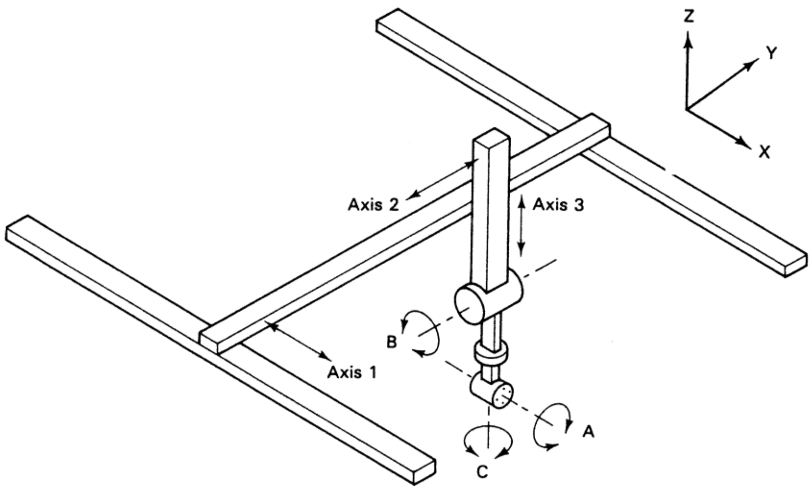
Geometric Classification

- **Cartesian Robot**





Traverse Robot



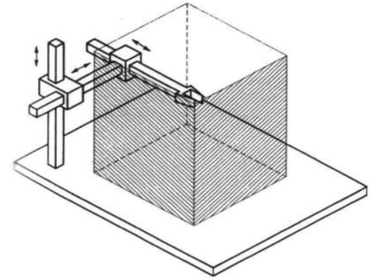
Rectilinear Geometry Robot or Gantry Robot

✓ Very large work envelopes
✓ Overmounting saves space
✓ Simpler Control systems

× Access to work envelope by overhead crane or other material-handling equipment may be impaired by the robot-supporting structure
× Difficult maintenance

Geometric Classification

- **Cartesian Robot**

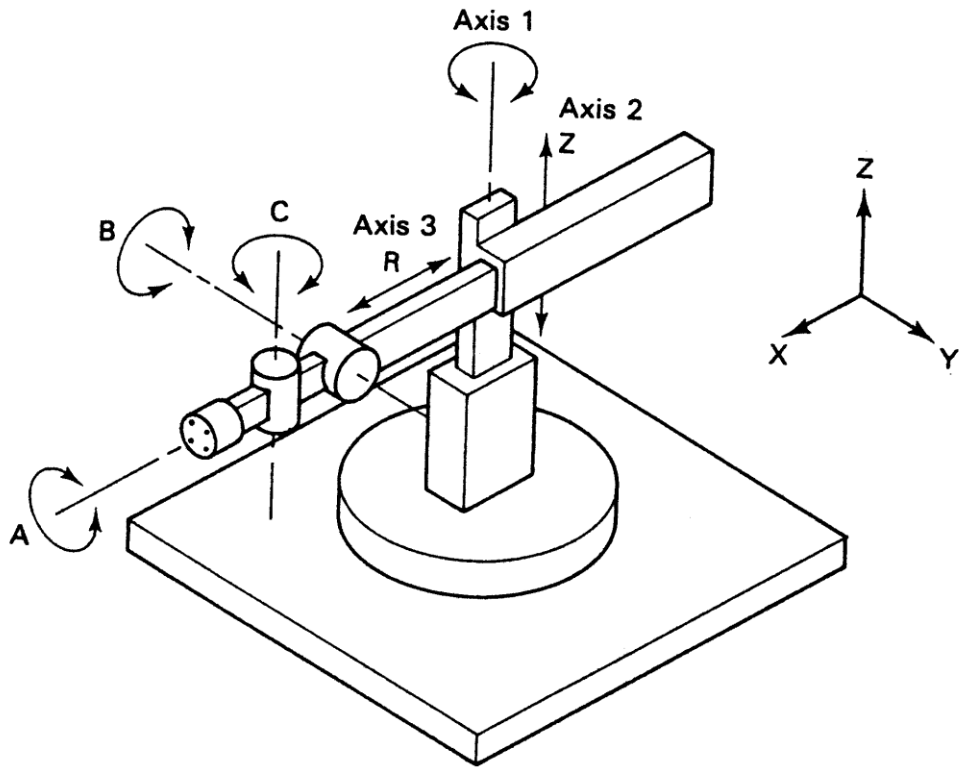


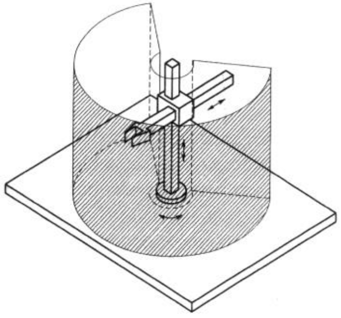
XRS System - Traverse Robot

GPM Gantry Robot

Geometric Classification

- **Cylindrical Robot**



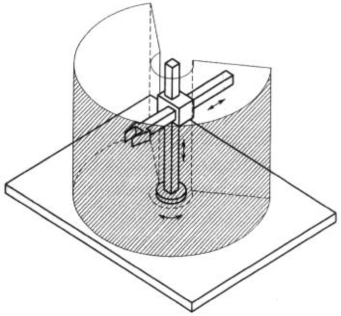


✓ Deep horizontal reach into production machines
✓ The vertical structure conserves floor space
✓ Large payloads and good repeatability

× Limited reach to left and right

Geometric Classification

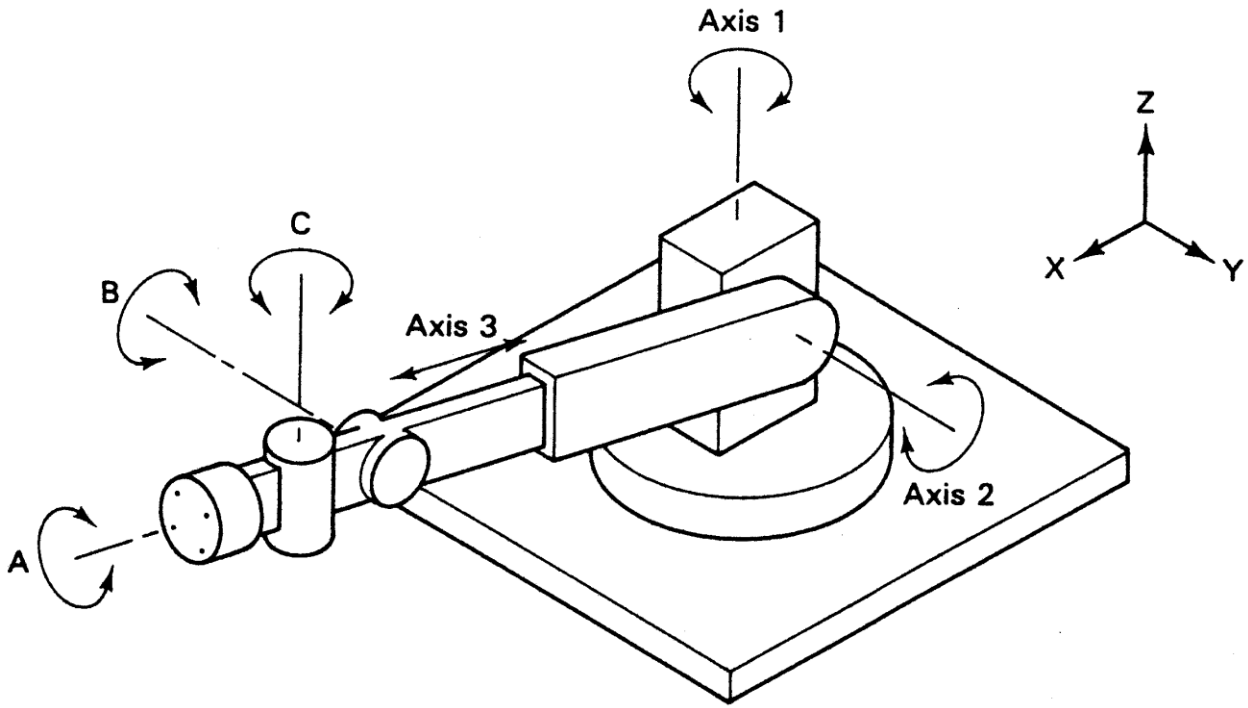
- **Cylindrical Robot**

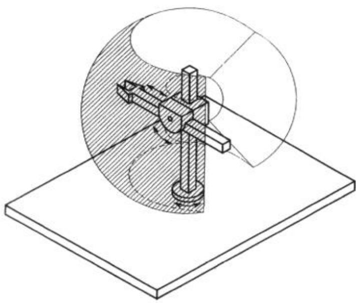


Robot RT33 (SEIKO Instruments)

Geometric Classification

- **Spherical or Polar Robot**



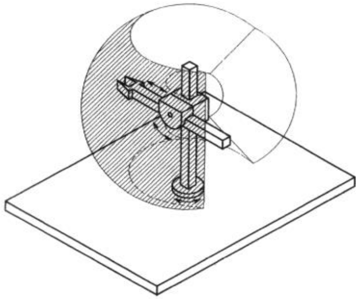


✓ Deep horizontal reach into production machines
✓ Low and long machine size conserves floor space
✓ Large payloads and good repeatability

× Limited reach to left and right

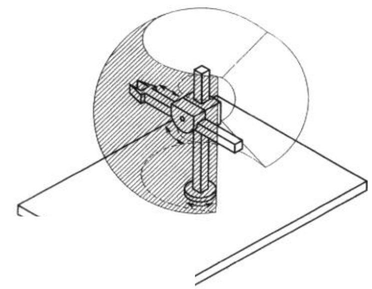
Geometric Classification

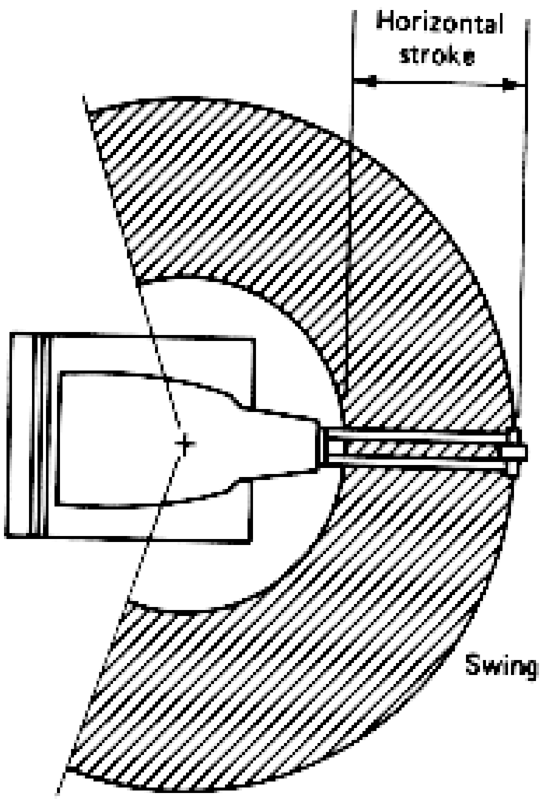
- **Spherical or Polar Robot**



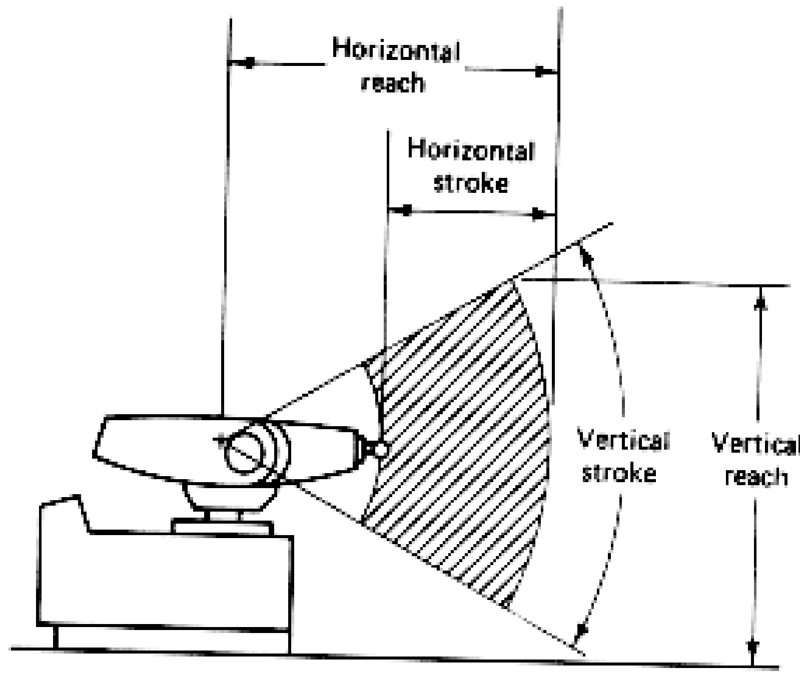
Geometric Classification

- **Spherical or Polar Robot: Work Envelope**





(a) Plan

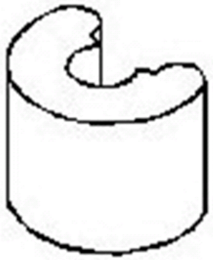


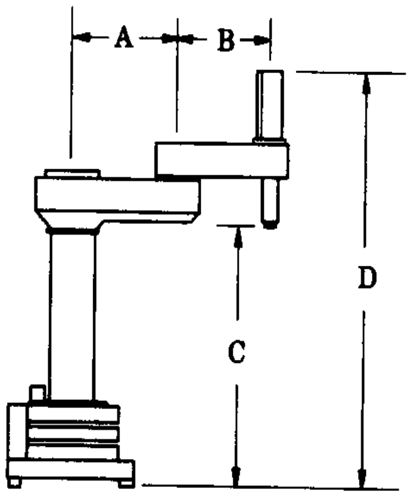
(b) Elevation

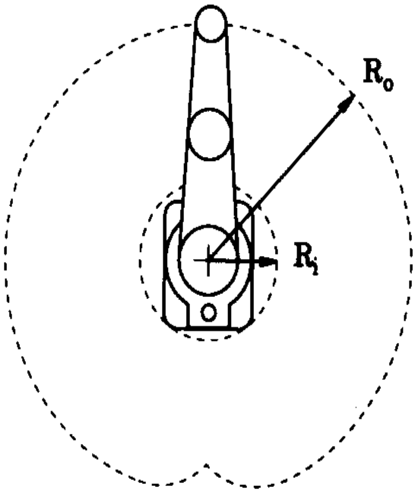
UNIMATION 2000

Geometric Classification

- **Articulated Robot (Jointed Arm, revolute, or anthropomorphic robot)**
  - **Horizontally Articulated Arms**







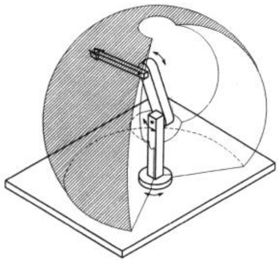
SCARA (Selective Compliance Articulated Robot Arm)

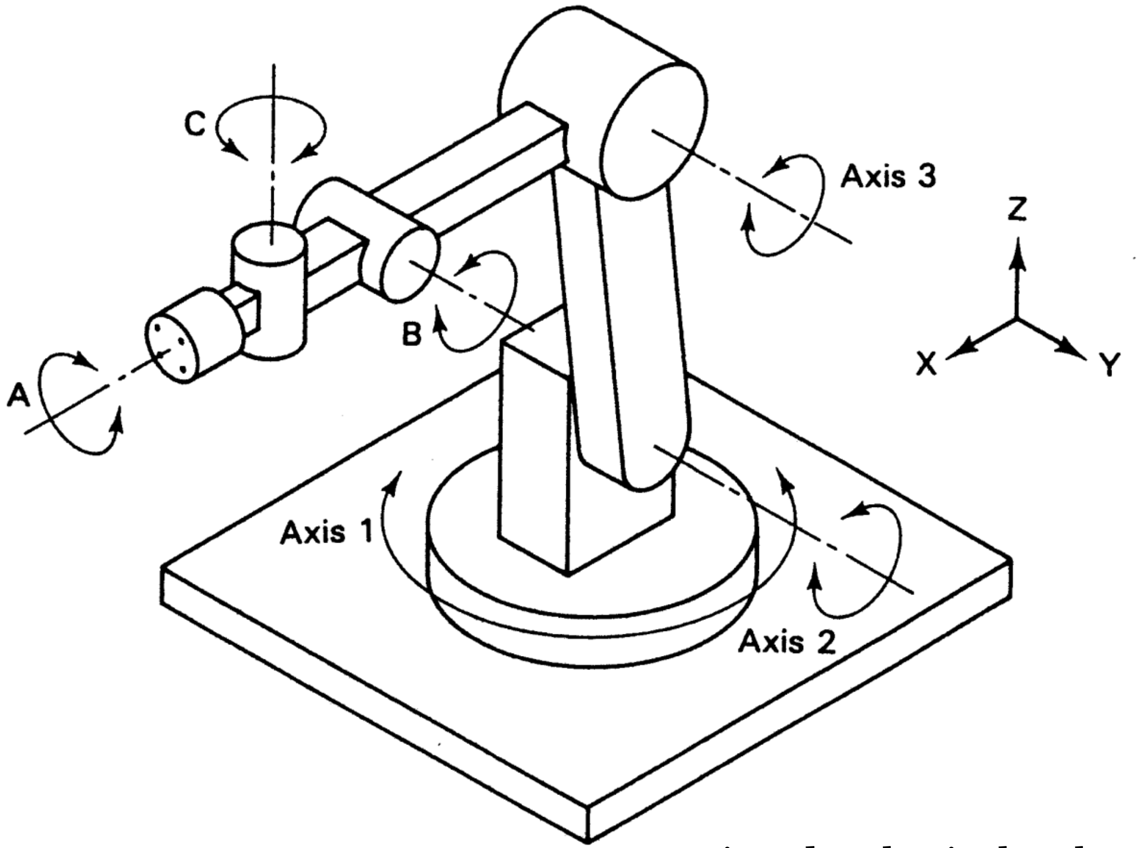
✓ Deep horizontal reach
✓ Good size-to-reach ratio
✓ High positioning mobility

× Requires more sophisticated control

Geometric Classification

- **Articulated Robot (Jointed Arm, revolute, or anthropomorphic robot)**
  - **Vertically Articulated Arms**



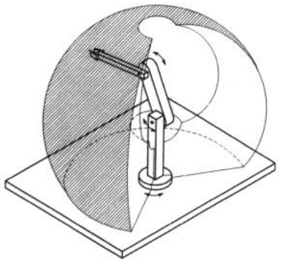


Jointed-Spherical Robot

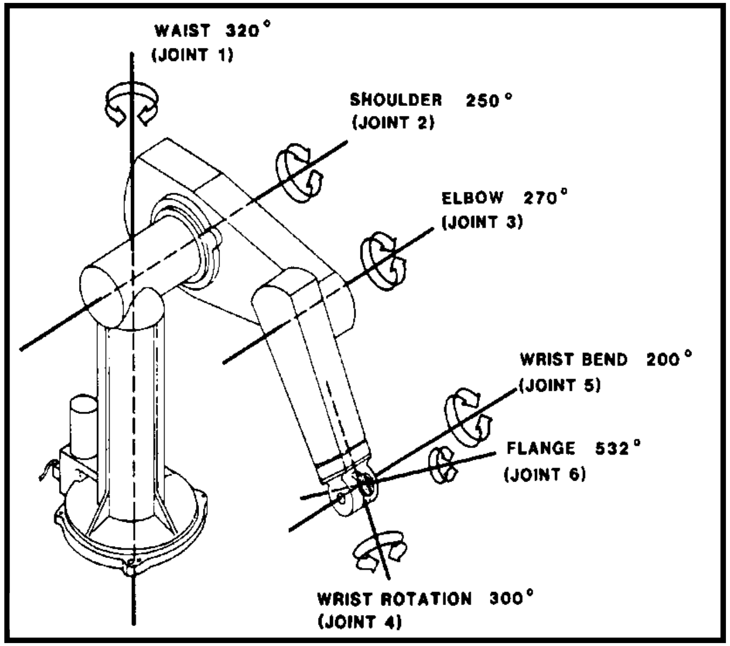
Geometric Classification

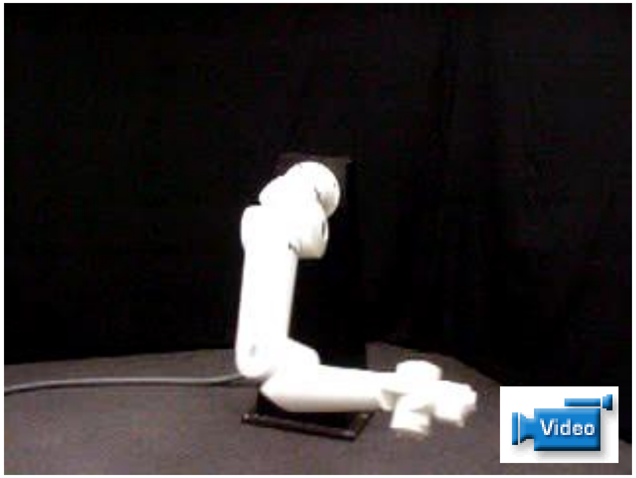
- **Articulated Robot (Jointed Arm, revolute, or anthropomorphic robot)**

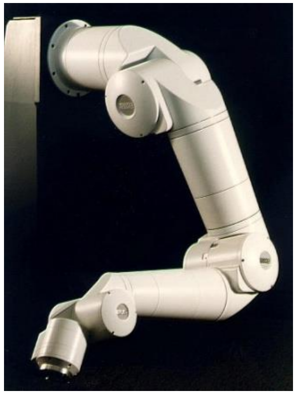
  - **Vertically Articulated Arms**



PUMA 560





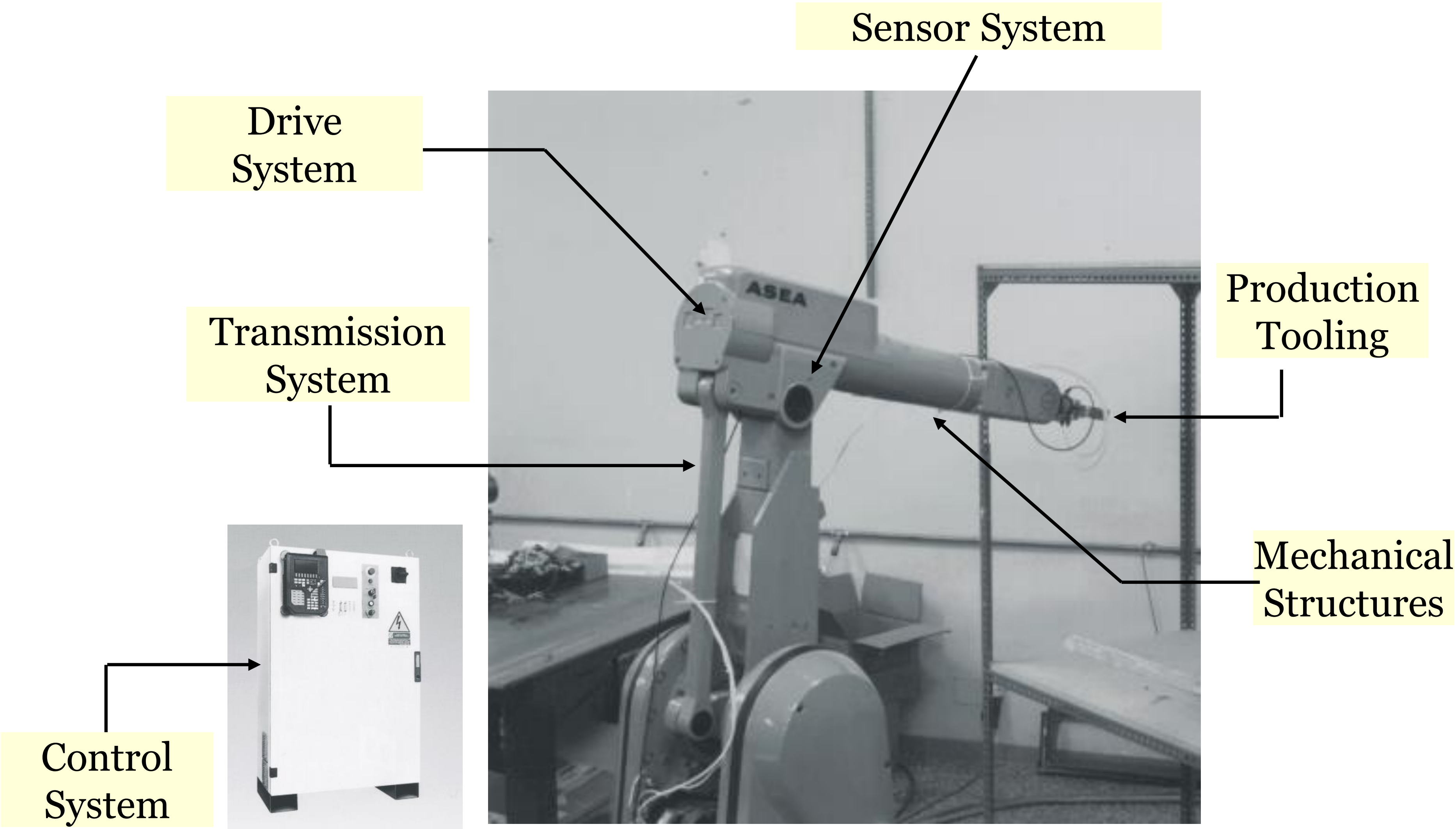


Robot K-1207i
7 GDL

Outline

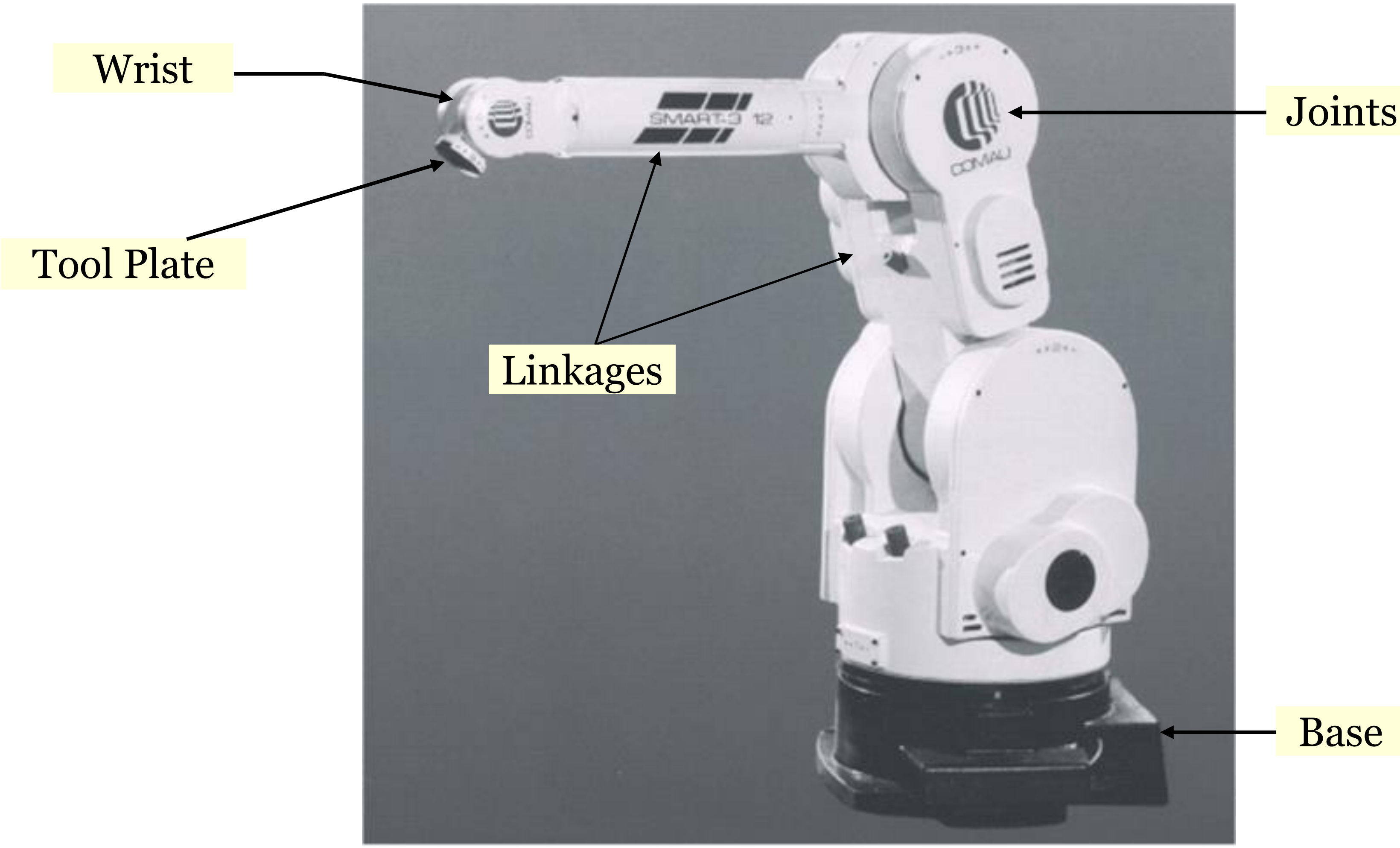
- What is an Industrial Robot?
- Basic Definitions
- Geometric Classification
- **Elements of Industrial Robot**
- Commercial Industrial Robots
- Summary

Elements of Industrial Robot



Elements of Industrial Robot

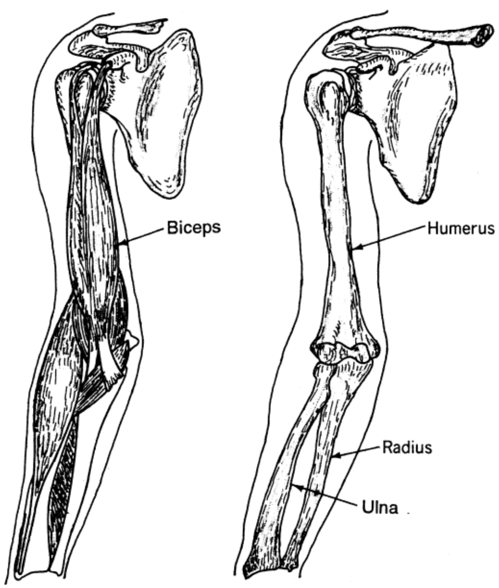
- **Mechanical Structure**

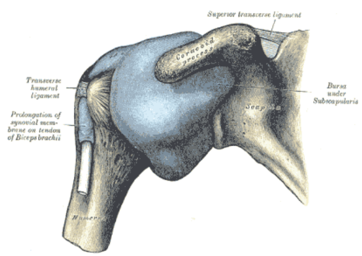


Elements of Industrial Robot

- **Joints**

A joint is a part at which two or more links are joined. Usually every joint or movable axis on the robot is a degree of freedom.

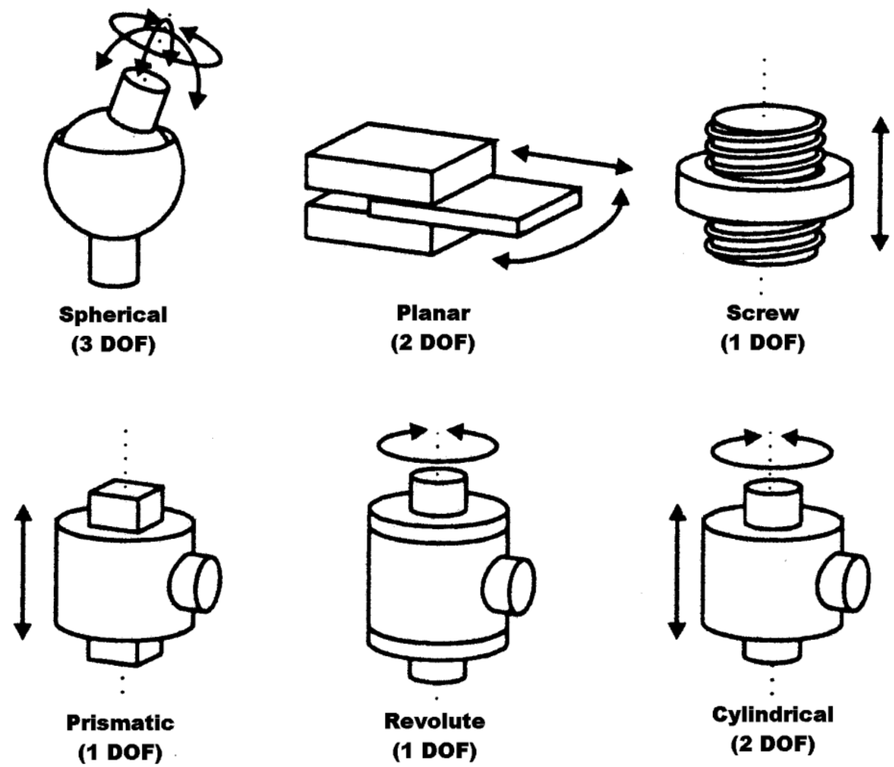




Shoulder: ball and socket joint

Elbow: hinged joint

Human Joints

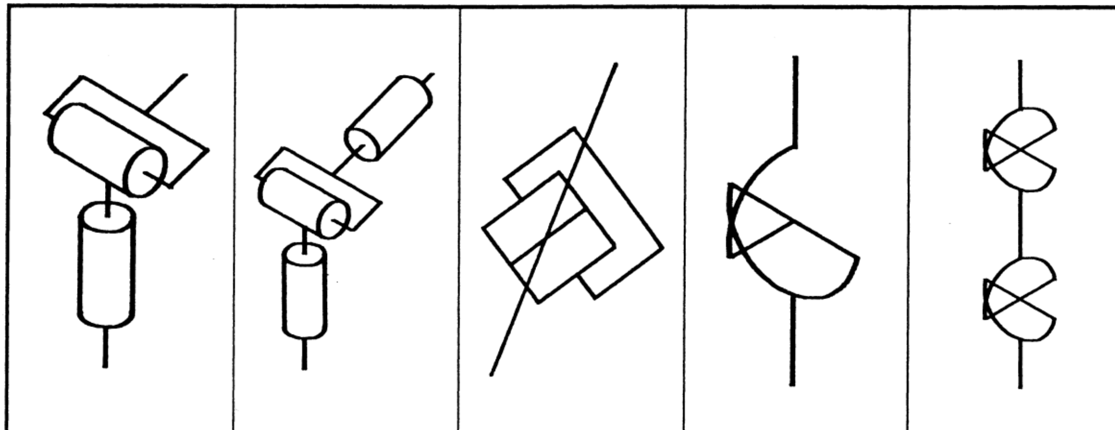


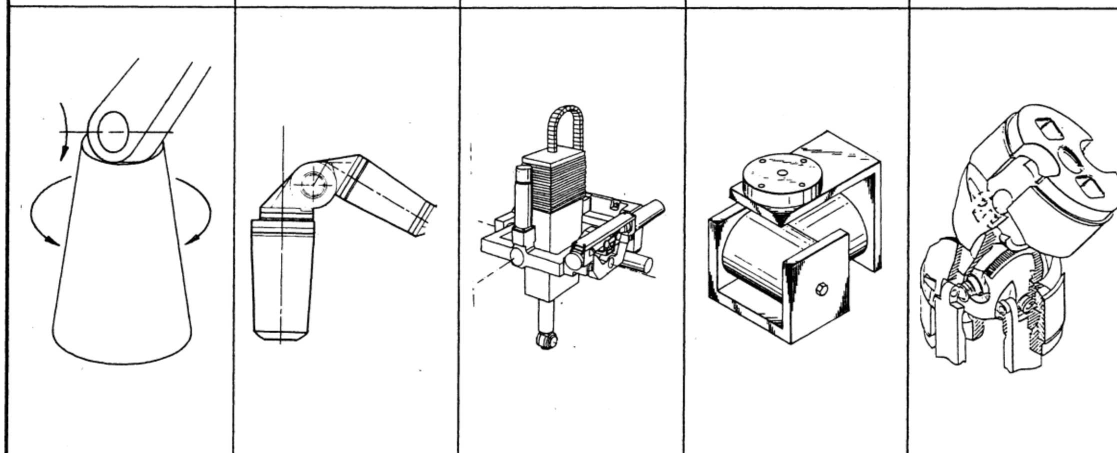
Robotic Joints

Note: Prismatic and revolute joints are the most commonly used

Elements of Industrial Robot

- **More Joints…**

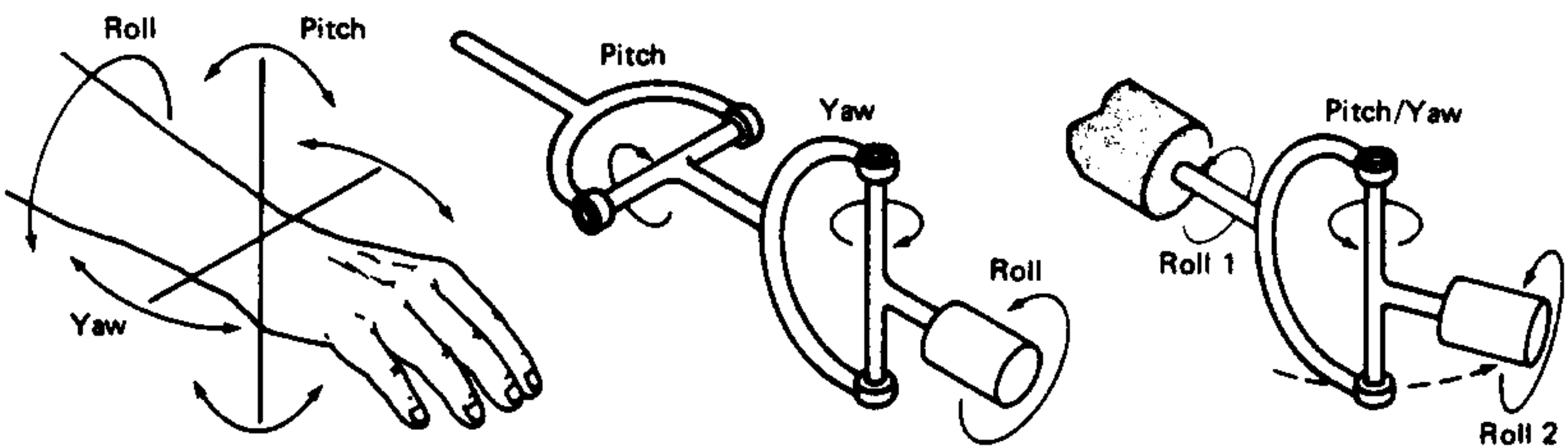




Roll-Pitch	Roll-Pitch-Roll	Gimbal, Single Center	U-Joint, Single Center	Double U-Joint
360° Roll 180° Pitch Standard design. Singularity	180° Roll 209° Yaw 360° Roll Becoming more common. Singularity	90° Pitch 90° Yaw 360° Roll Same applies to Tripod. Singularity-free	180° Pitch 90° Yaw 360° Roll Difficult to intergrate roll. Singularity-free	180° Pitch 180° Yaw 360° Roll Equivalent to human shoulder. Singularity-free

Elements of Industrial Robot

- **Wrist**
  - The wrist is a joint between the end-effector and the forearm of the robot.
  - Most of the arm geometries have 3-DOF, thus to obtain a 6-DOF robot, we need a 3-DOF wrist.

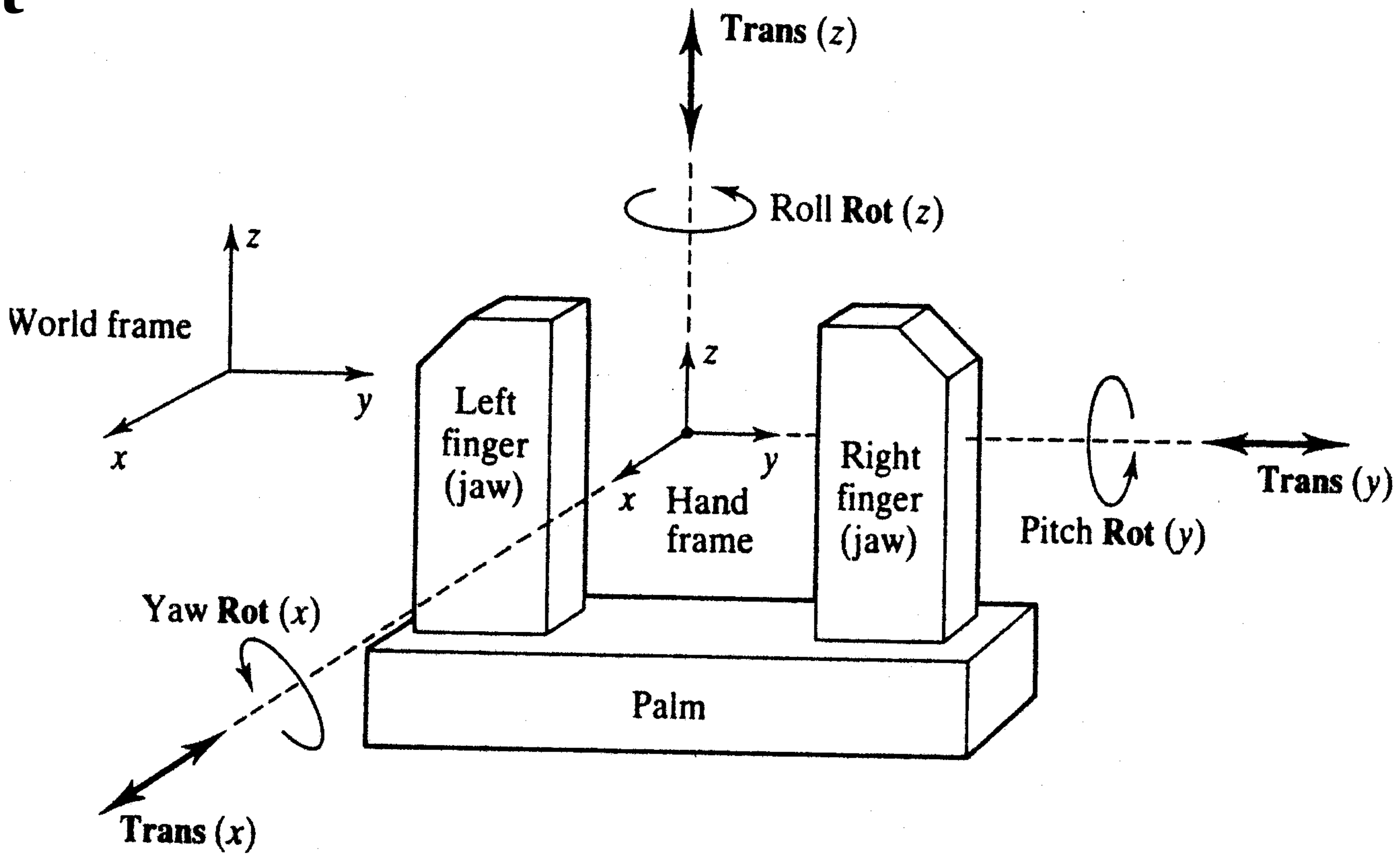


A. Human wrist B. Robot wrist C. Robot wrist

Hint: Roll, pitch, and yaw are nautical terms used to describe rotations.

Elements of Industrial Robot

- **Wrist**



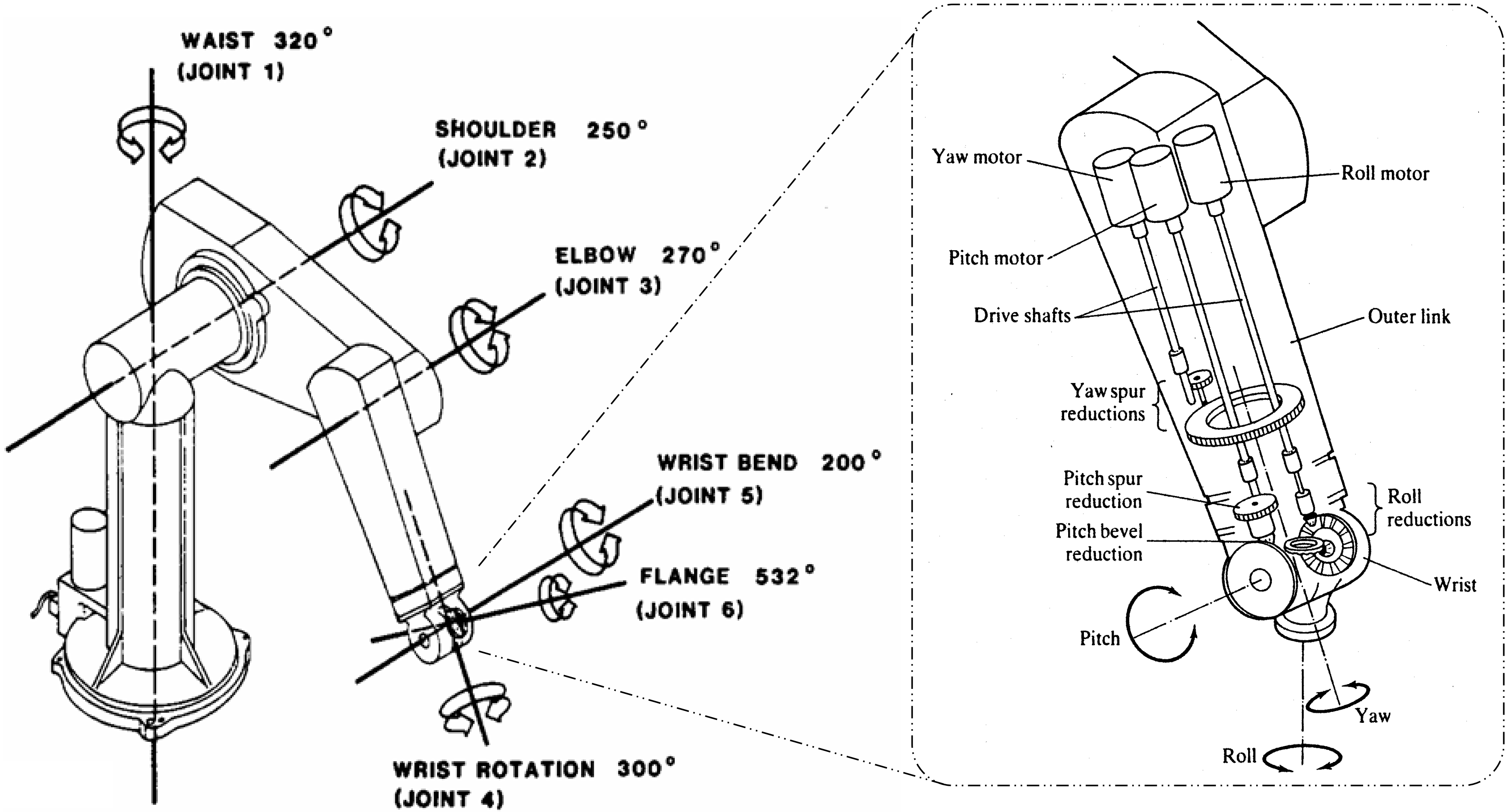
Six motions- three of rotation and three of translation- are required to position and orient a gripper at any point in space with any orientation.

Elements of Industrial Robot

- **Wrist: Desirable Features**
  - Small size
  - Axes close together to increase mechanical efficiency
  - Tool plate close to the axes to increase strength and precision
  - Soluble mathematical model, for example a spherical wrist where axes intersect at a point.
  - No singularities in the work volume
  - Back-driving to allow programming by teach and playback
  - Decoupling between motions around the three axes.
  - Actuators mounted away from the wrist to allow size reduction
  - Paths for end-effector control and power through the wrist
  - Power proportionate to the proposed task
  - Rugged housing.

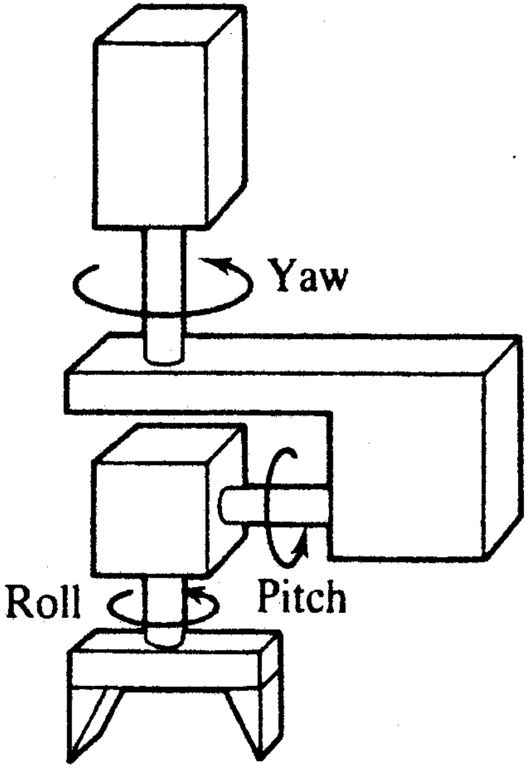
Elements of Industrial Robot

- **Wrist: Unimation Puma 3-axis Wrist**



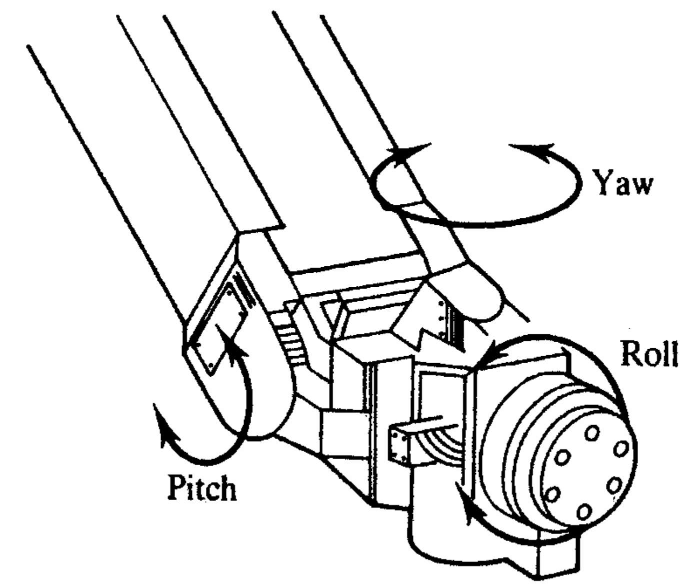
Elements of Industrial Robot

- **Wrist: IBM 7665 Wrist**
  - This wrist archives a spherical configuration, with the joints physically spread out.
  - It has been designed for use in precision assembly applications where high power is not needed.
  - When roll and yaw axes line up, one degree of freedom is lost.
  - Technically it is more correct to refer to this wrist as a roll-pitch-roll wrist.



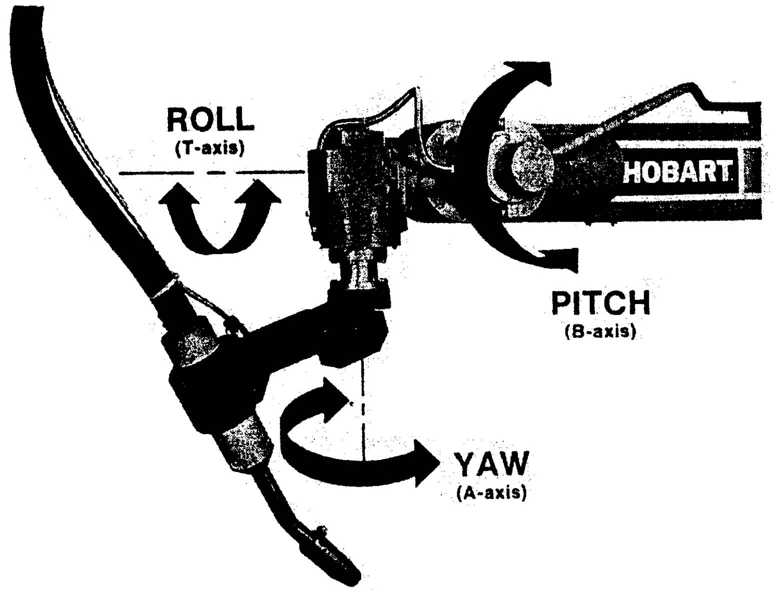
Elements of Industrial Robot

- **Wrist: IBM 7665 Wrist**



Cincinnati Milacron T3 Wrist

This wrist effectively decouples pitch, yaw, and roll actions, but it is very large, partly because the hydraulic motors are mounted at the joints.



Hobart Wrist

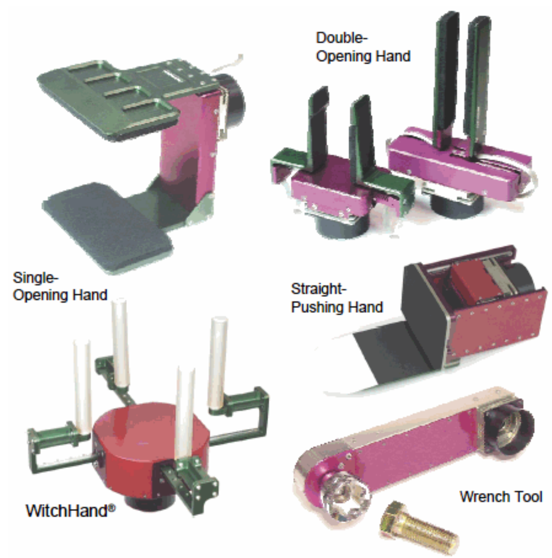
2-DOF wrist upgraded to a 3-DOF wrist on a Hobart Motoman Robot

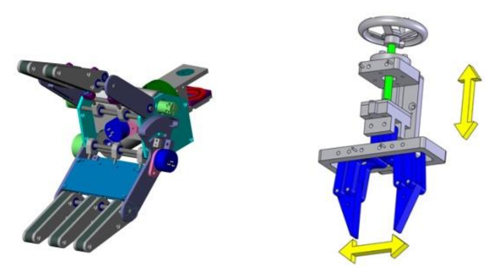
Elements of Industrial Robot

- **Production Tooling**

  Duplication of human hand with its ability to grasp, sense, and manipulate objects remains one of the most difficult tasks facing robot designers.

Human Hand

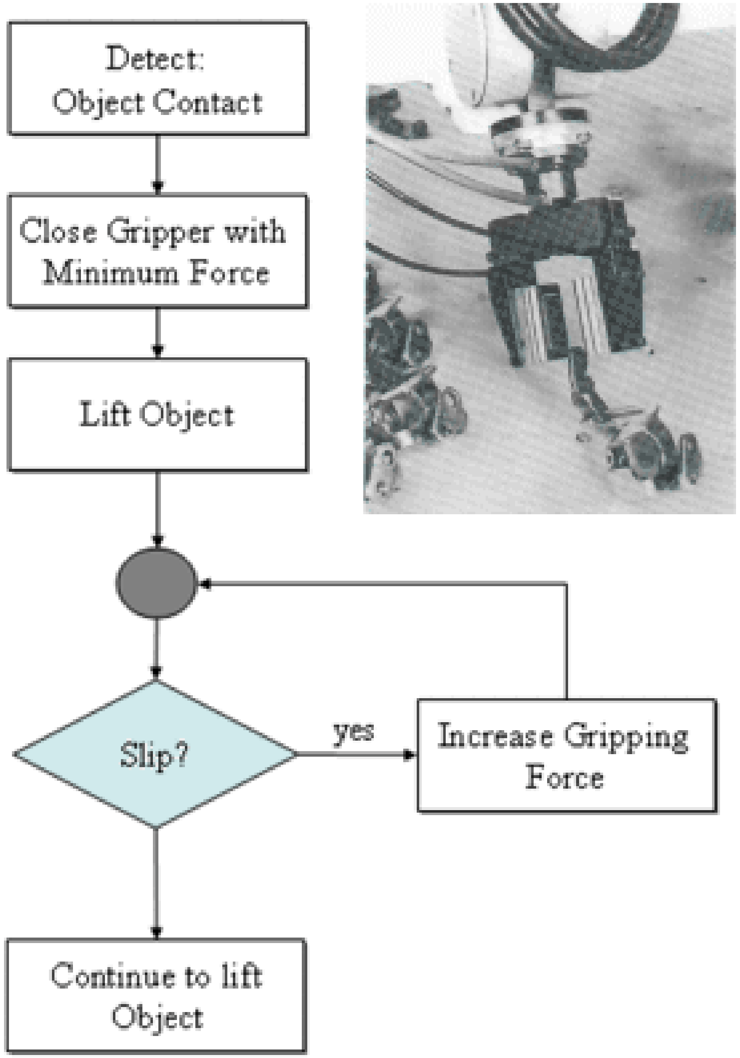




Robotic Hands

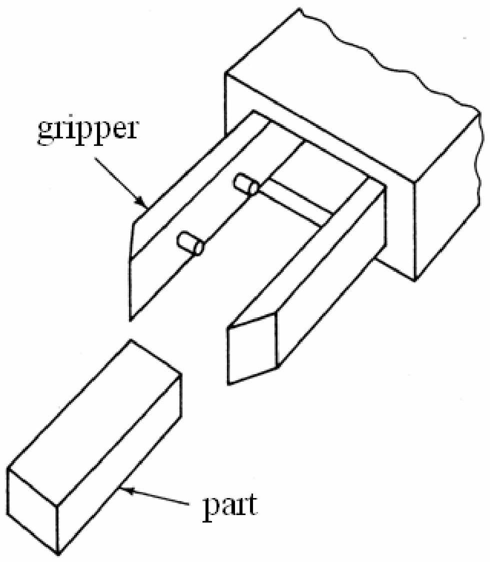
Elements of Industrial Robot

- **Production Tooling: Necessary Characteristics**
  - The tooling must be capable of gripping, lifting, and releasing the part or family of parts required by the manufacturing process.
  - The tooling must sense the presence of a part in the gripper, using sensors located either on the tooling or at a fixed position in the work cell.



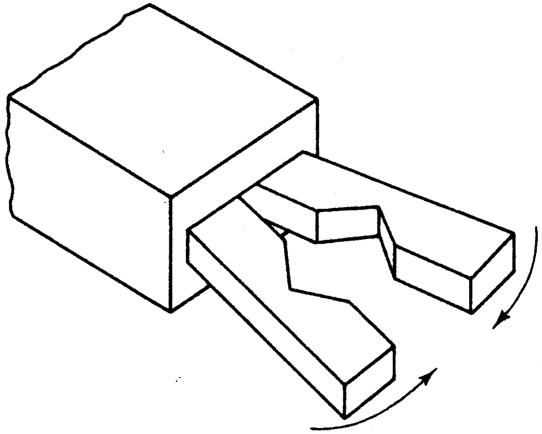
Elements of Industrial Robot

- **Production Tooling: Necessary Characteristics**
  - Tooling weight must be kept to a minimum since it is added to part weight to determine maximum payload.
  - Containment of part in the gripper must be assured under conditions of maximum velocity at the tool plate and loss of gripper power.
  - The simplest gripper which meets the first four criteria should be one implemented.

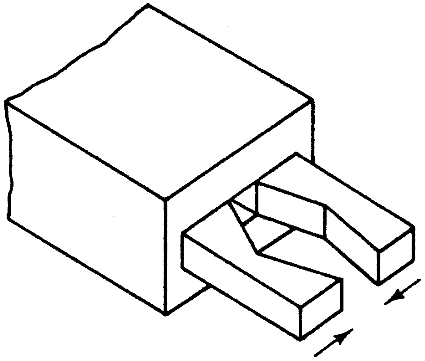


Elements of Industrial Robot

- **Production Tooling: Standard Grippers**
  - Standard grippers can have two different closing motions, angular or parallel.



Angular

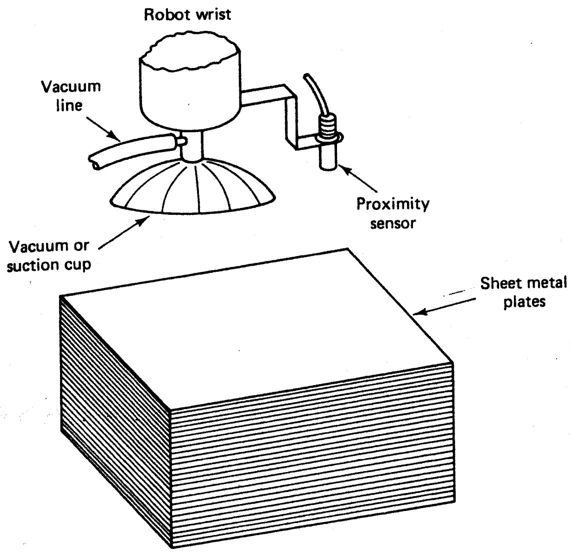


Parallel

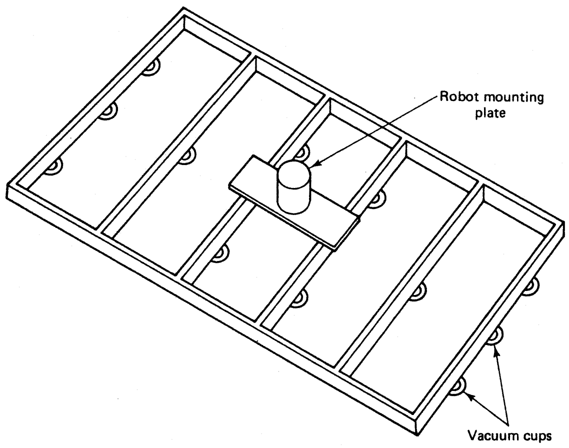
  - It can have pneumatic, hydraulic, electric, or spring power for closing and opening.
  - The gripper must be closed and opened by program commands as the robot moves through the production operation.

Elements of Industrial Robot

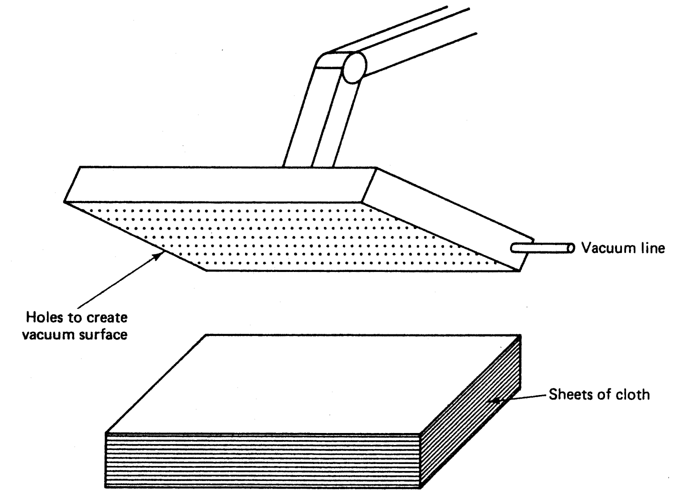
- **Production Tooling: Vacuum Grippers**
  - ➢ The part is lift by vacuum cups, by a vacuum surfer or a vacuum sucker gun incorporated into the end-of-arm tooling.



Vacuum Cup System to Unstack Sheet Metal Plates



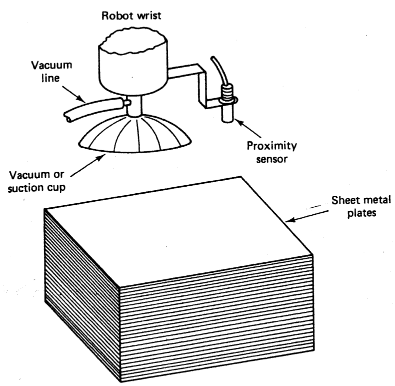
Multiple Vacuum Cup System to Handle Large Sheets of Material

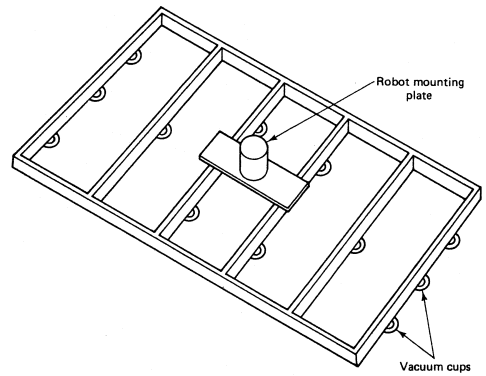


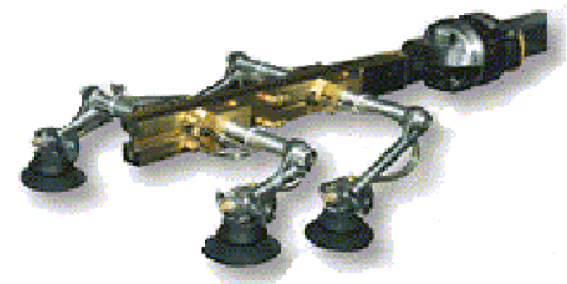
Vacuum Surface

Elements of Industrial Robot

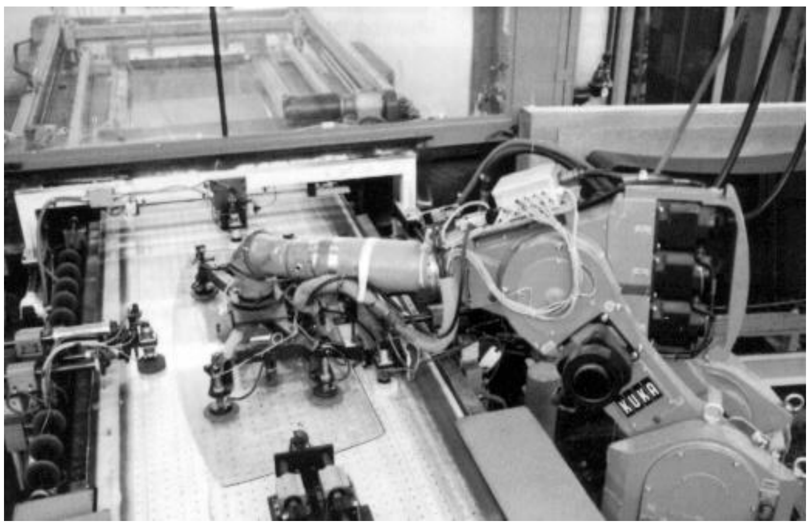
- **Production Tooling: Vacuum Grippers**







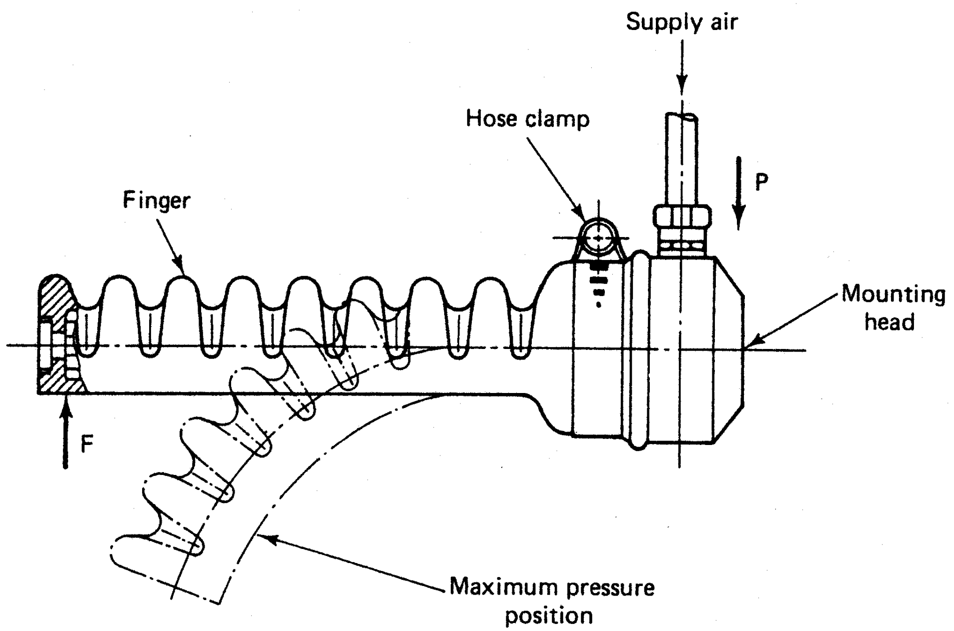
Vacuum Cup



Multiple Vacuum Cup System

Elements of Industrial Robot

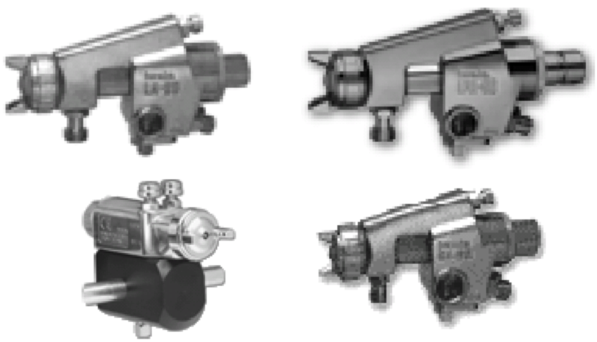
- **Production Tooling: Air-Pressure Grippers**
  - Fingers, mandrel grippers, and pin grippers form a group that uses air pressure to grip parts.
  - The fingers have a hollow rubber-like body with a smooth surface on one side and a ribbed surface on the opposite side. With pressure applied to inside of the hollow body, the finger deflects in the direction of the smooth side



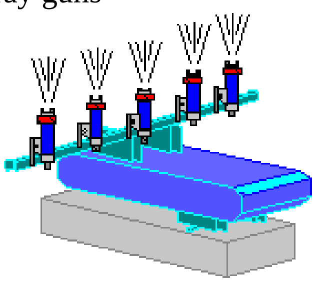
Pneumatic Finger

Elements of Industrial Robot

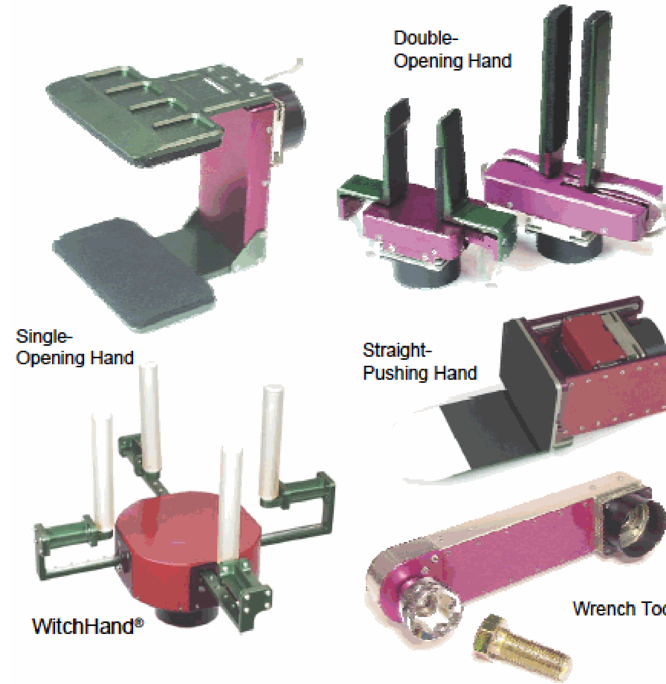
- **Production Tooling: other tools**



Paint Spray guns



Welding torch



Elements of Industrial Robot

- **Production Tooling: Tool Changer**

  Tool Changer provides an easy and convenient method of running jobs requiring multiple tooling

Elements of Industrial Robot

- **Drive System**

Actuation System

Electric Actuation

Pneumatic Actuation

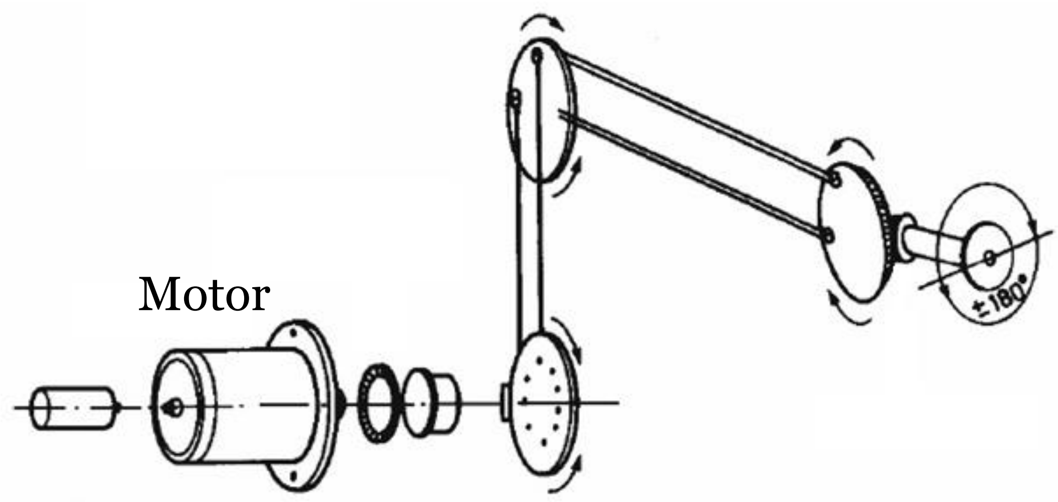
Hydraulic Actuation

Self-study: A-Robot Report: Actuation Systems

Elements of Industrial Robot

- **Transmission System**

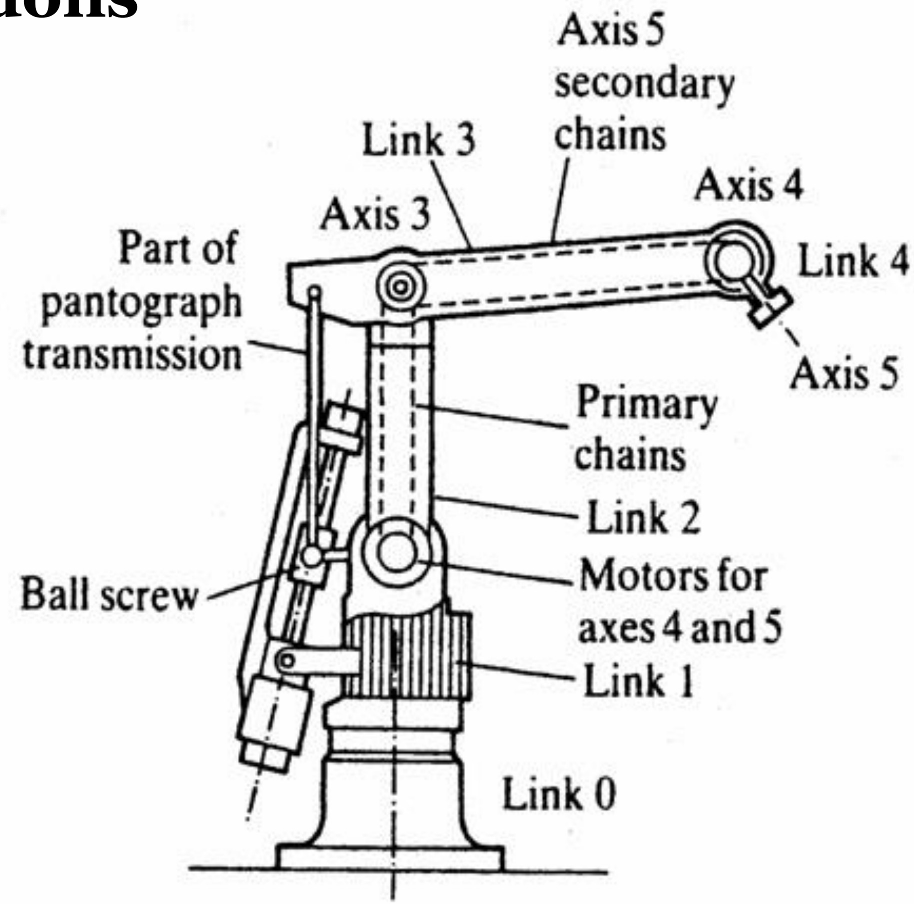
  Transmission system helps to transmit the power from an actuator to the object it is moving, for example, from an electric motor to a linkage.



  ➢ Typical transmission devices are tendons, linkages, and gears.

Elements of Industrial Robot

- **Transmission System: Tendons**
  - Tendons are made of wires, chains, and timing belts.
  - They are used when the designer wants the actuator to be remote from the application.
  - This allows joints to be smaller, and reduces the load applied to the actuators of he previous joints



Chain Transmission in Yakamor Motoman Robot

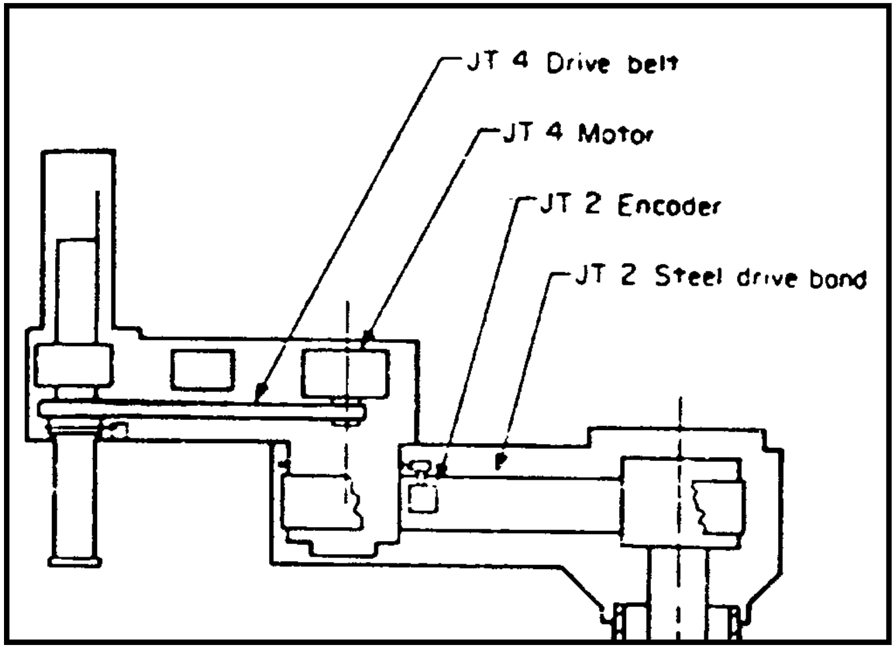
Using chains to transmit power from actuators in the truck to joints 4 and 5 of robot manipulator.

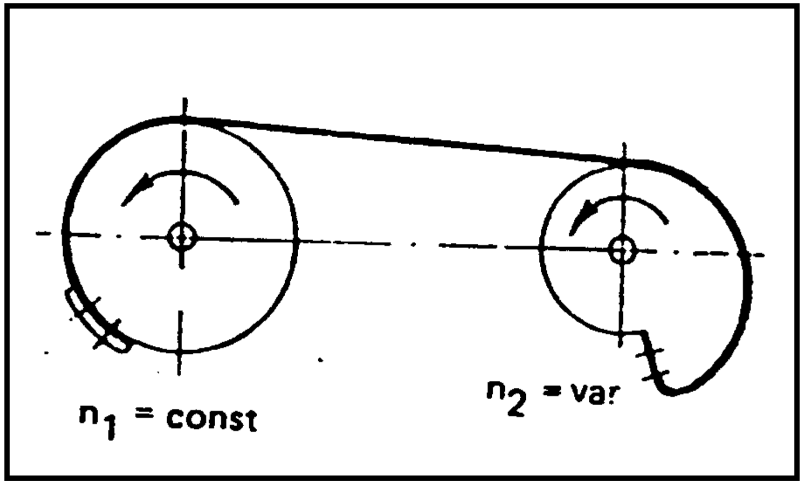
Elements of Industrial Robot

- **Transmission System: Tendons**
  - When tendons are used, actuators are often mounted in the base of the robot, allowing the overall bulk of the robot to be reduced, improving the power-to-weight ratio.
  - Tendons provide smooth control al low speed, however, they can stretch, reducing control accuracy.

Elements of Industrial Robot

- **Transmission System: Tendons - Belts**

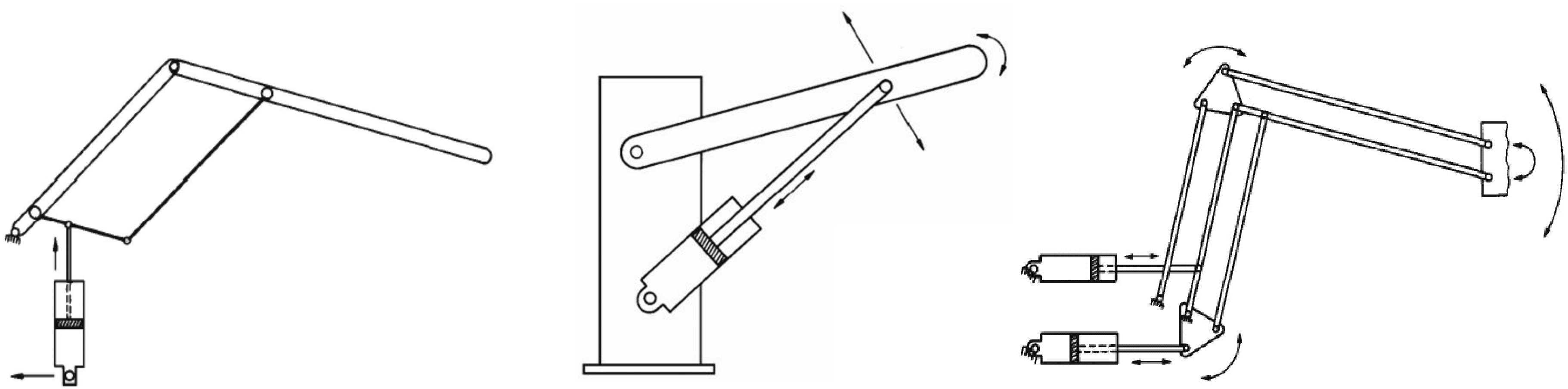




Elements of Industrial Robot

- **Transmission System: Linkages**

  Some robots use linkages to transmit power to the joints, because linkages do not suffer from inaccuracies due to stretching and wear.



➢ Even though linkages are stiff, transmission stiffness is limited by the bearings and shafts that connect the linkages

Elements of Industrial Robot

- **Transmission System: Gears**

  Gears are the most common transmission elements used in robots.

$$\mathbf{T_{shaft} = \eta\, T_{motor}\, N}$$

$$\mathbf{N = \omega_{motor}/\omega_{shaft}}$$

$\mathbf{T_{shaft}}$ **:** Shaft Torque (output)

$\mathbf{T_{motor}}$ **:** Motor Torque (input)

$\mathbf{\eta}$ **:** Performance

N: the gear size ration

$\mathbf{\omega_{shaft}}$ **:** Shaft Angular Velocity (output)

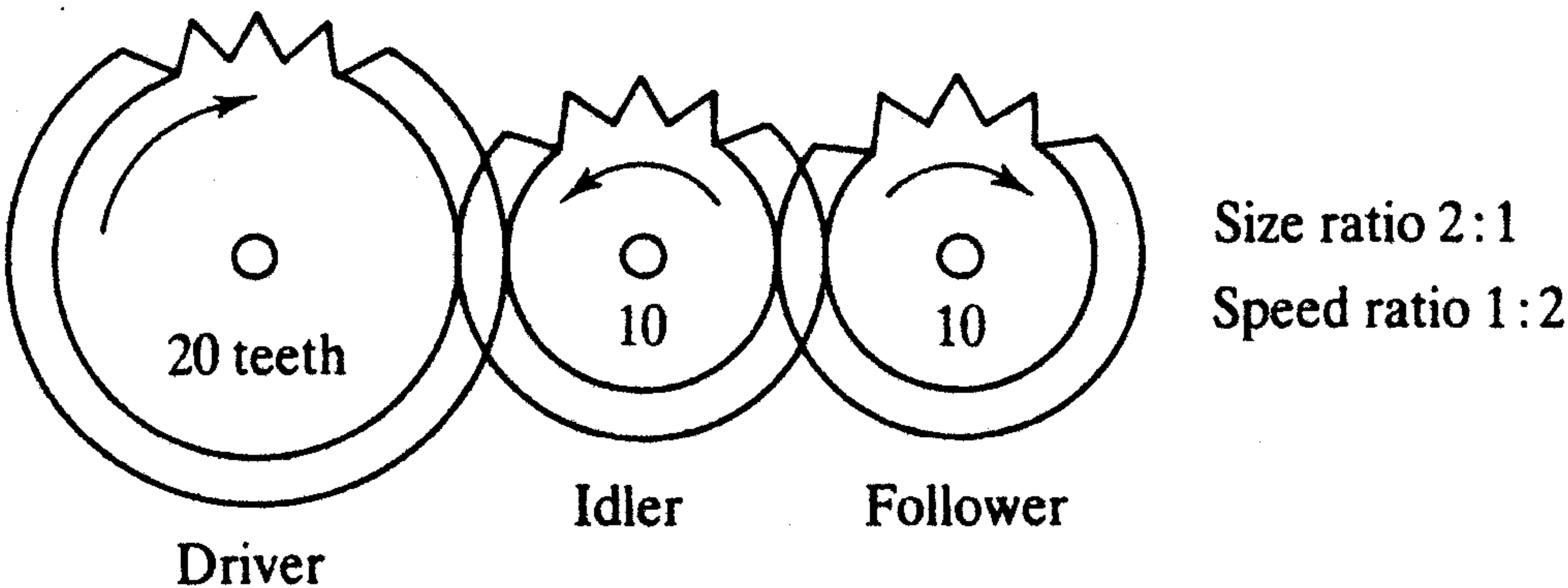
$\mathbf{\omega_{motor}}$ **:** Motor Velocity (input)

For N>1 ➢➢ Shaft torque increases and velocity decreases

For N<1 ➢➢ Shaft torque decreases and velocity increase

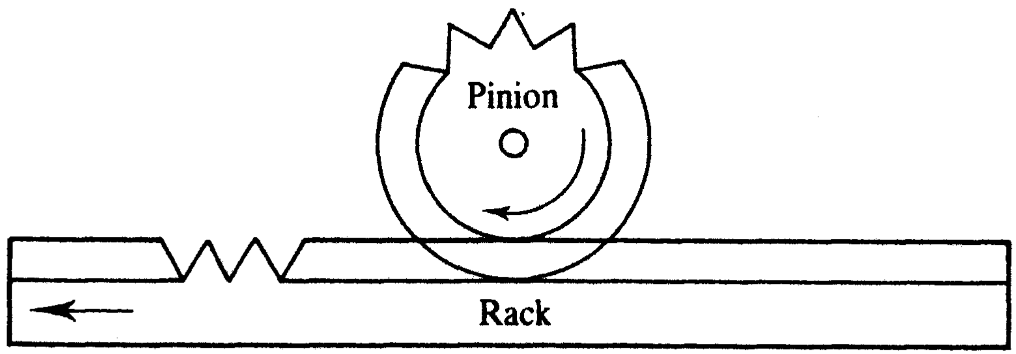
Elements of Industrial Robot

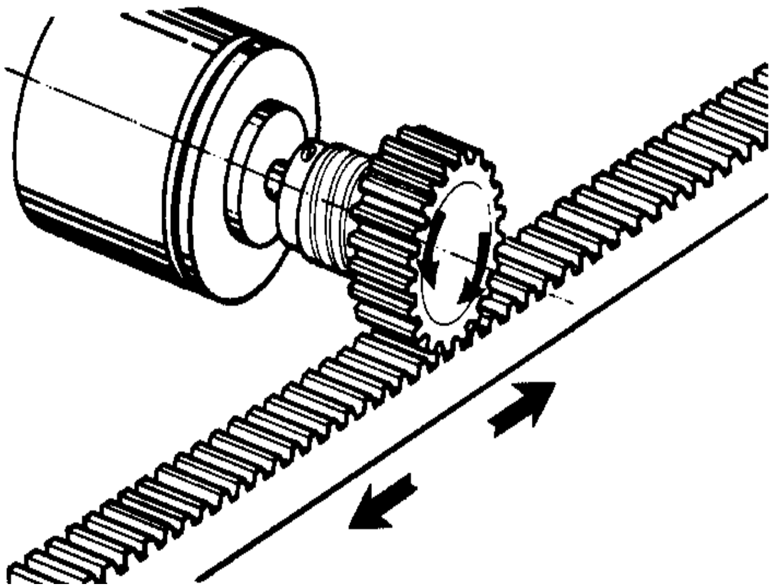
- **Transmission System: Gears – Spur Gear**



Elements of Industrial Robot

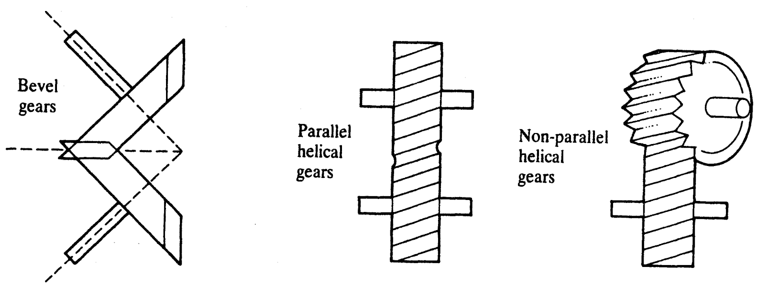
- **Transmission System: Gears – Rack and Pinion Gear**

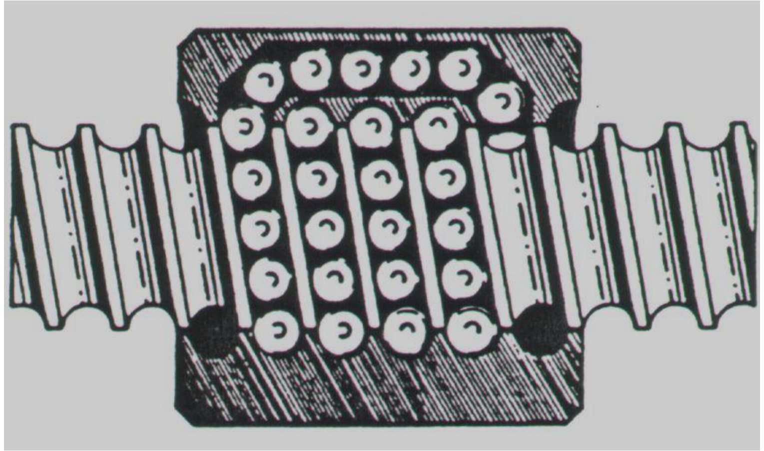


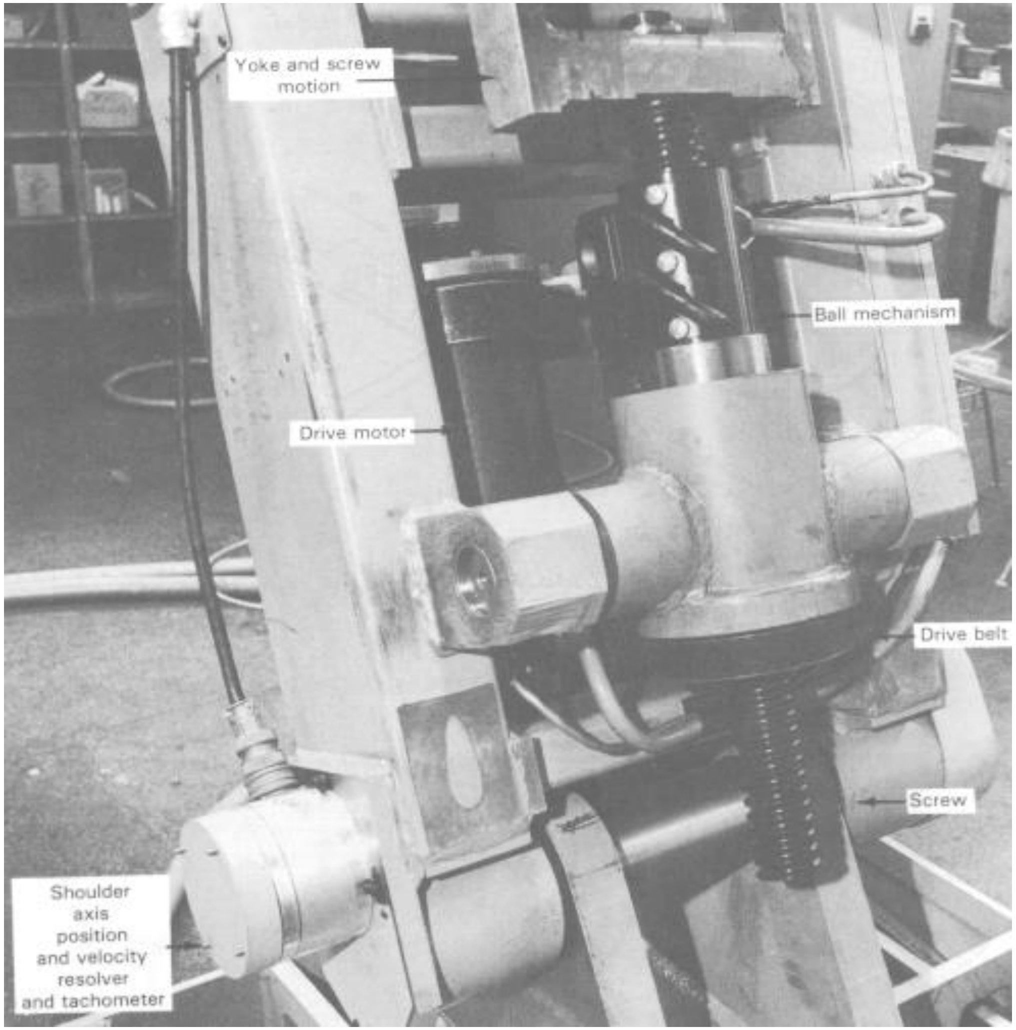


Elements of Industrial Robot

- **Transmission System: Gears – Helical (Spiral) Gear**

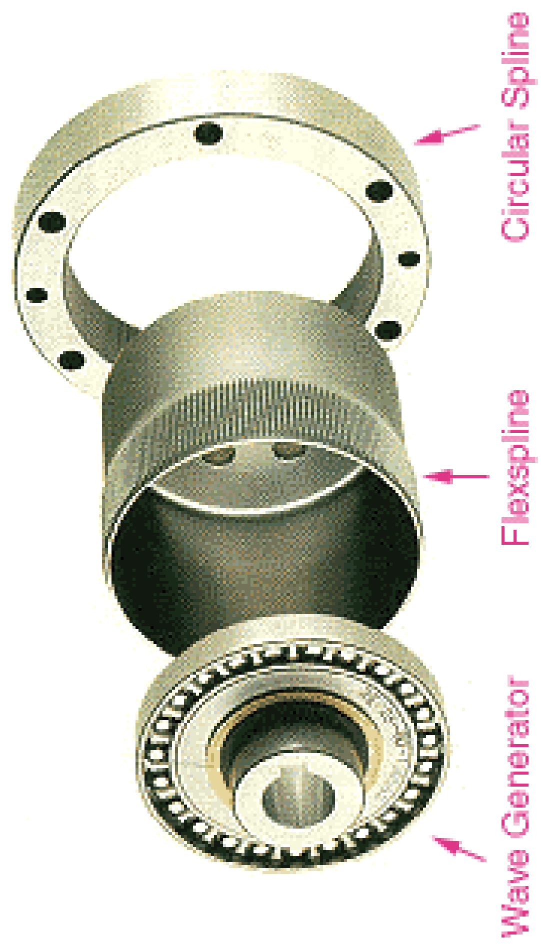






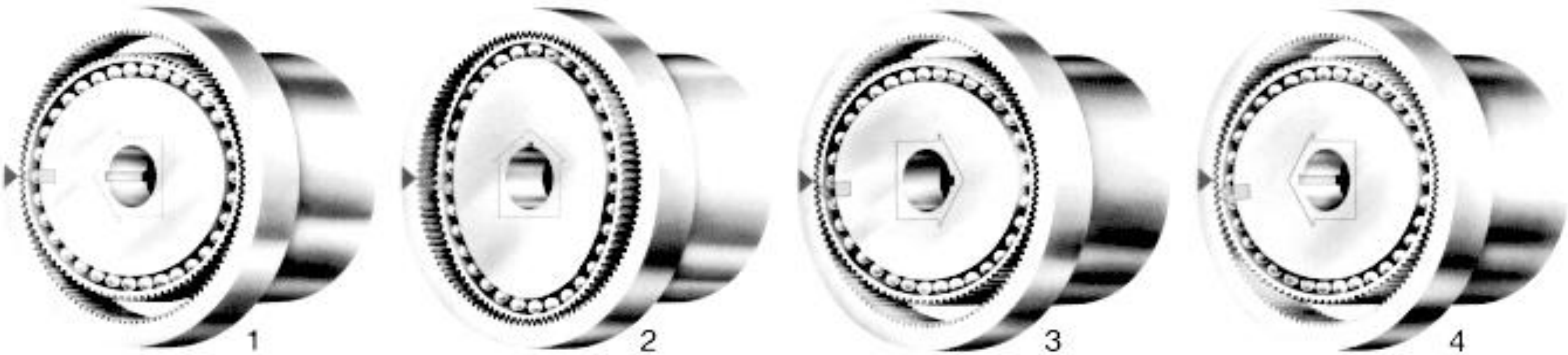
Elements of Industrial Robot

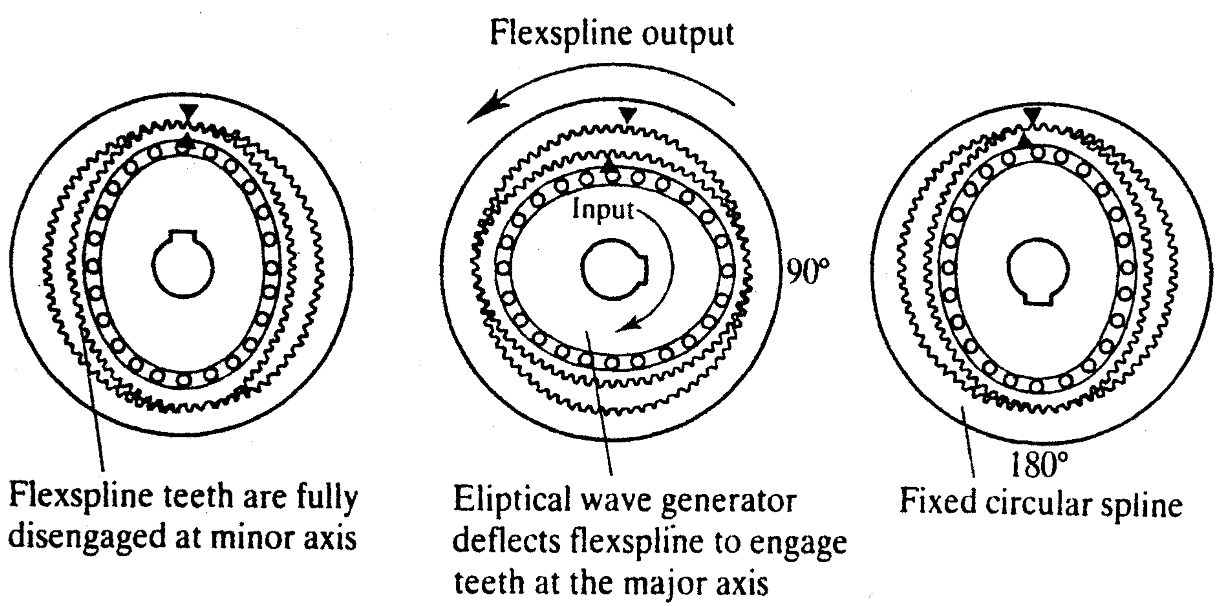
- **Transmission System: Gears – Harmonic Drive**
  - Harmonic drives are commonly used with revolute joints.
  - These drives have in-line parallel shafts, very high gear ratios, high mechanical advantages, compact packages, and with proper parts matching, near-zero backlash.
  - They suffer from high static friction and cyclic frictional toque variations called cogging.
  - Velocity reduction **ratio up to 320**.

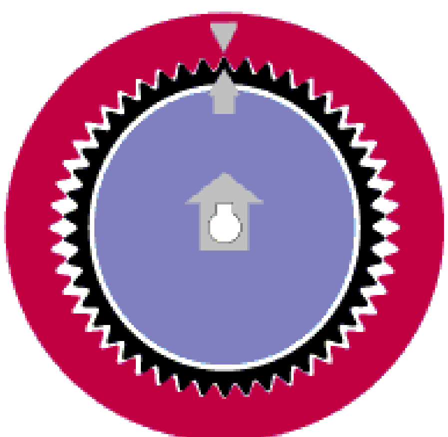


Elements of Industrial Robot

- **Transmission System: Gears – Harmonic Drive**



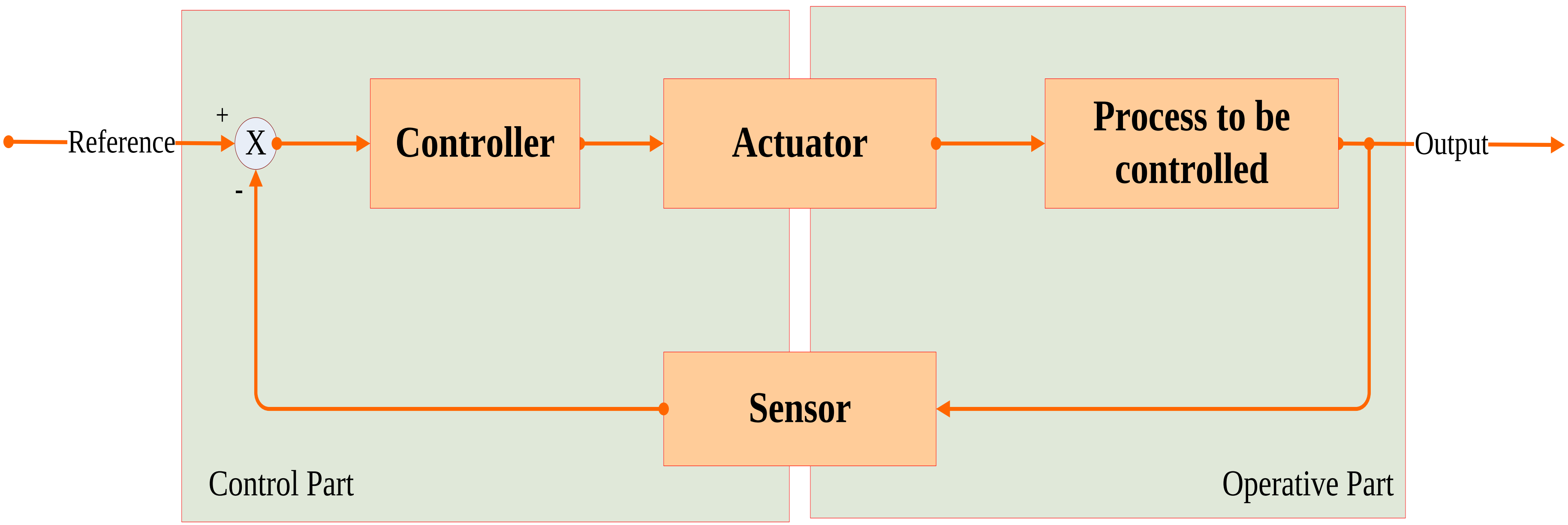




Video

Elements of Industrial Robot

- **Sensor System**



Self-study: A-Robot Report: Sensors for Industrial Robots

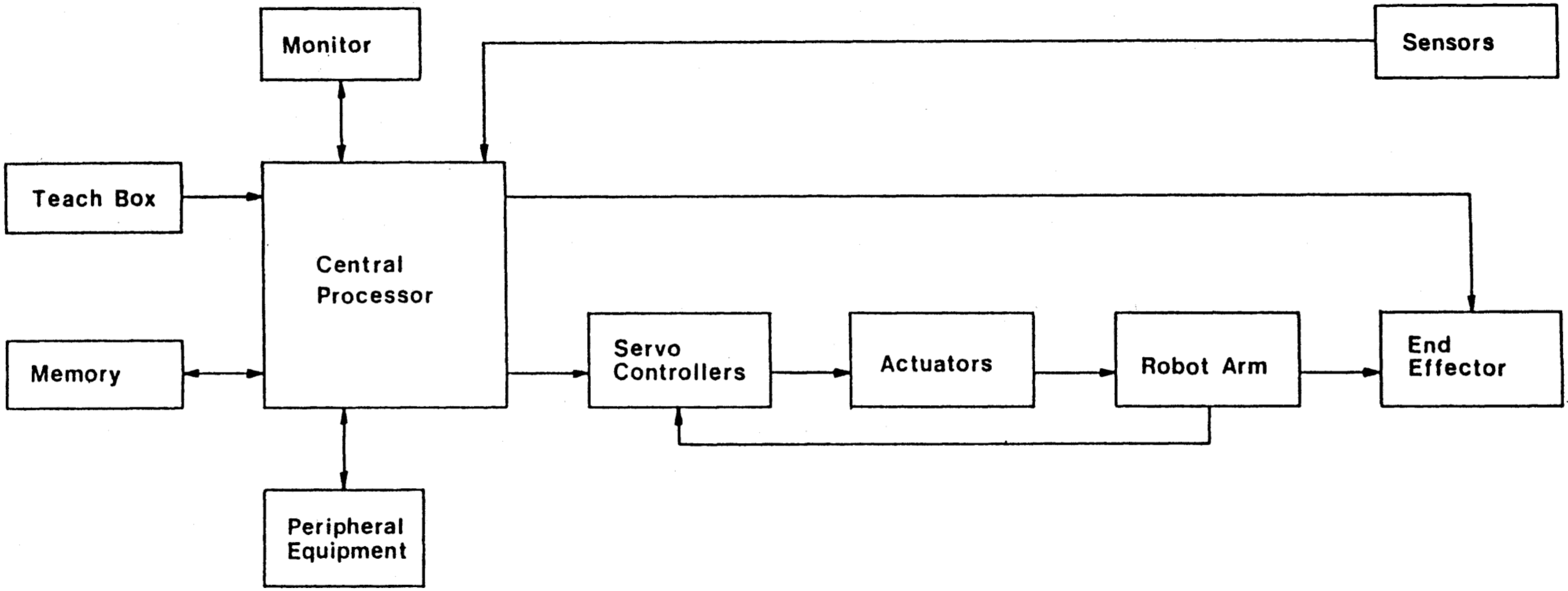
Elements of Industrial Robot

- **Control System**

Control Unit

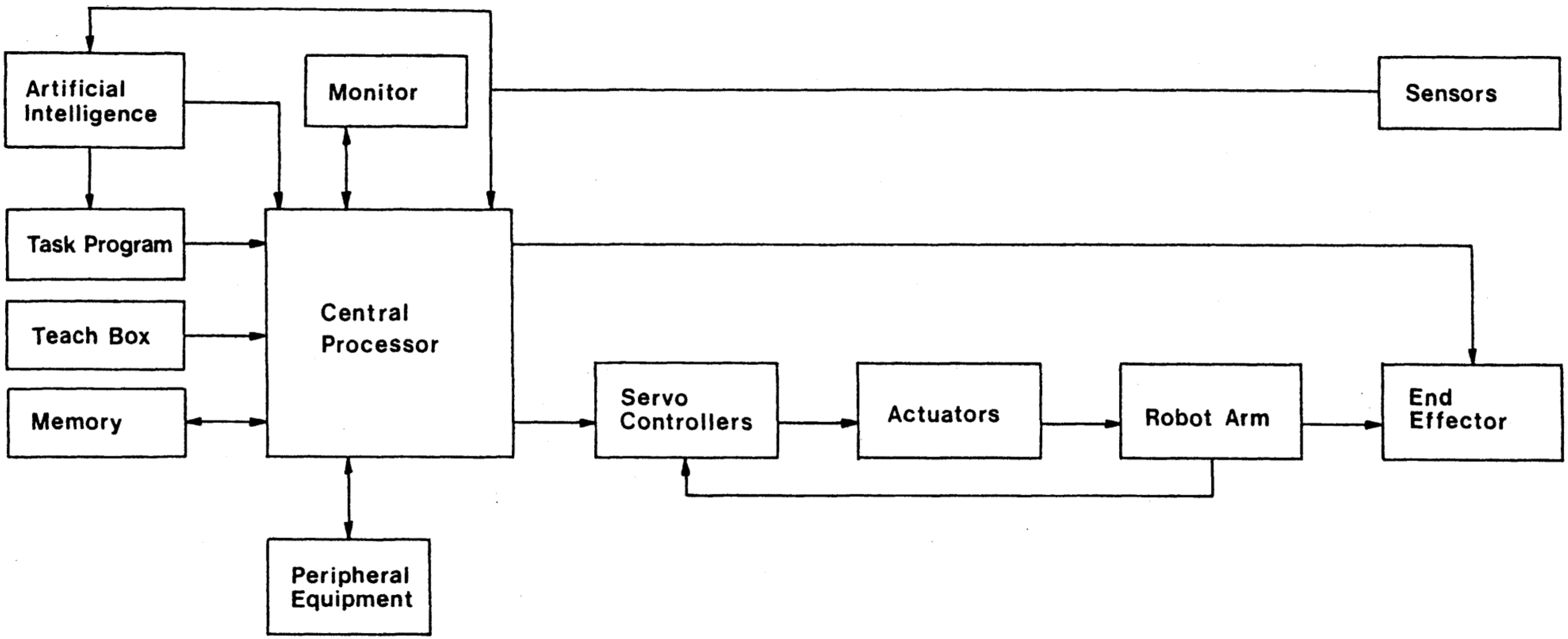
Elements of Industrial Robot

- **Control System: Traditional Control System**



Elements of Industrial Robot

- **Control System: Intelligent Control System**



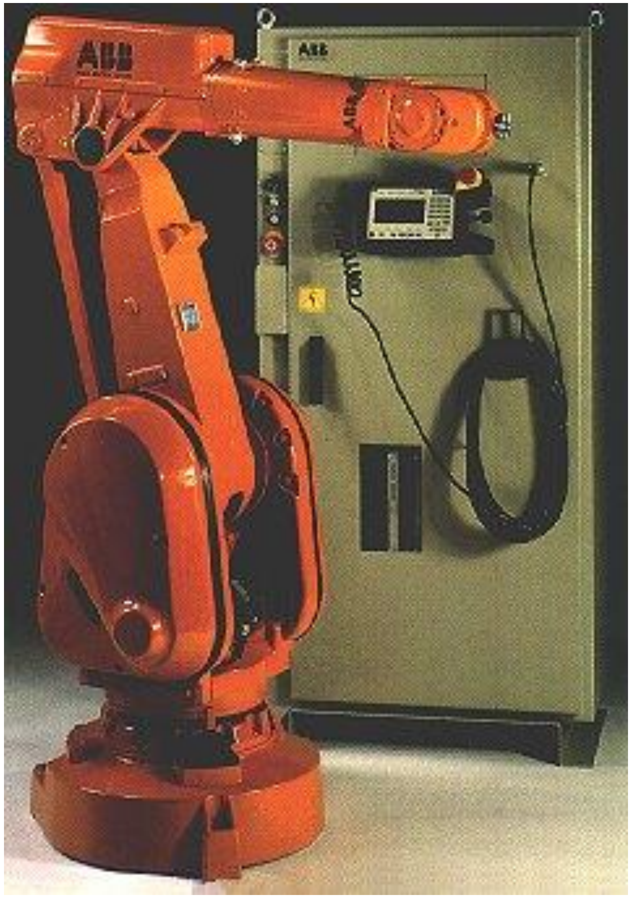
Outline

- What is an Industrial Robot?
- Basic Definitions
- Geometric Classification
- Elements of Industrial Robot
- **Commercial Industrial Robots**
- Summary

Commercial Industrial Robots

- **ABB IRB2400**

Fabricant	ABB
Model	IRB2400
Application	General Use*
Configuration	Articulated
DOF	6
Horizontal Reach	1542 mm
Payload	10 Kg.
Max. Velocity	4000 mm/s
Repeatability	0.08 mm.
Drive	Electric AC Drive



* Material handling, arc welding, water jet cutting, cleaning/spraying, deburring, assembly.

Commercial Industrial Robots

- **ABB IR5002**

Fabricant	ABB
Model	IR5002
Application	Painting
Configuration	Articulated
DOF	6
Horizontal Reach	2574 mm
Payload	5 Kg.
Max. Velocity	2000 mm/s
Repeatability	1.0 mm.
Drive	Electric AC Drive

Commercial Industrial Robots

- **Adept Three**

Fabricant	Adept
Model	Three
Application	General Use
Configuration	SCARA
DOF	4
Horizontal Reach	1070 mm
Payload	25 Kg.
Max. Velocity	11000 mm/s
Repeatability	0.025 mm.
Drive	Electric DC Drive

Commercial Industrial Robots

- **DEA Bravo 2205**

Fabricant	DEA
Model	Bravo
Application	Measurement
Configuration	Cartesian
DOF	3
Horizontal Reach	X:2521 Y:1185 mm
Payload	-
Max. Velocity	500 mm/s
Repeatability	0.3 mm.
Drive	Electric AC Drive

Commercial Industrial Robots

- **Kawasaki JS10**

Fabricant	Kawasaki
Model	JS10
Application	General Use*
Configuration	Articulated
DOF	6 (7 Optional)
Horizontal Reach	1475 mm
Payload	10 kg.
Max. Velocity	1500 mm/s
Repeatability	0.1 mm.
Drive	Brushless Motors

* Material handling, palletizing, machine loading, packaging, dispensing, water jet cutting.

Commercial Industrial Robots

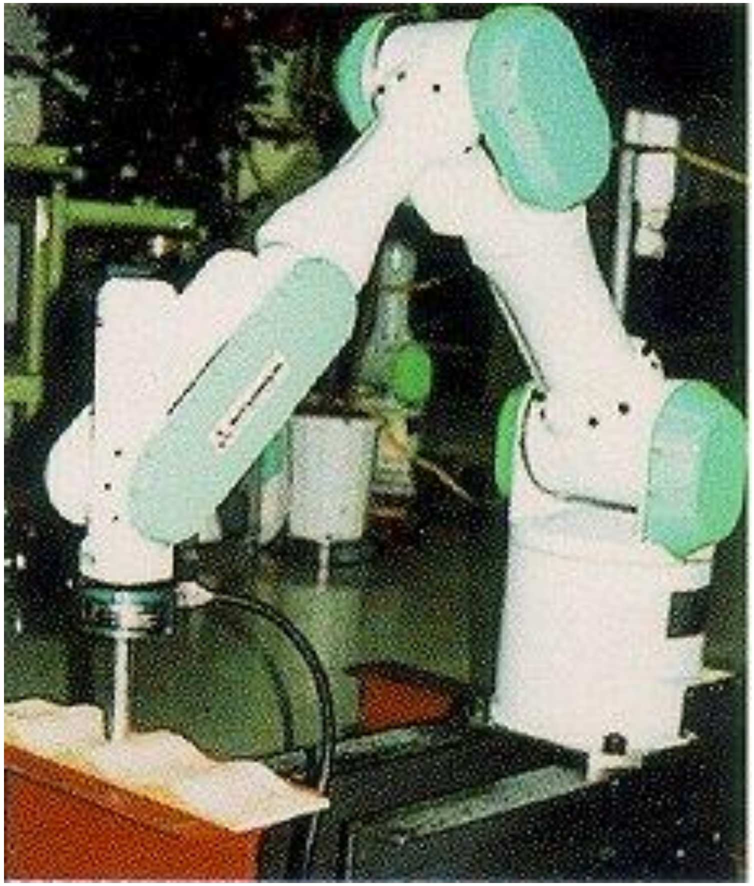
- **Kawasaki ARCJS**

Fabricant	Kawasaki
Model	ARCJS
Application	Arc Welding
Configuration	Articulated
DOF	6
Horizontal Reach	1475 mm
Payload	6 kg.
Max. Velocity	-
Repeatability	0.1 mm.
Drive	-

Commercial Industrial Robots

- **Mitshubishi PA-10**

Fabricant	Mitshubishi
Model	PA-10
Application	General Use
Configuration	Articulated
DOF	7
Horizontal Reach	1030 mm
Payload	10 kg.
Max. Velocity	1550 mm/s
Repeatability	0.1 mm.
Drive	Electric AC Drive



Commercial Industrial Robots

- **Fanuc Robotics M-420iA**

Fabricant	Fanuc Robotics
Model	M-420iA
Application	General Use
Configuration	Articulated
DOF	4
Horizontal Reach	1855mm
Payload	40 kg.
Max. Velocity	1550 mm/s
Repeatability	±0.5mm.
Drive	Electric servo

For more info: http://www.fanucrobotics.com/products/robots/AtoZ.aspx

Outline

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Summary

- Industrial Robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks
- An articulated arm emulates the characteristics of a human arm but, unlike a human arm, each joint has only one degree of freedom.
- The degree of mobility of a robot is the number of independent joints.

Summary

- The main elements of an industrial robot are mechanical structure, production tooling, drive system, transmission system, sensor system, and control system.
- An end-effector is the tooling or gripper that is mounted on the robot tool plate.
- Tool changer provides an easy method of running jobs requiring multiple tooling.
- The three primary power sources to drive manufacturing systems, namely, hydraulics, pneumatics, and electromotive force, are also used as prime movers in current robots.

Summary

- The controller has all the elements commonly found in computers, such as central processing unit (CPU), memory, and input and output devices.