Chapter 1

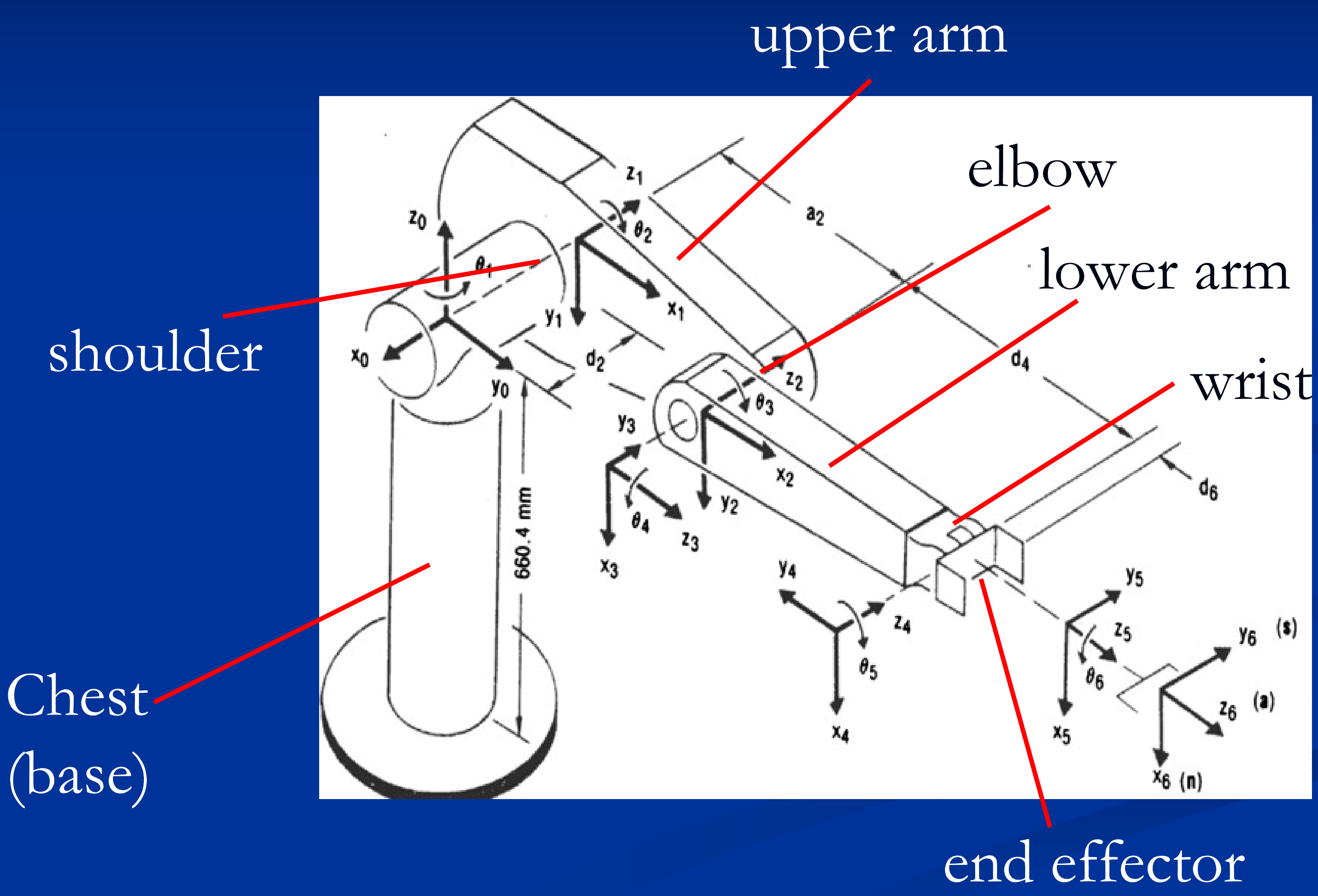
Introduction to Robotics

PS: Most of the pages of this presentation were obtained and adapted from various sources in the internet.

I. Definition of Robotics

- Definition (Robot Institute of America):
  - A robot is a programmable multifunction manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.
- Robots can be autonomous or semi-autonomous and range from humanoids to industrial robots, and even microscopic nano robots.
- By mimicking a lifelike appearance or automating movements, a robot may convey a sense of intelligence or thought of its own.

A typical robot



Applications of robotics

- Assembly
- Welding, painting
- Surveys
- Medical applications
- Pick and place.
- Assisting disabled individuals
- Hazardous environments
- Underwater, space, and remote locations

Robot examples

An experimental robot picks up a simulated pipe bomb during a demonstration for the media.

This new technology enables to make bomb disposal easier and safer for police bomb squads.

(Sandia National Laboratories in Albuquerque)

Robot examples

The Nomad robot during its solo drive on an icy Antartic plain.

The robot, a product of the university's Robotics Institute, began testing its wheels in January after it was taken by helicopter to a harsh region known as Elephant Moraine where it was left to inspect rocks and look for meteorites.
(Carnegie Mellon Uniuversity)

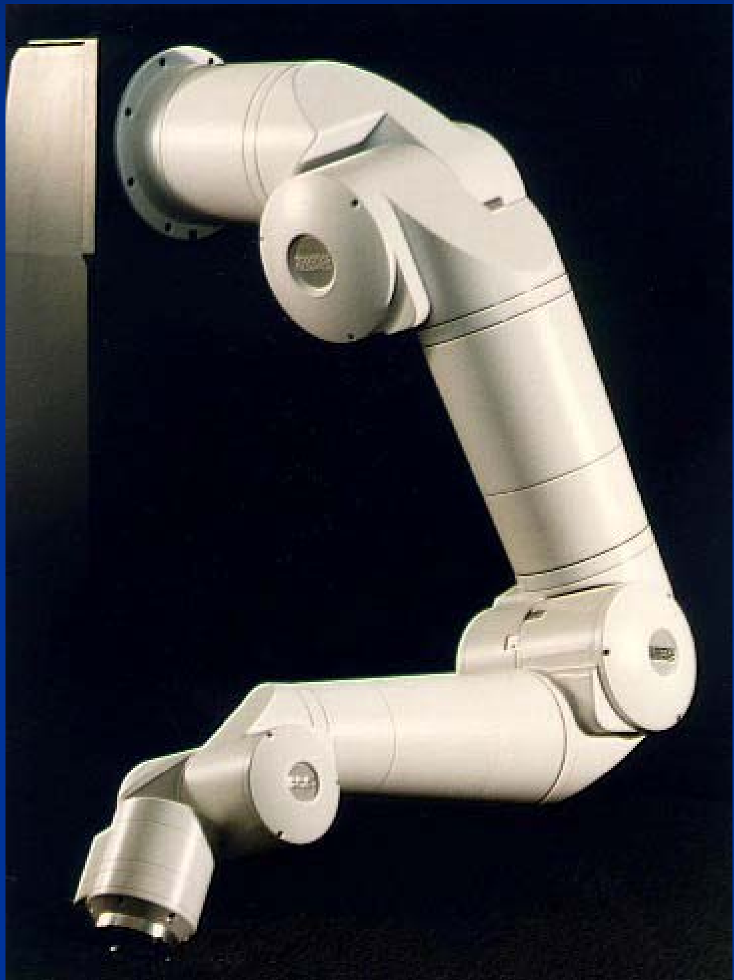
Robot examples

Robotics surgery

Doctor Franckle watches a video monitor as he assists in a gall bladder (safra kesesi) operation using a robotic surgery machine called da Vinci Surgical System.

Franckle assited Dr. Andrew Boyarsky, who was manipulating small robotic instruments, one is seen on monitor, while looking at a three-dimensional image of the patient's abdomen from a work station about 10 feet away from the patient.

Robot examples

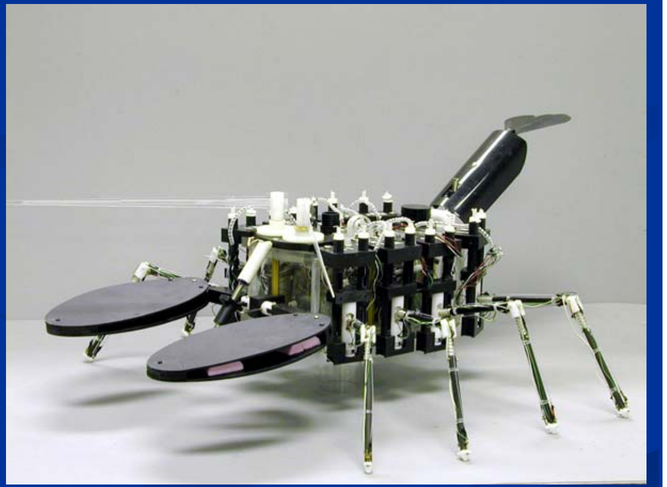


Robot examples: Biomimetic Robots

- Using biological principles to reduce design space

BigDog; Boston Dynamics

MFI; Harvard & Berkeley



Ayers; Northeastern

Basic components of robots

- Manipulators
- End effectors
- Sensors
- Software
- Actuators
- Controller
- Processor

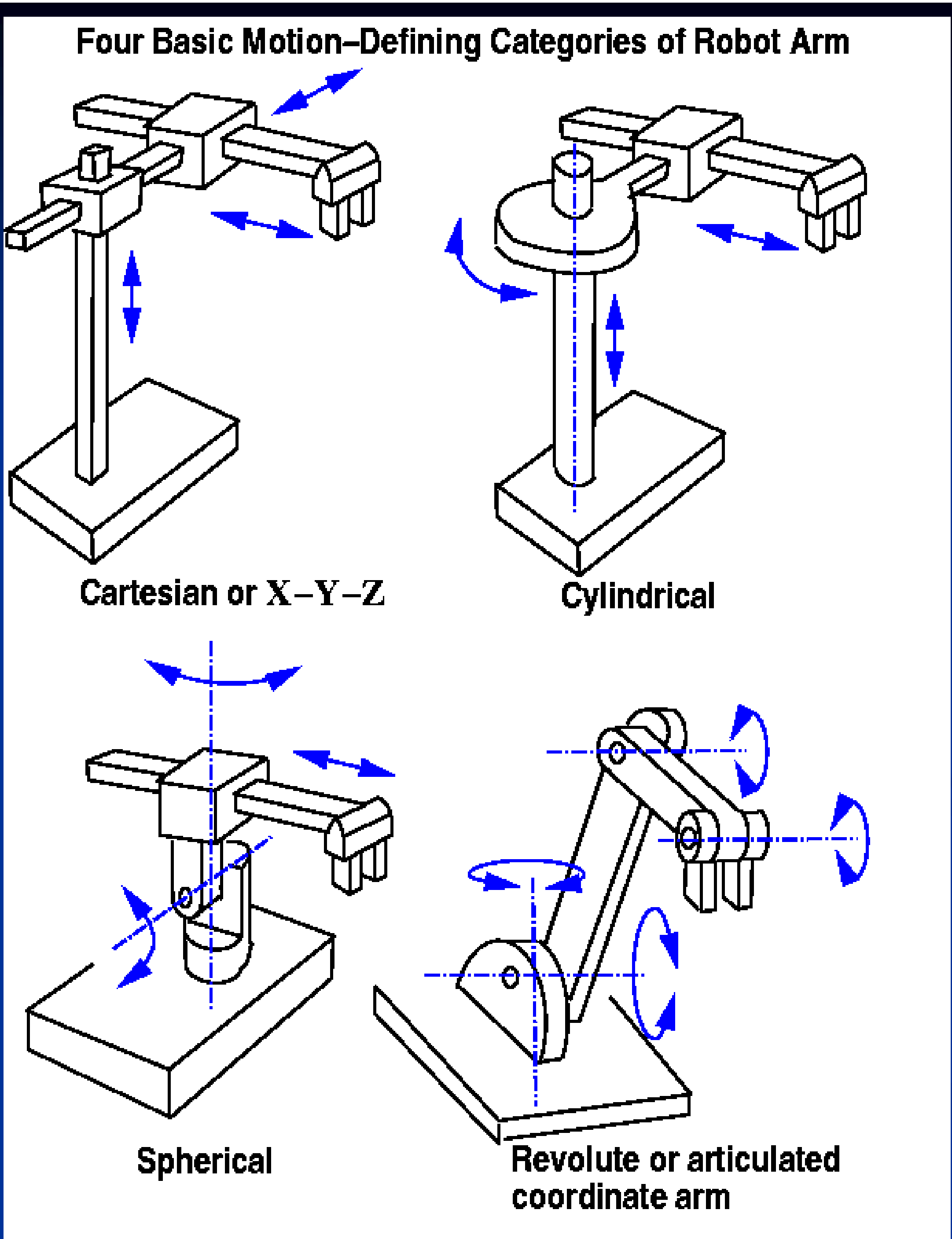
Manipulator

- Open chain kinematic structure with mostly six DoF.
- Manipulator = arm + wrist

  6 DoF = 3 DoF + 3 DoF

Arm: Used for positioning the wrist

Wrist: Used for angular positioning (orientation) the end effectors.



Types of robot arms

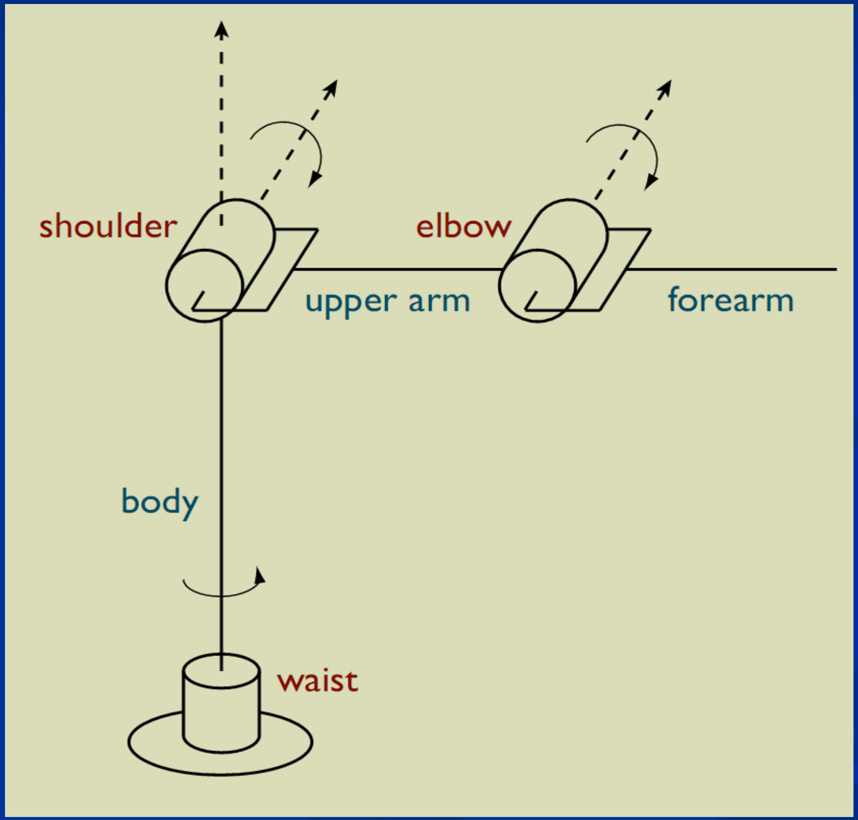
Types of robot arms

- Articulated robot arm

3R: Three revolute joint.

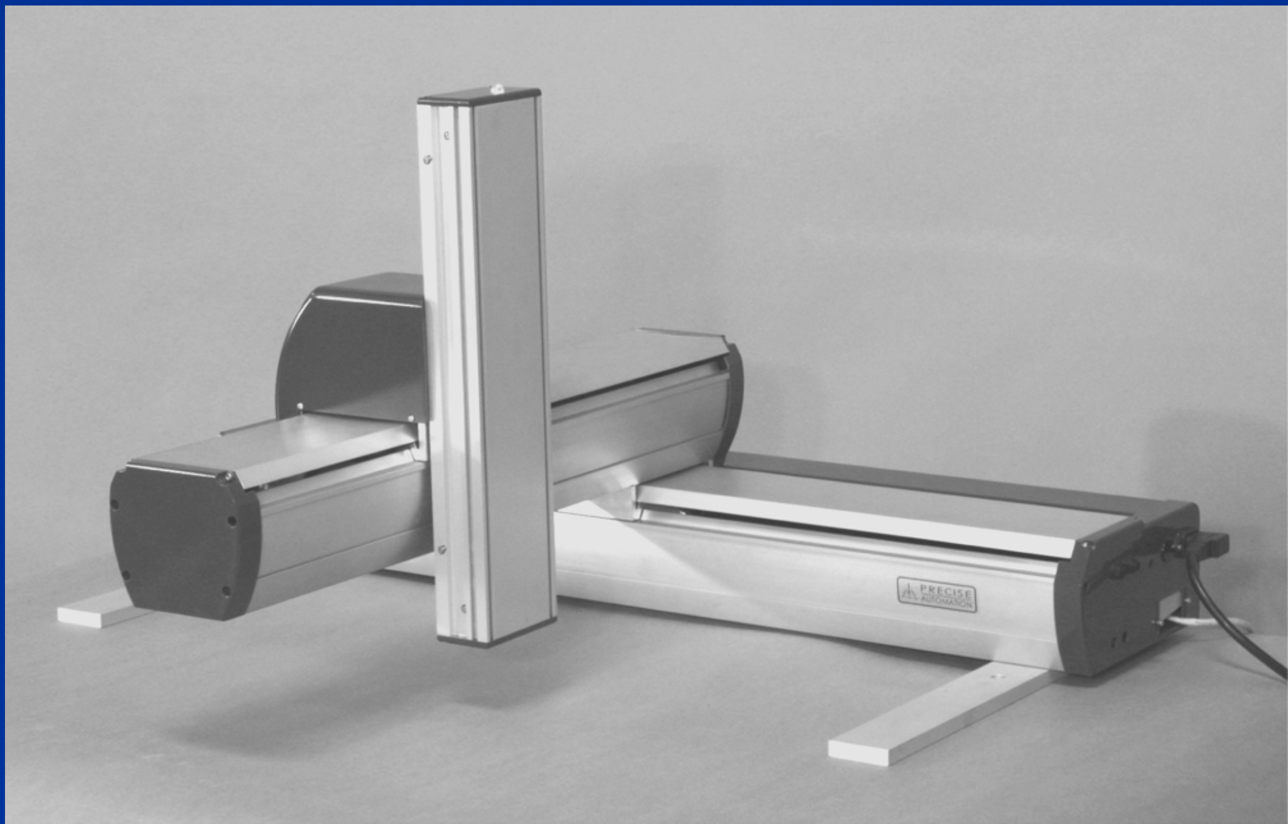
Articulated Configuration

- Features
  - Light payload capacity
  - Lower accuracy
  - Easy to integrate with other manipulators



Types of robot arms

- Cartesian robot arm

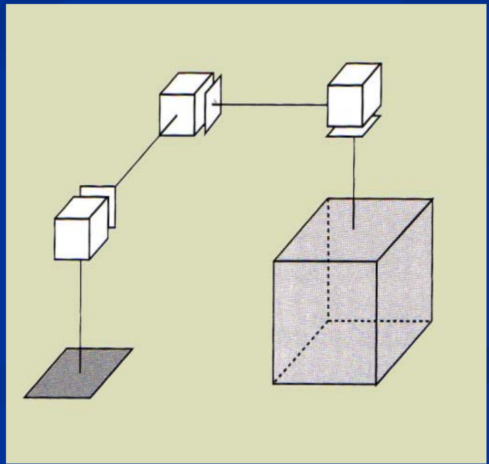


3P: Three prismatic joint.

Cartesian Configuration

- Features
  - High resolution
  - High accuracy
  - High payload capacity
  - More volume needed for motion
  - Difficult to integrate with other machines
  - Uniform resolution

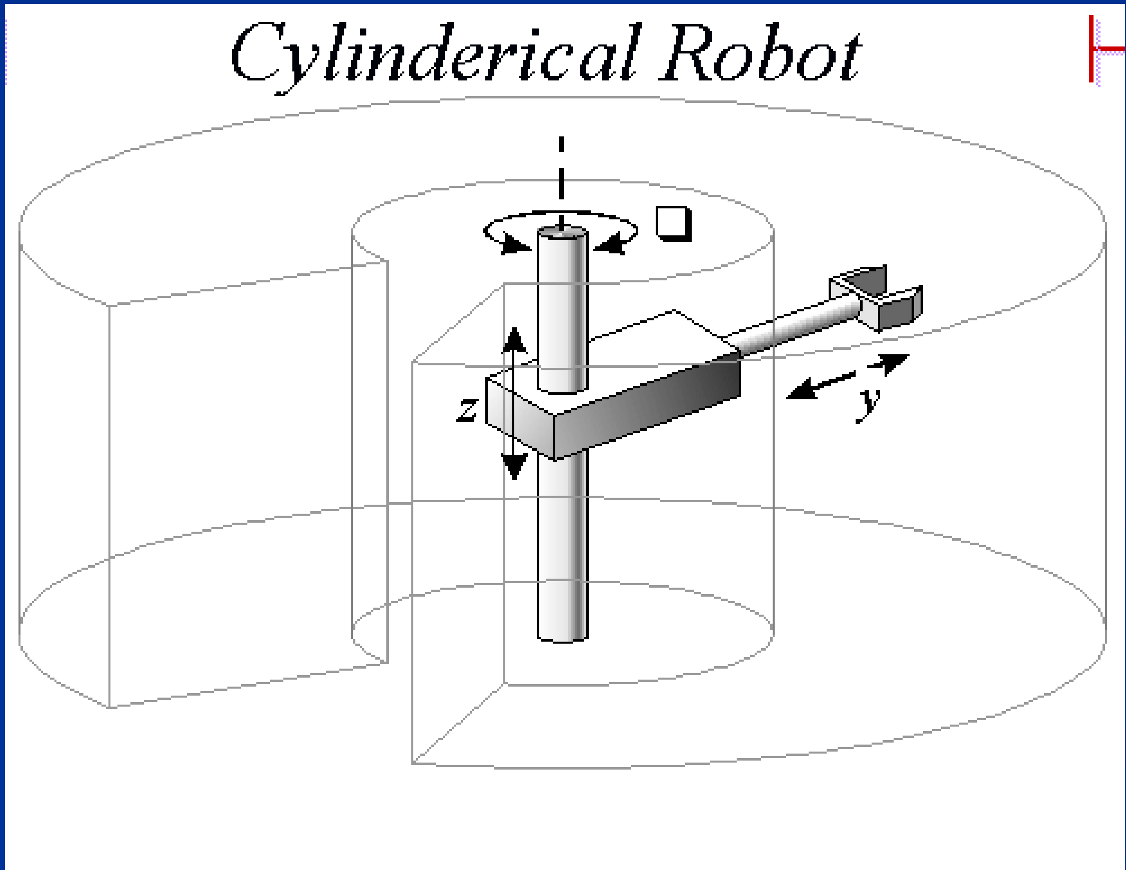
Epson Cartesian Arm



Reachable Workspace

Types of robot arms

- Cylindirical robot arm

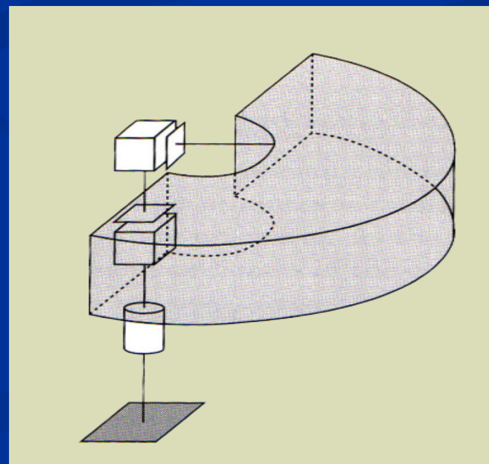


R2P

Cylindrical Configuration

- Joint coordinates map to cylindrical coordinates
  - r, θ, z
- Non-uniform precision
  - Horizontal precision highest along inside edge of work envelope

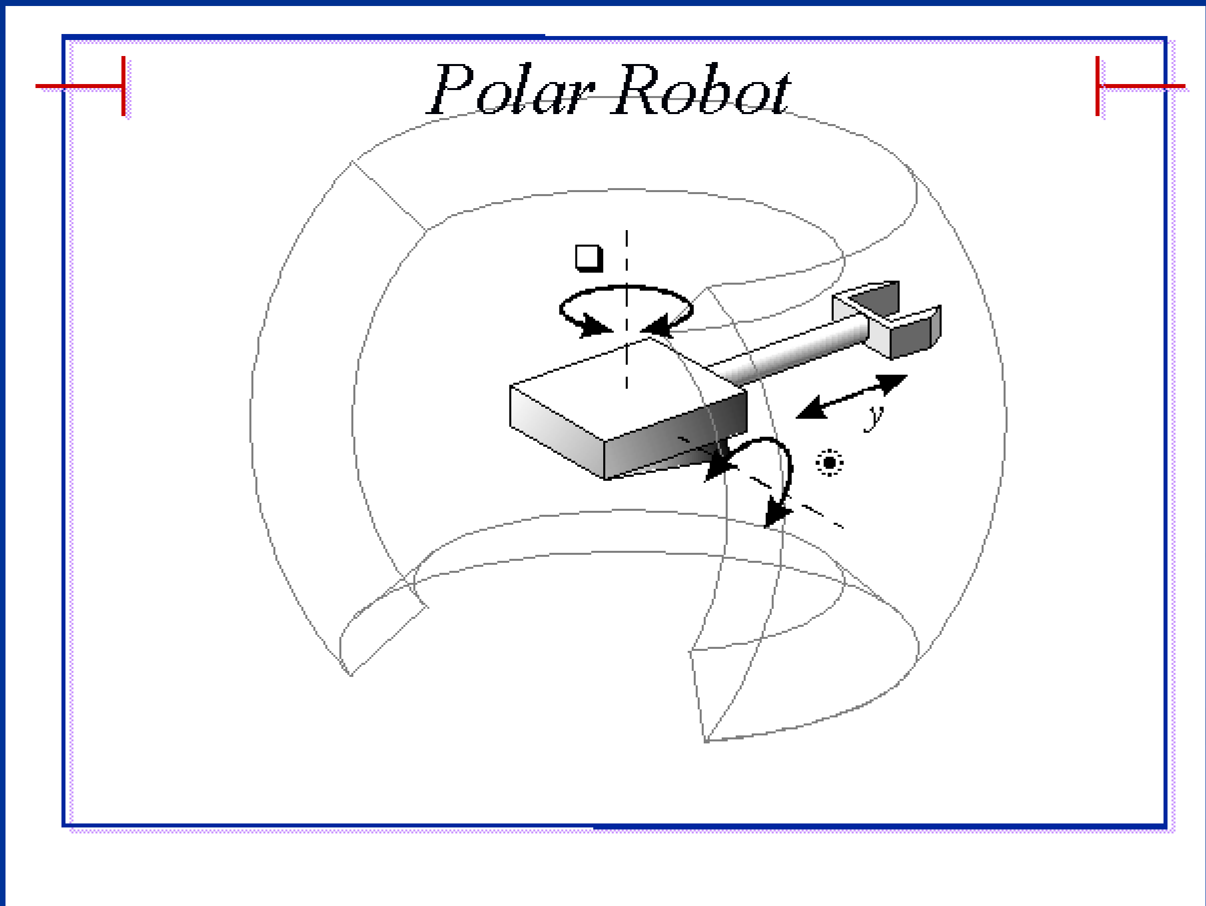
Denso Cylindrical arm



Reachable Workspace

Types of robot arms

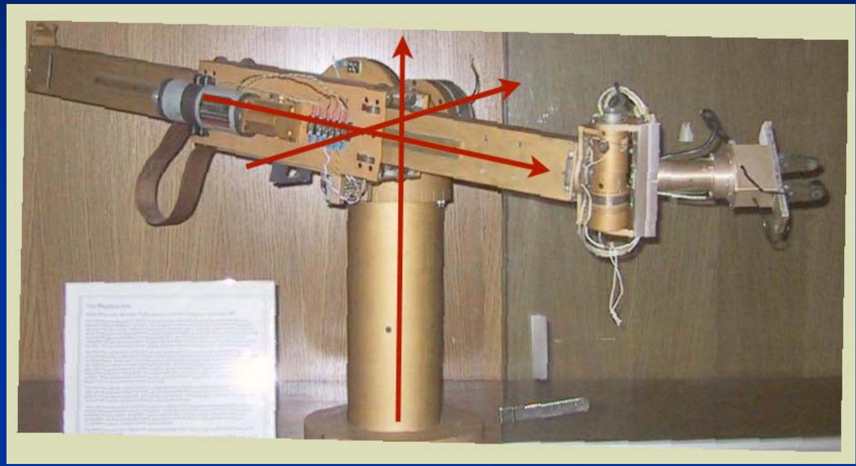
- Spherical robot arm

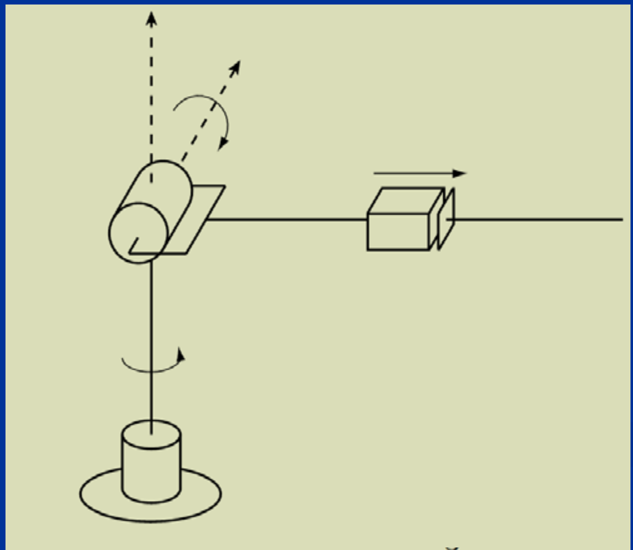


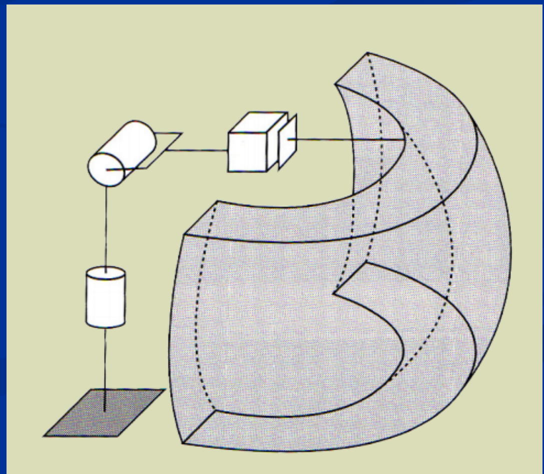
2RP

Spherical Configuration

- Joint variables directly correspond to spherical coordinates
  - φ
  - θ
  - r

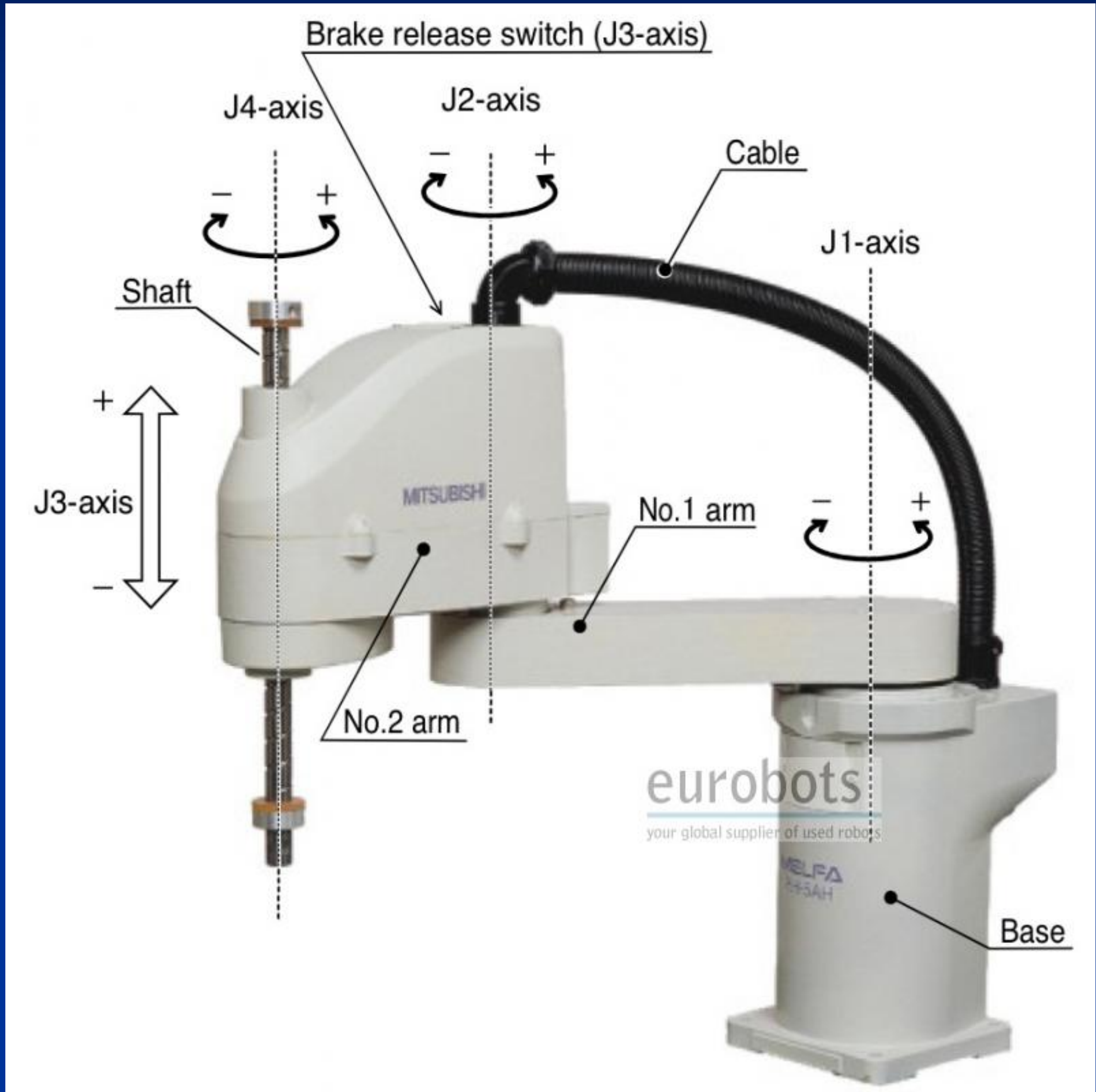






Reachable Workspace

Types of robot arms

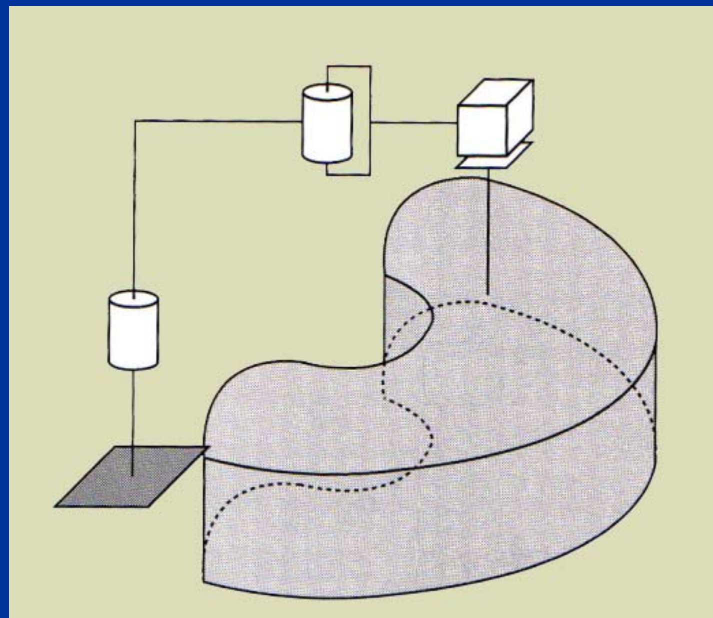


SCARA (selective compliance assembly robot arm) robot arm

SCARA Configuration

Introduced in 1979

- Revolutionized manufacturing of small electronics

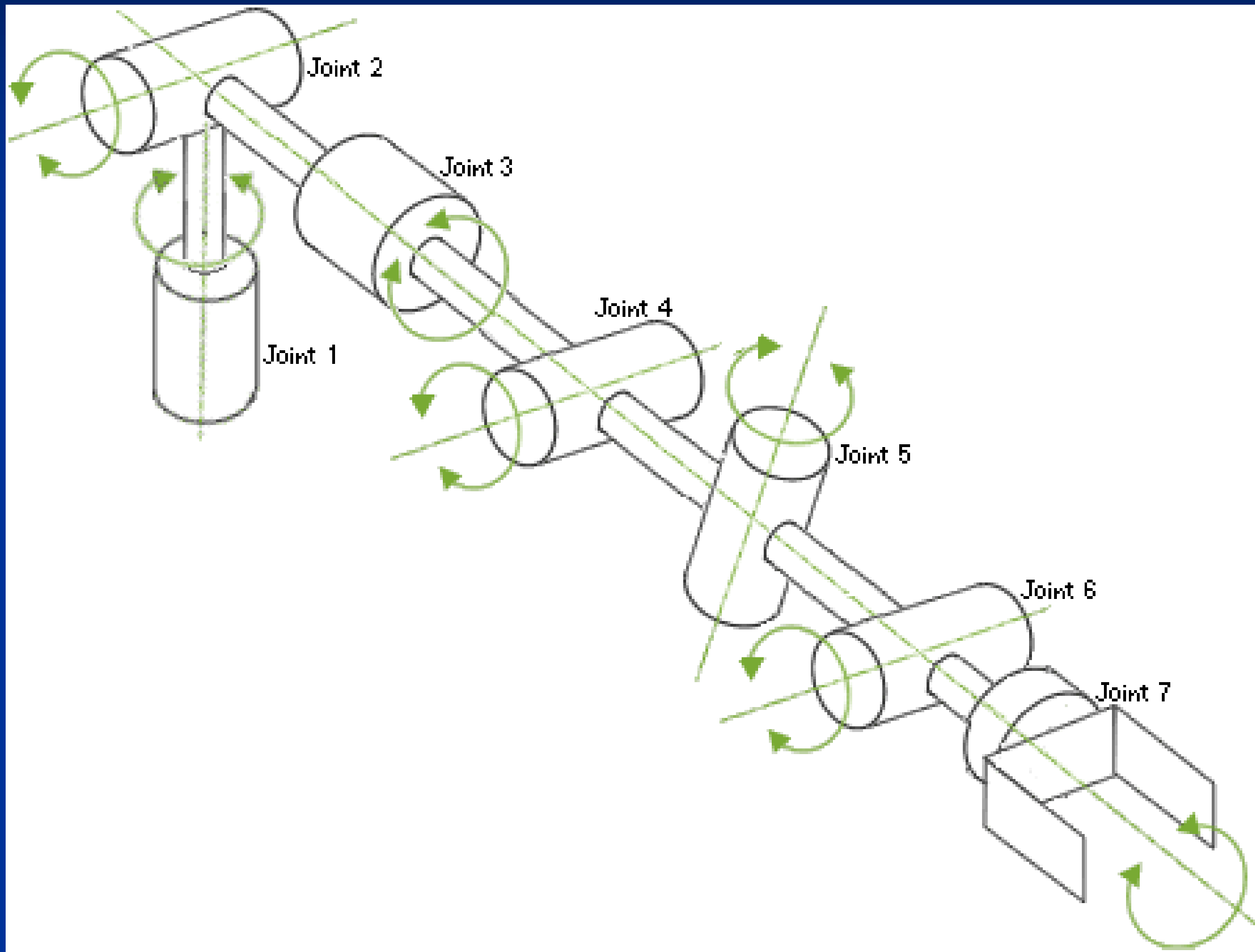


Reachable Workspace

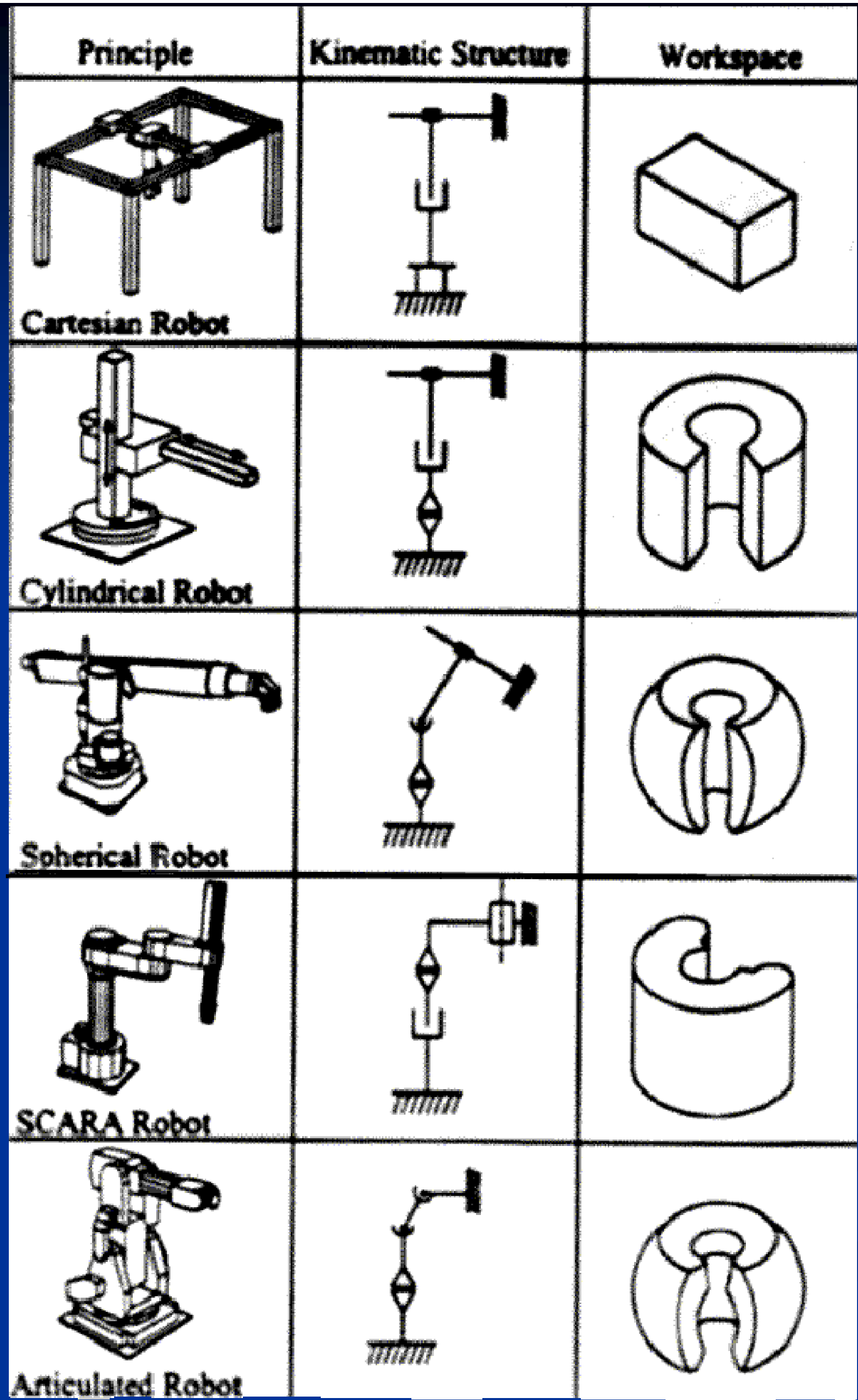
Types of robot arms

Human arm

Types of robot arms

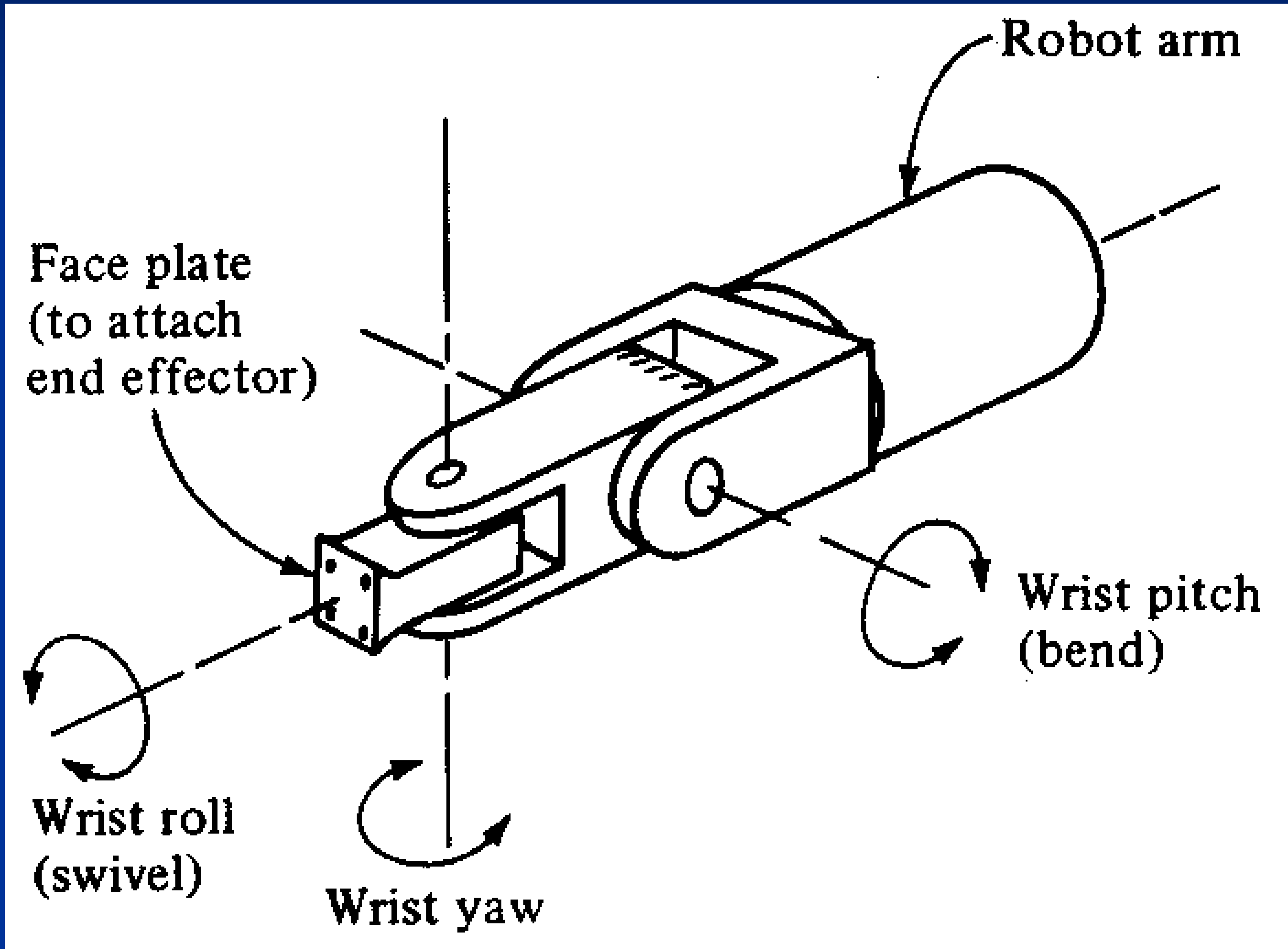


Human arm model



(http://www.robot-welding.com/robots.htm)

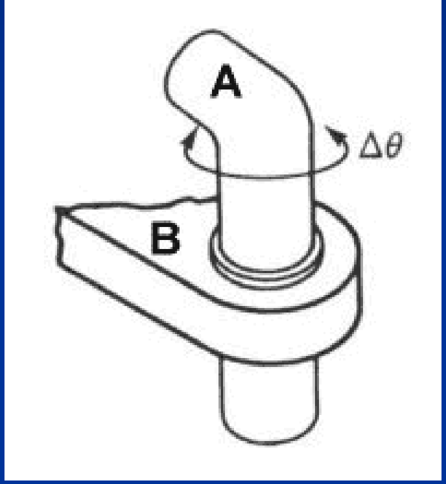
Wrist motions



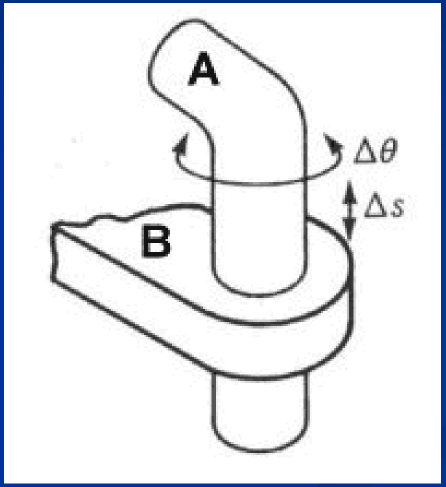
Robots degrees of freedom

- Degrees of Freedom: Number of independent position variables which would has to be specified to locate all parts of a mechanism.
- In most manipulators this is usually the number of joints.

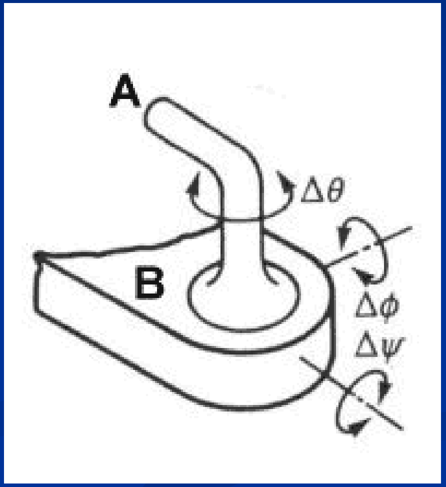
Robots degrees of freedom



1 DoF

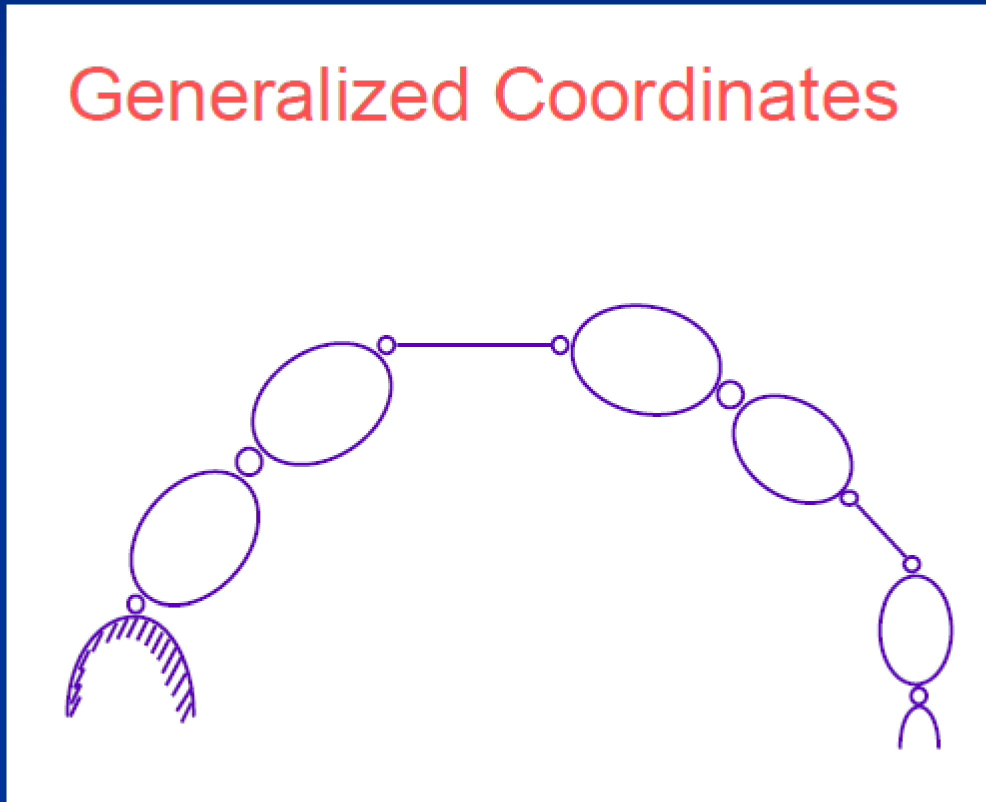


2 DoF



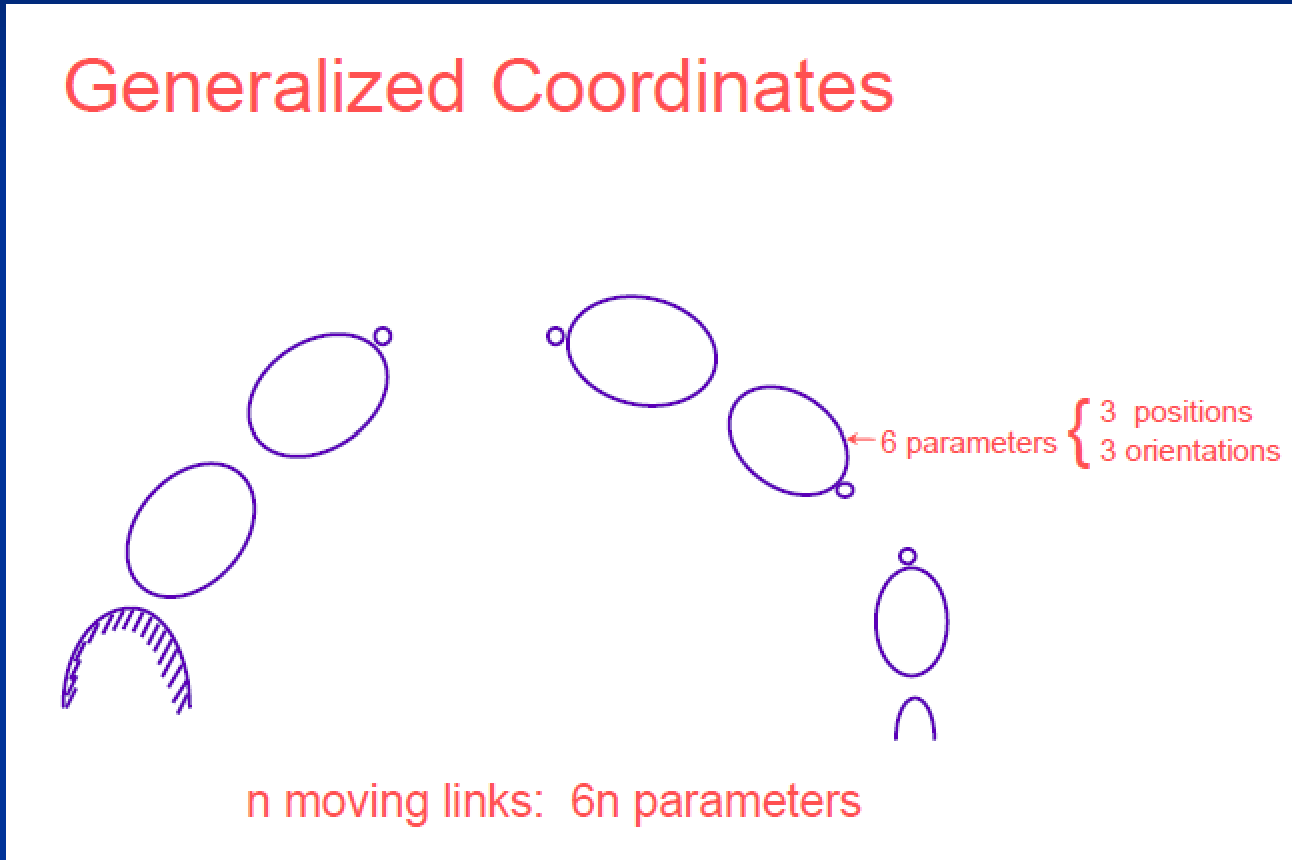
3 DoF

Robots degrees of freedom



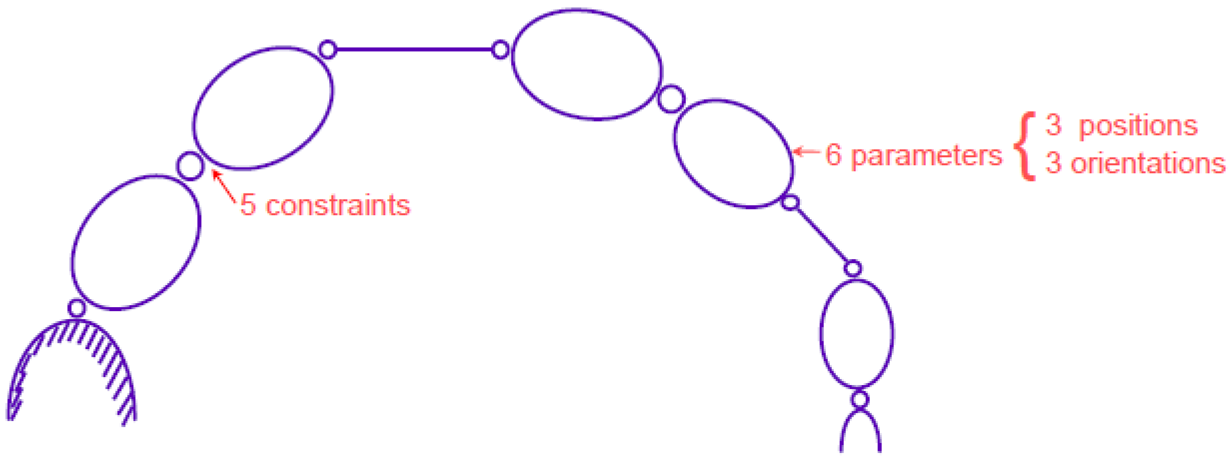
Oussama Khatib, Lecture Notes.

Robots degrees of freedom



Robots degrees of freedom

Generalized Coordinates



n moving links: 6n parameters

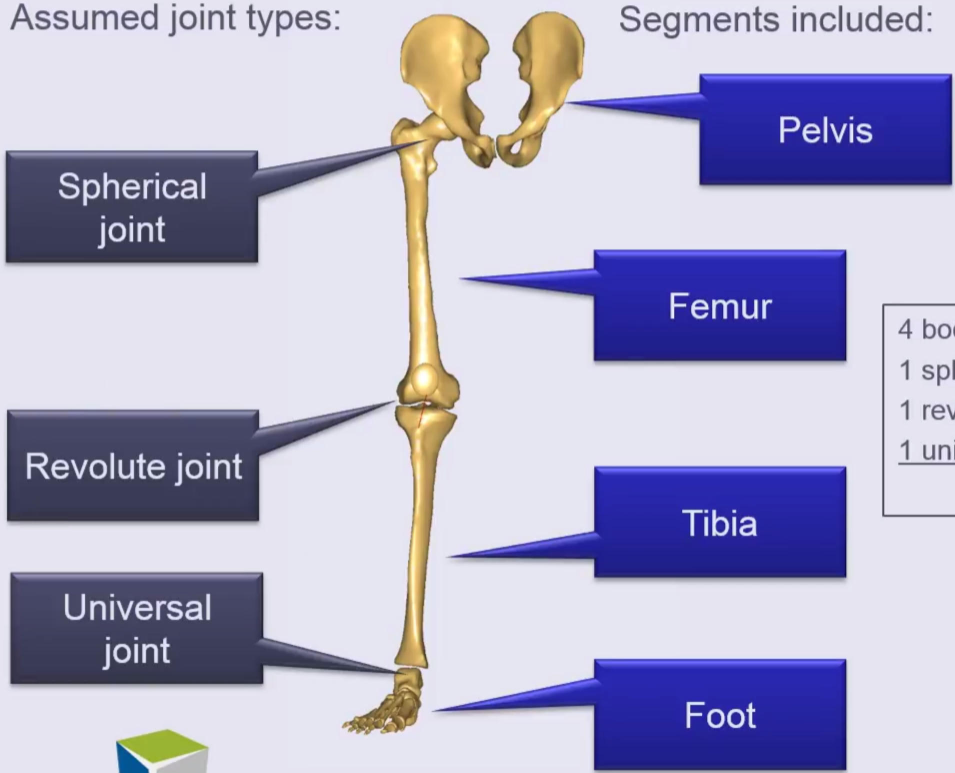
n 1 d.o.f. joints: 5n constraints

d.o.f. (system): 6n - 5n = n

If the robot is a mobile robot, then, DoF of the system is

n + 6

Degrees of freedom



4 bodies	x 6 DOF	24
1 spherical joint	x 3 DOF	-3
1 revolute joint	x 5 DOF	-5
1 universal joint	x 4 DOF	-4
		12 DOF

What is the DoF of this moving human model ?

Pelvis : 6 DoF body

3 DoF joint

Total = 6+ 3x3 + 2x1 + 2x2 + 2x1
Total = 23 DoF

1 DoF joint

2 DoF joint

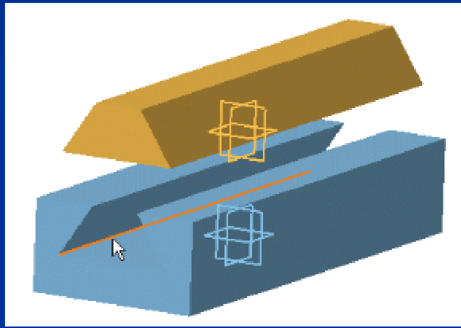
1 DoF joint

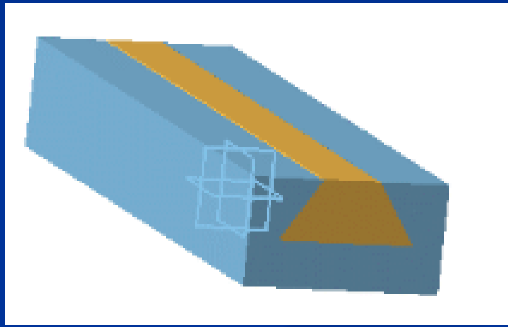
Anderson&Pandy, 1999

Robot Joints

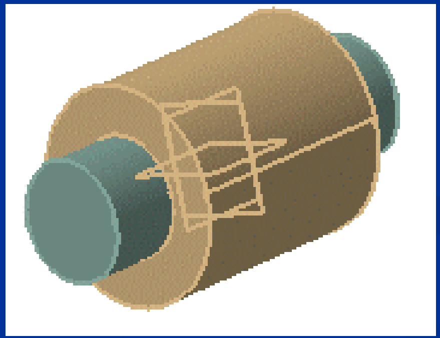
Prismatic Joint: Linear, No rotation involved.

(Hydraulic or pneumatic cylinder)



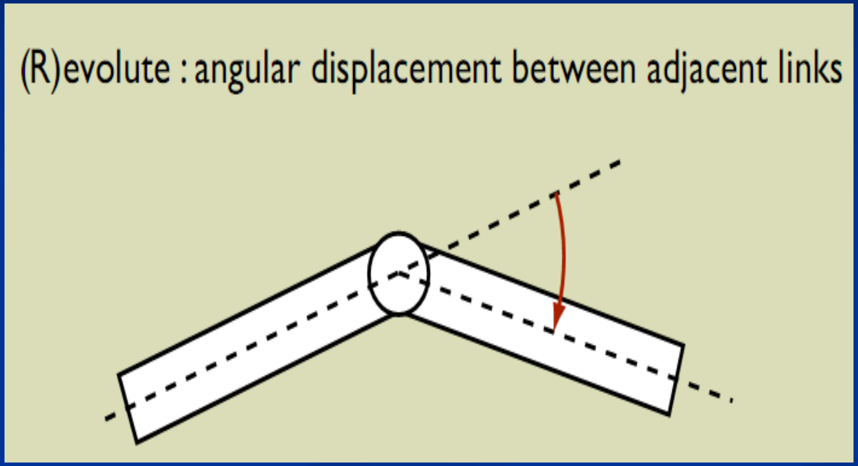


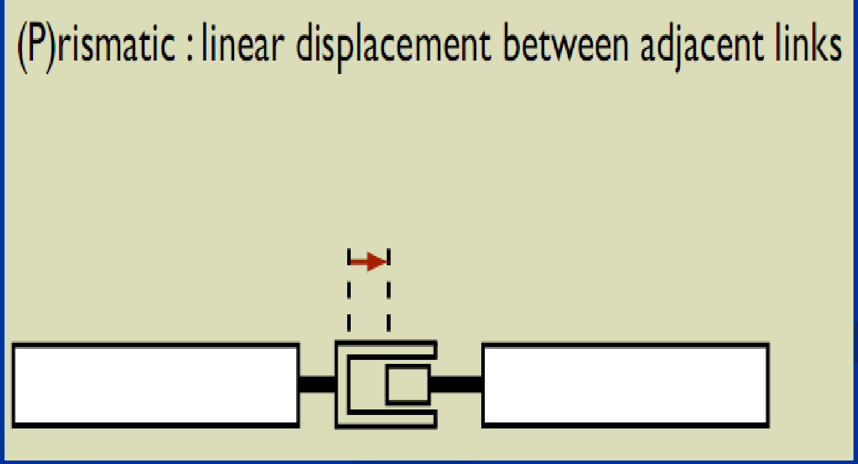
Revolute Joint: Rotary, (electrically driven with stepper motor, servo motor)



Common Robot Configurations

- Revolute joints (R)
  - Compact
  - Increased dexterity – easier to maneuver around obstacles
  - Large kinematic and dynamic coupling between links
  - Larger error accumulation
  - Difficult control problem
- Prismatic joints (P)
  - Increased accuracy
  - Higher payload
  - Difficult to integrate
  - Require more volume

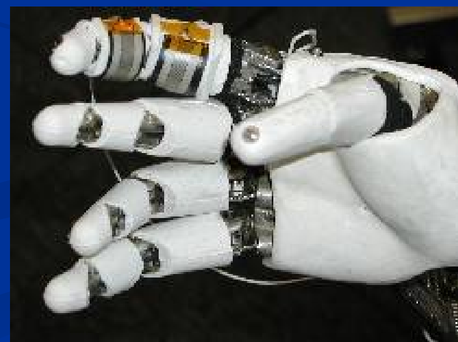




Example end-effector: Grippers

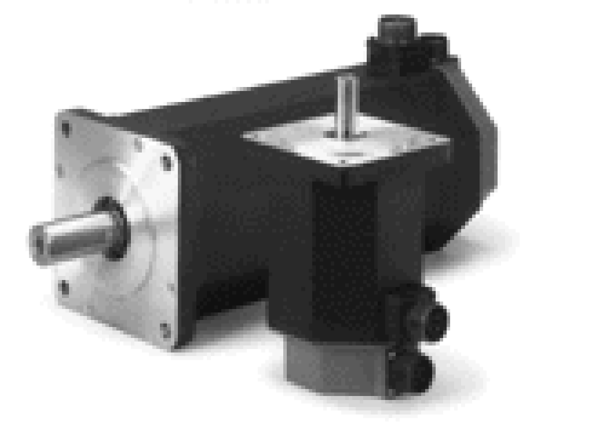
- Anthropomorphic or task-specific
  - Force control v. position control

Utah MIT hand



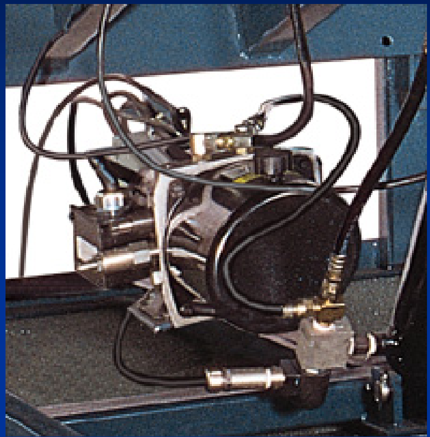
Actuators

- Common robotic actuators utilize combinations of different electro-mechanical devices
  - Synchronous motor
  - Stepper motor
  - AC servo motor
  - Brushless DC servo motor
  - Brushed DC servo motor



http://www.ab.com/motion/servo/fseries.html

Actuators



Hydraulic Motor

Pneumatic Cylinder

Stepper Motor

Pneumatic Motor

DC Motor

Servo Motor

Sensors

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

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

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

Accelerometer
Using Piezoelectric Effect

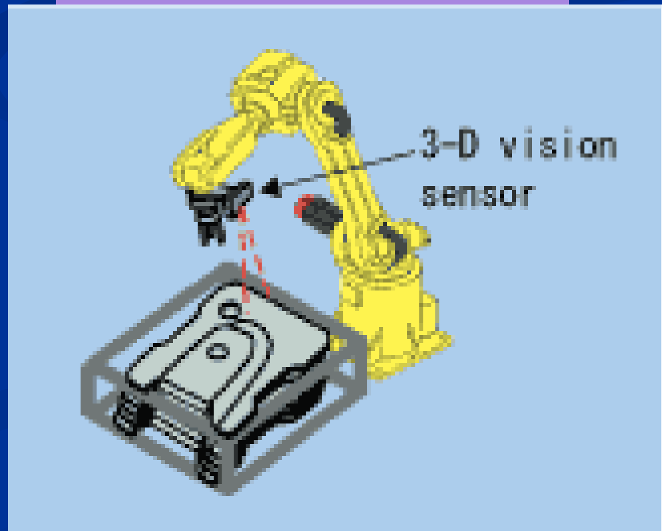
Flexiforce Sensor

Sensors

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

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

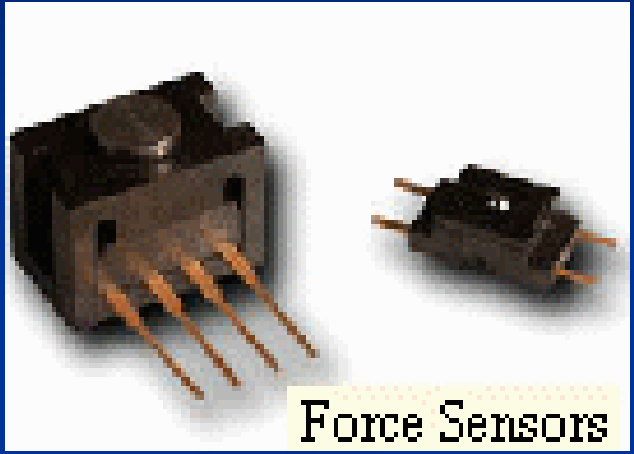
In-Sight Vision Sensors

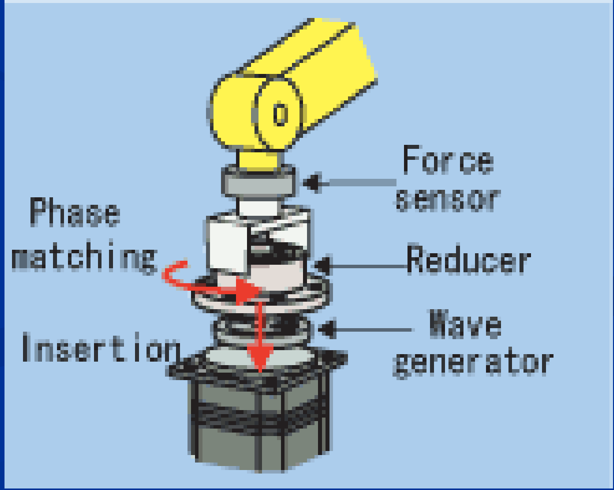


Sensors

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

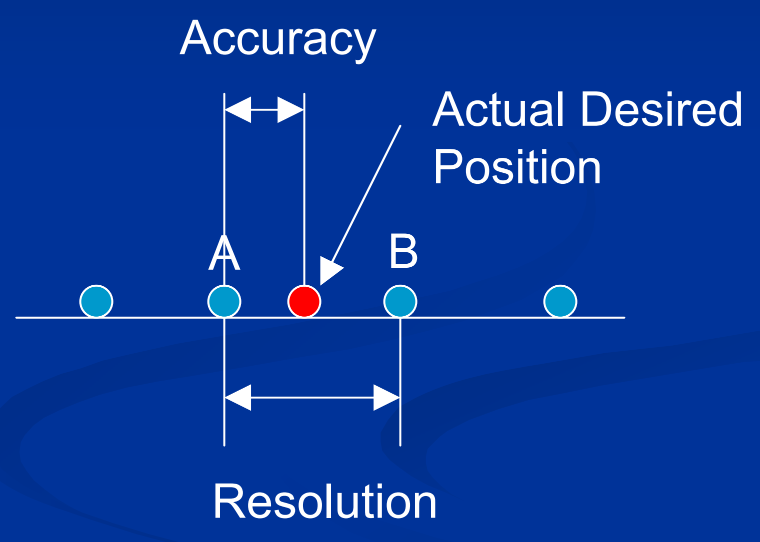
Parts fitting and insertion: Robots can do precise fitting and insertion of machine parts by using force sensor. A robot can insert parts that have the phases after matching their phases in addition to simply inserting them. It can automate high-skill jobs.





Accuracy, Repeatability and Resolution

- Accuracy: A measure of how close a manipulator can come to a given point within its workspace
- Repeatability: A measure of how close a manipulator can return to a previously taught point
- Resolution (Precision): The smallest increment of motion that can be sensed (executed). It is a function of distance traveled and the number of bits of encoder accuracy.



Robot Specifications

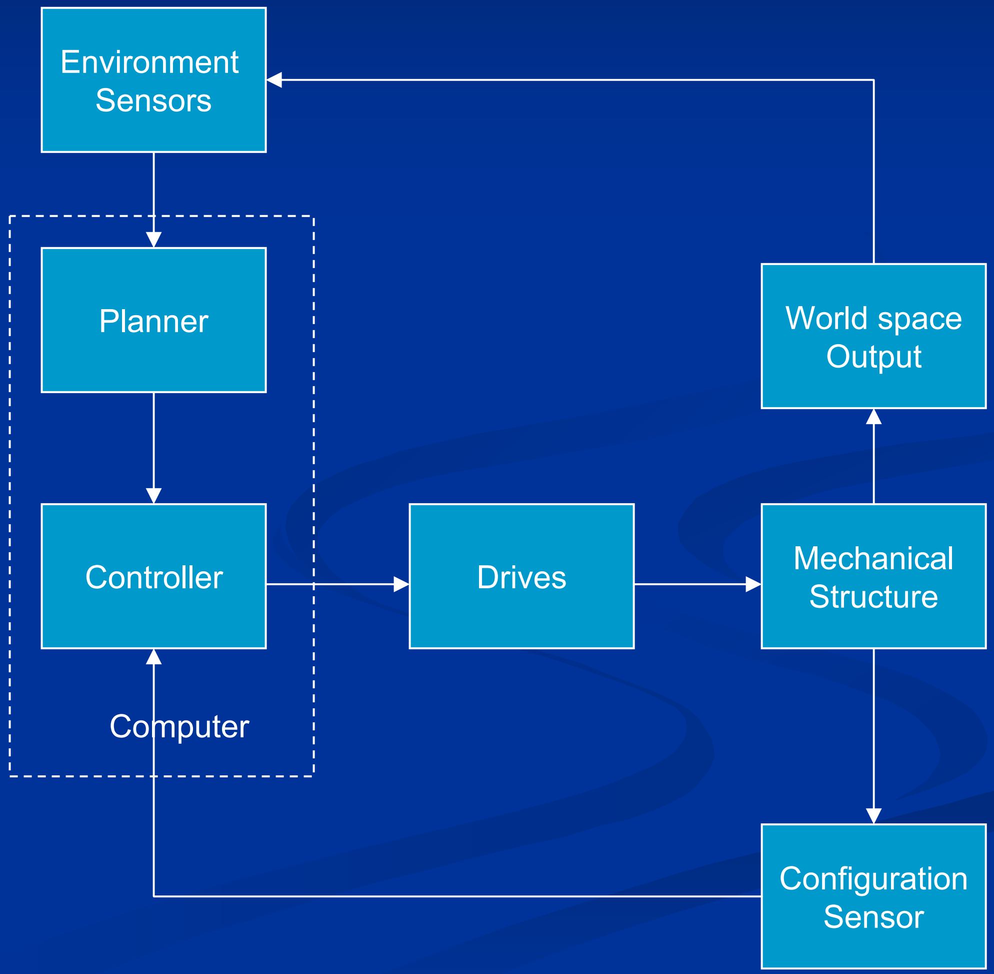
- Joint Variable (joint):
  - Relative displacement between adjacent links. Can be revolute or prismatic.
- End effector:
  - Gripper or tool used to perform the robots tasks.
- Degree of freedom (DOF)
  - Number of joints (DOF > 6 implies redundant robot)
- Workspace (work envelope):
  - Total volume spread out by the end effector as the manipulator executes all possible motions
- Accuracy, Repeatability and Resolution
- Speed and Acceleration (min and max)
- Payload Capacity

Typical Robot Specifications

- Hydraulic or Electric
- Payload capacity
  - 50 – 100 Kgs (Hydraulic)
  - 1 – 25 Kgs (Electric)
- Degrees of freedom: 4 to 7 based on application
- Repeatablity
  - ± 1 mm – 1.5mm (Hydraulic)
  - ± 0.05mm – 0.01mm (Electric)
- Cost
  - $80,000 - $200,000 (Hydraulic)
  - $40,000 – $100,000 (Electric)

Robotic System Architecture

- Components
  - Mechanical structure
  - Drives
    - Electric
    - Hydraulic
    - Pneumatic
  - Computing and Control
  - Sensors
    - Encoders
    - Force
    - Vision
    - many more
  - Communication
    - CAN, ethernet, Wireless, Serial link (RS232), USB, analog link, PROFIBus, GPIB, and many more



Robot Programming

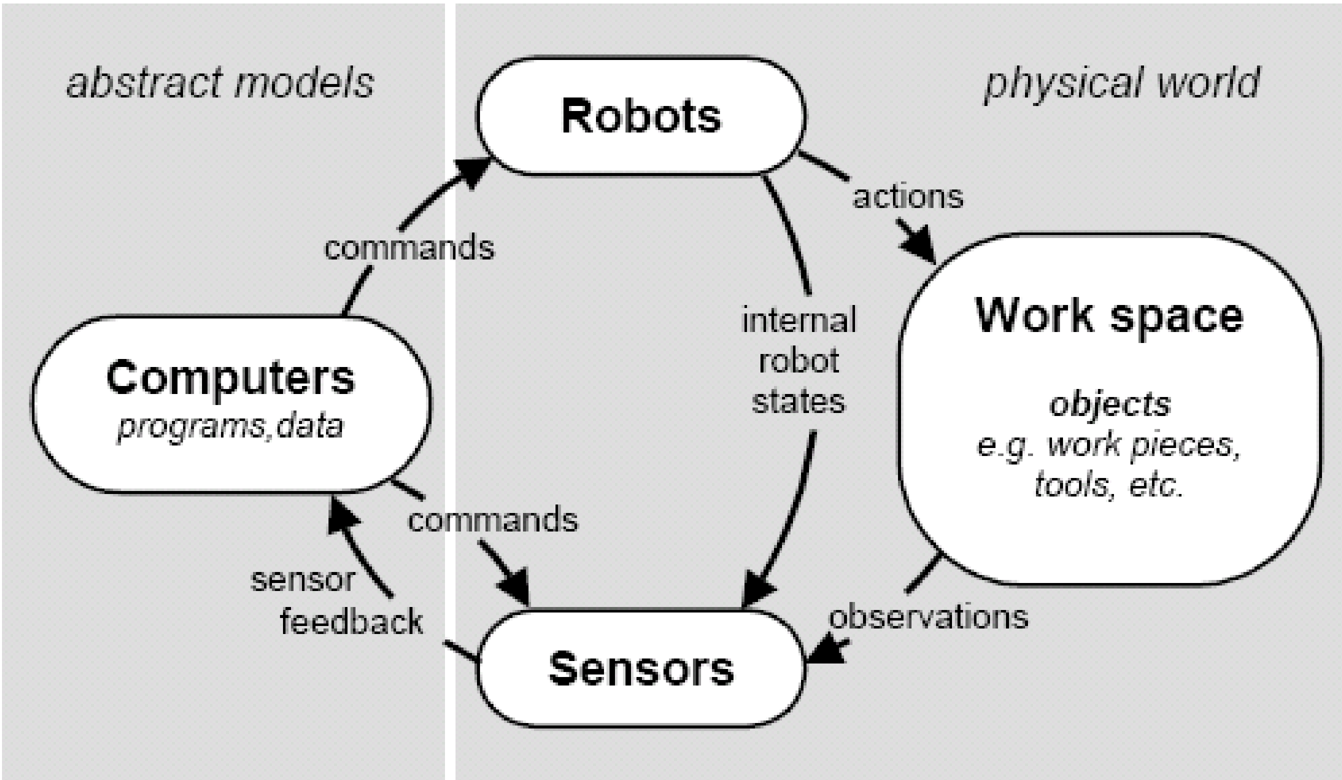


Figure 1: General robot programming paradigm.