Industrial Robotics

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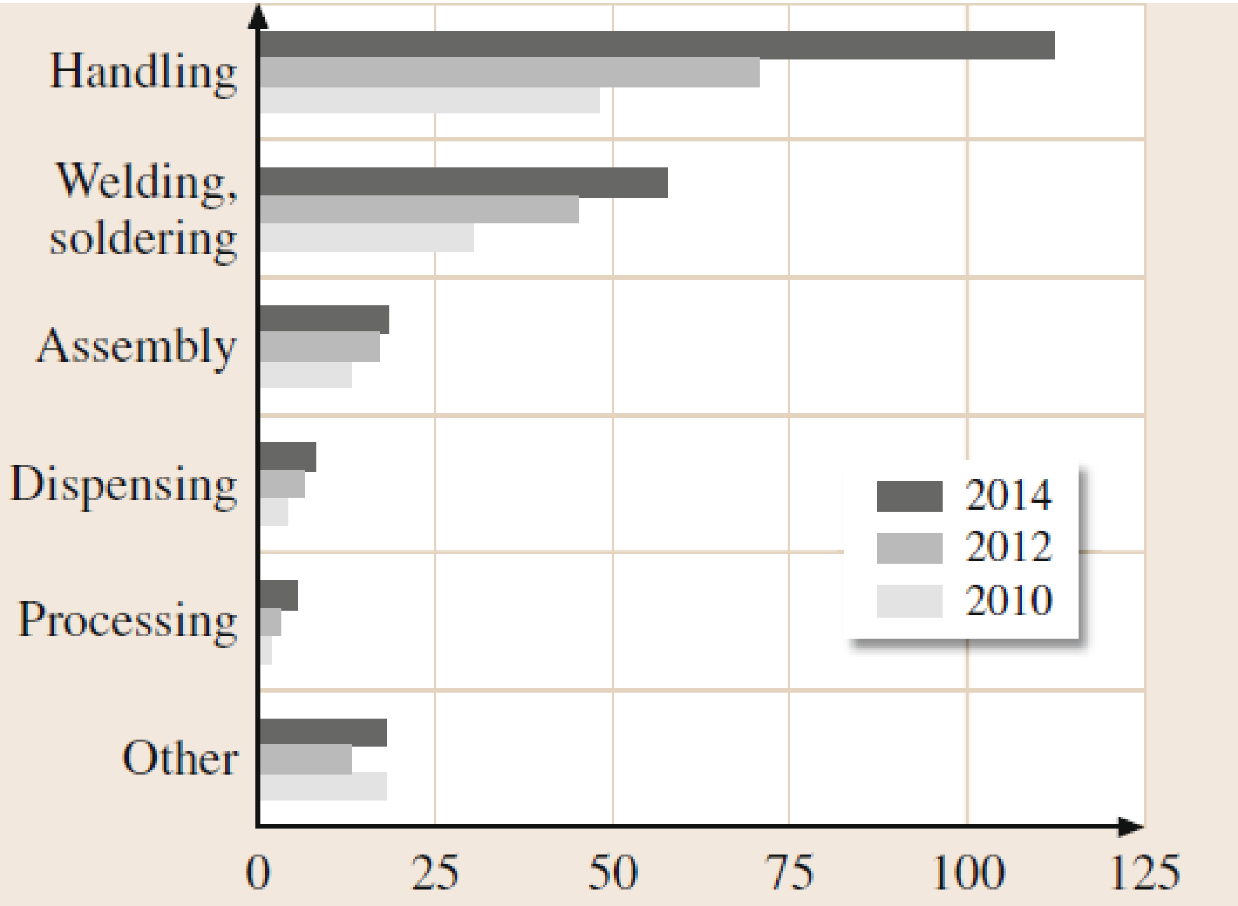
Quiz (10 pts)

- (6 pts) List at least two applications for industrial robots
- (4 pts) Why is industrial robotics important?

Statistics of Worldwide Industrial Robot Use

- Estimated worldwide annual shipments of industrial robots in main application areas (2014)



Latest Technology Industrial Robots

Industrial robots

- The largest commercial application of robotics technology
- Year of 2014
  - Estimated installation = 1.5 million units
  - 171 000 new installations
  - Estimated annual turnover of the robotics industry = $ 32 billion

Industrial robots

- Foundations for robot motion planning and control
- The origin of robotics science
- Many unsolved problems

Robot Geometry

Geometric Characteristics of Robots

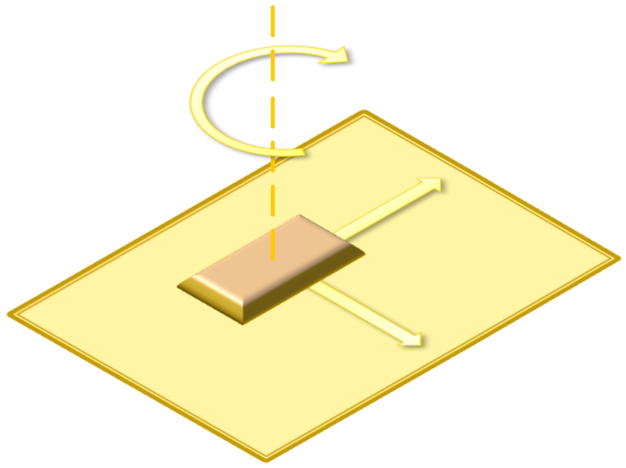
- Degrees of freedom
  - Mechanisms, joints, kinematic pairs
- Robot configuration
  - Combination of mechanisms, joints, kinematic pairs
- Robot motion limits
  - Payload, reach, precision/accuracy, repeatability, workspace

Degrees of freedom

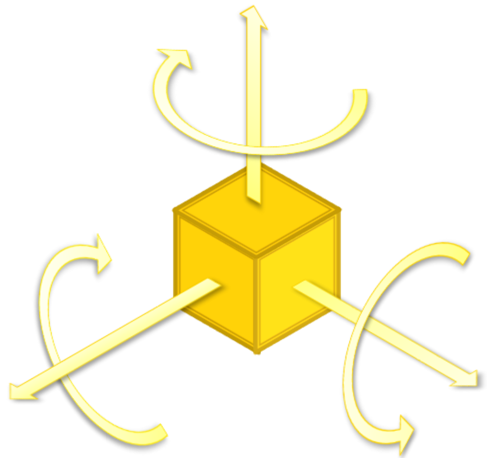
Degrees of Freedom (DOF)

- The minimum number of required independent coordinates to completely specify robot motions
  - # of required actuators?
  - # of joints?

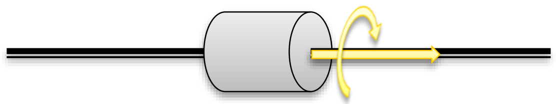
Degrees of Freedom (DOF)



Rigid body planar motion:
2 Translational + 1 Rotational = 3-DOF

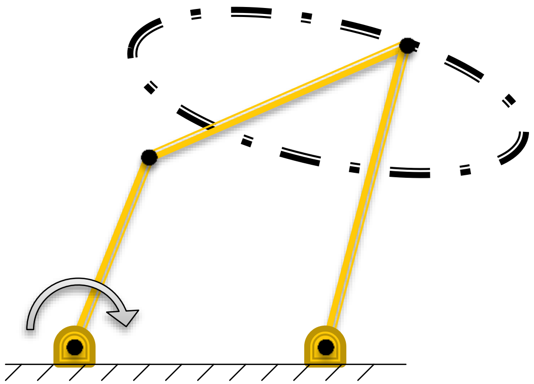


Rigid body spatial motion:
3 Translational + 3 Rotational = 6-DOF



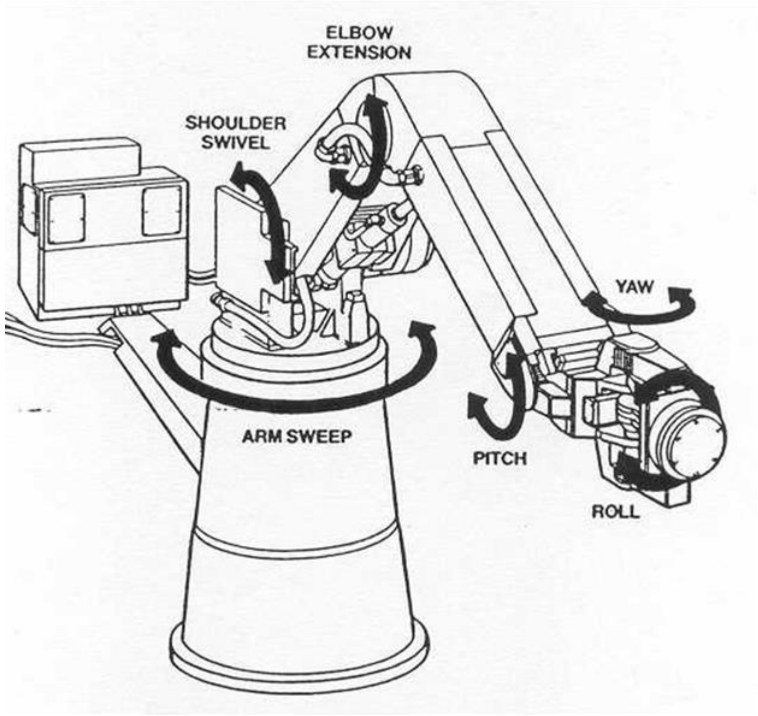
Constrained motion - bead on a wire:
1 Translational + 1 Rotational = 2-DOF

Degrees of Freedom (DOF)



Four Bar Linkage Mechanism

Closed-Loop Kinematic Chain



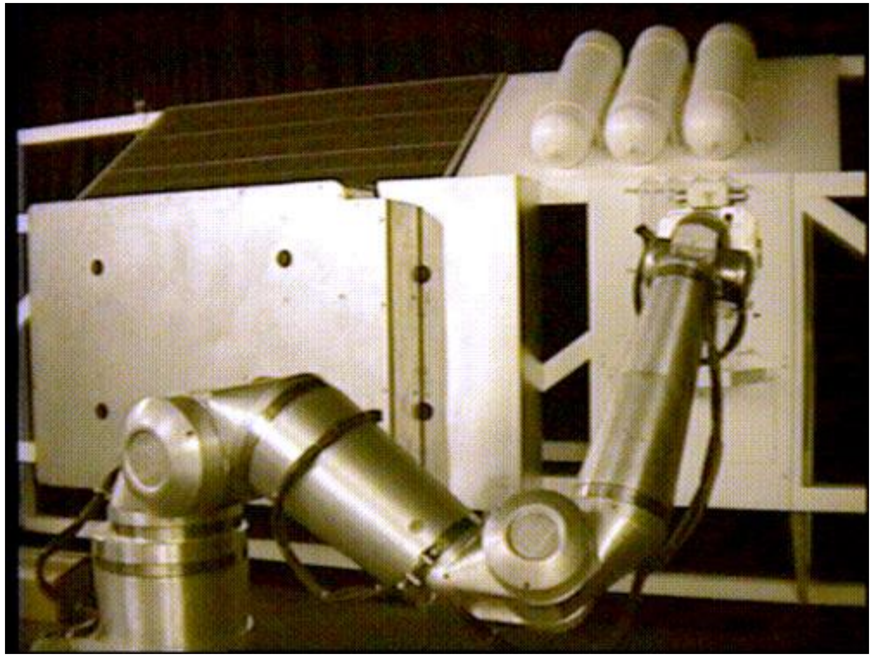
Industrial Robot

Open-Loop Kinematic Chain

More than 6-DOF

- Kinematics redundancy
  - No unique solution (No. of solutions = ∞)
- Need another parameter to determine configuration
  - Typically choose one DOF – then solve for the other six
- Less often used in industry
  - Too computationally intensive

More than 6-DOF



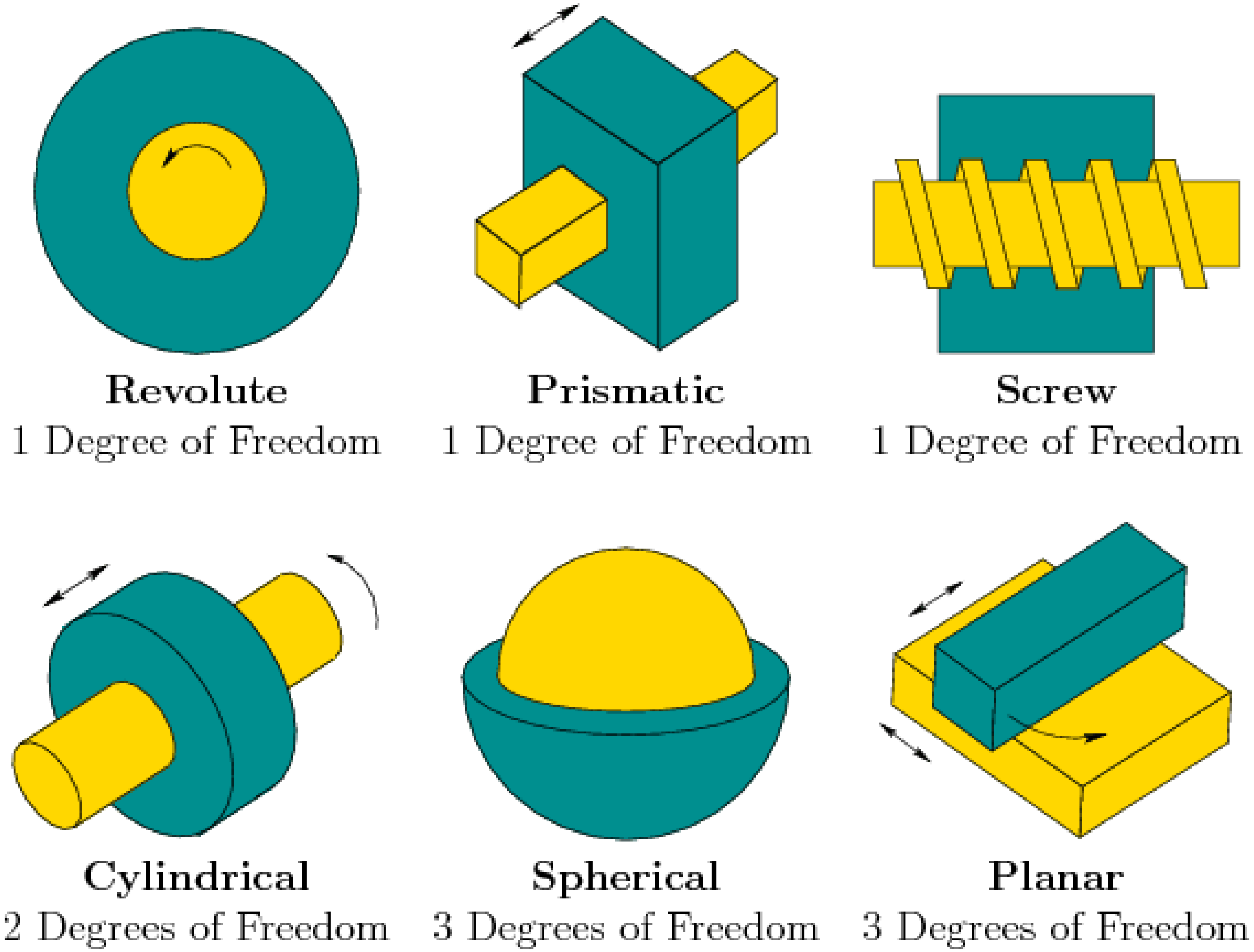
JPL 7-DOF Robotic Manipulator

(http://www-robotics.jpl.nasa.gov/tasks/showBrowseImage.cfm?TaskID=137&tdaID=800004)

Motoman 7-DOF VS50 Spot Welding Robot

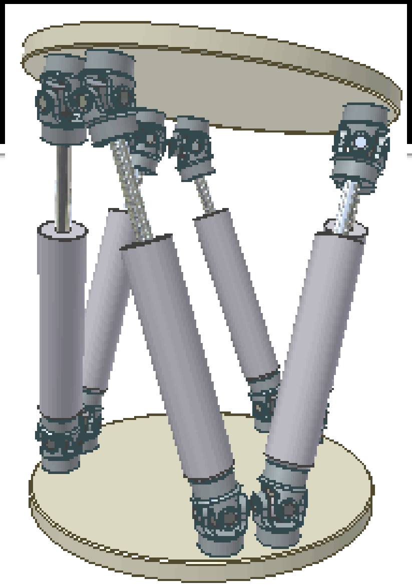
Kinematic Pairs

Kinematic pairs



Serial and parallel robots

Parallel Kinematics



- Parallel Kinematic Machines (PKMs)
  - Closed kinematic loops
  - Stewart Platform / hexapods

- Pros:
  - Greater rigidity – parallel links
  - Higher speed – less mass to move
  - Higher accuracy – averaged error

- Cons:
  - Limited work envelope
  - Requires a large space for large motion
  - Inability to avoid objects

Stewart Platform

Serial Kinematics

- Serial Linkage Manipulators
  - Open kinematic loops
- First three joints
  - Combination of prismatic and revolute joints
  - Determines position of the end effector
- Last three joints
  - Generally comprised of a spherical system – RRR
  - Determines orientation of the tool

Robot motion limits

Robot motion limits

- Payload
- Reach
- Accuracy/repeatability
- Workspace

Robot motion limits

- Payload
  - The weight a robot can carry and still remain within its other specifications
  - A robot’s maximum load capacity may be much larger than its specified payload, but at the maximum level, it may become less accurate, may not follow its intended path accurately, or may have excessive deflections.

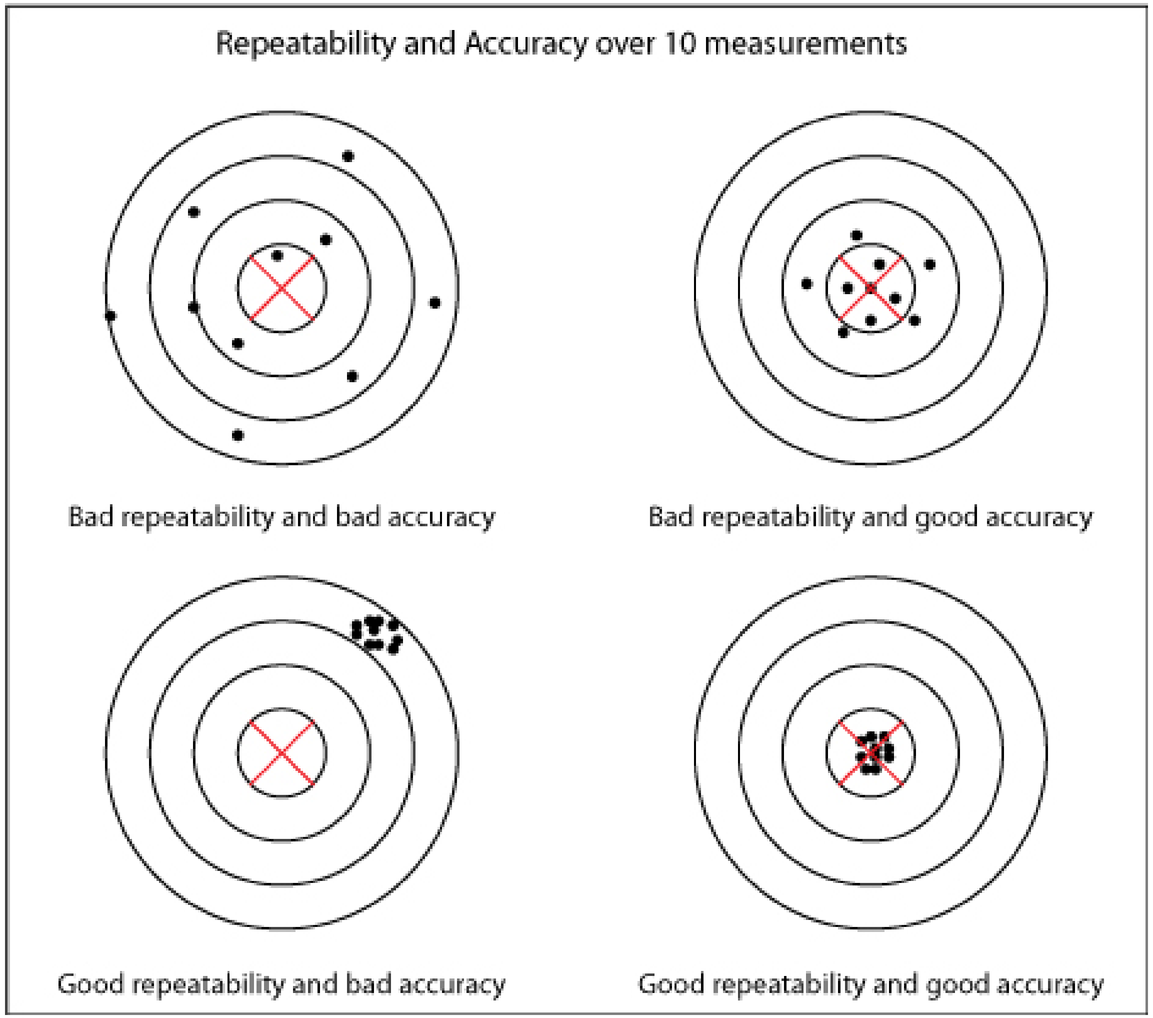
Robot motion limits

- Reach
  - The *maximum distance* a robot can achieve within its work envelope
  - For a robot, many points within the work envelope of the robot may be reached with any desired orientation, while for other points, close to the *limit of a robot's reach* capability, *orientation* cannot be specified as desired.
  - Reach is a function of the robot's *joint lengths* and its *configuration*.

Robot motion limits

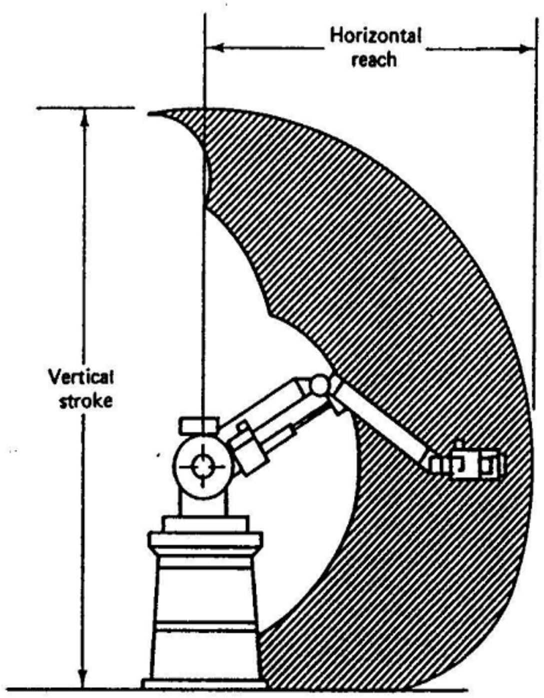
- Accuracy
  - How accurately a specified point can be reached.
- Repeatability
  - How accurately the same position can be reached if the motion is repeated many times
- Accuracy/ repeatability depend on
  - Resolution of the actuators
  - Robot feedback devices

Robot motion limits



Robot motion limits

- Workspace
  - Collection of points that a robot can reach



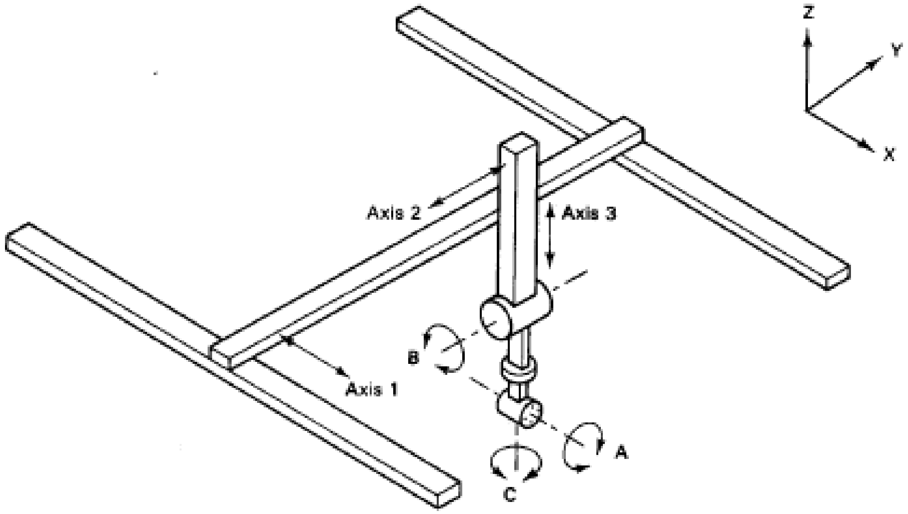
(b) Elevation

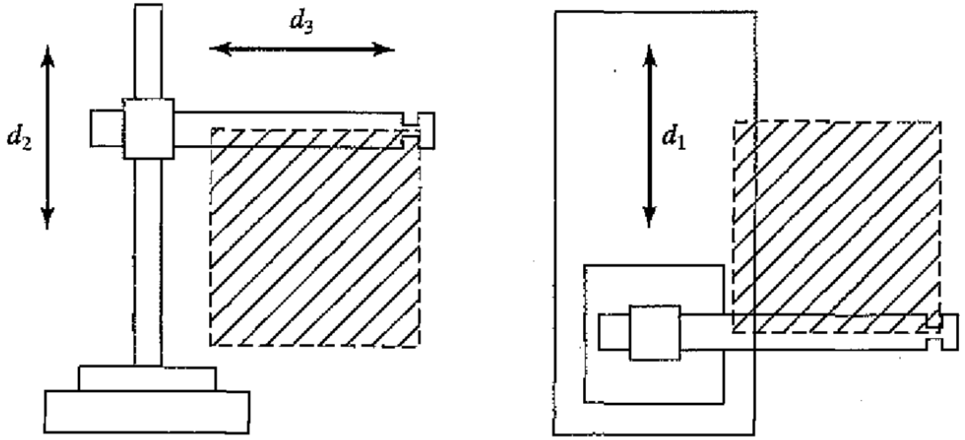
Five Basic Serial Robot Configurations

- Cartesian/rectangular/gantry (PPP)
- Cylindrical (RPP)
- Spherical (RRP)
- SCARA (RRP)
- Articulated (RRR)

Cartesian/rectangular/gantry (PPP)

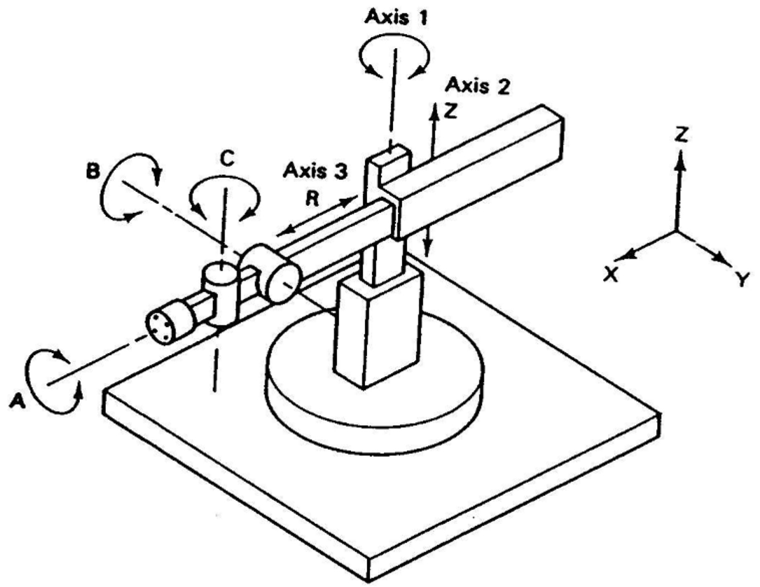
Work Envelope of Cartesian Robot

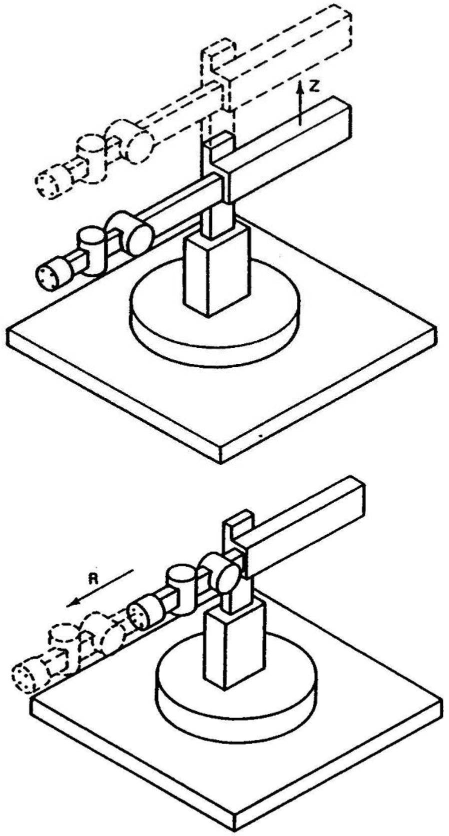


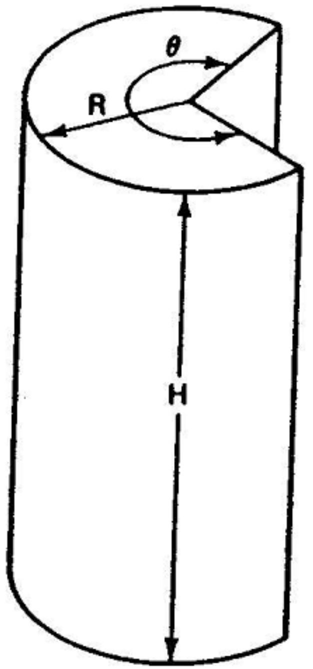


Cylindrical (RPP)

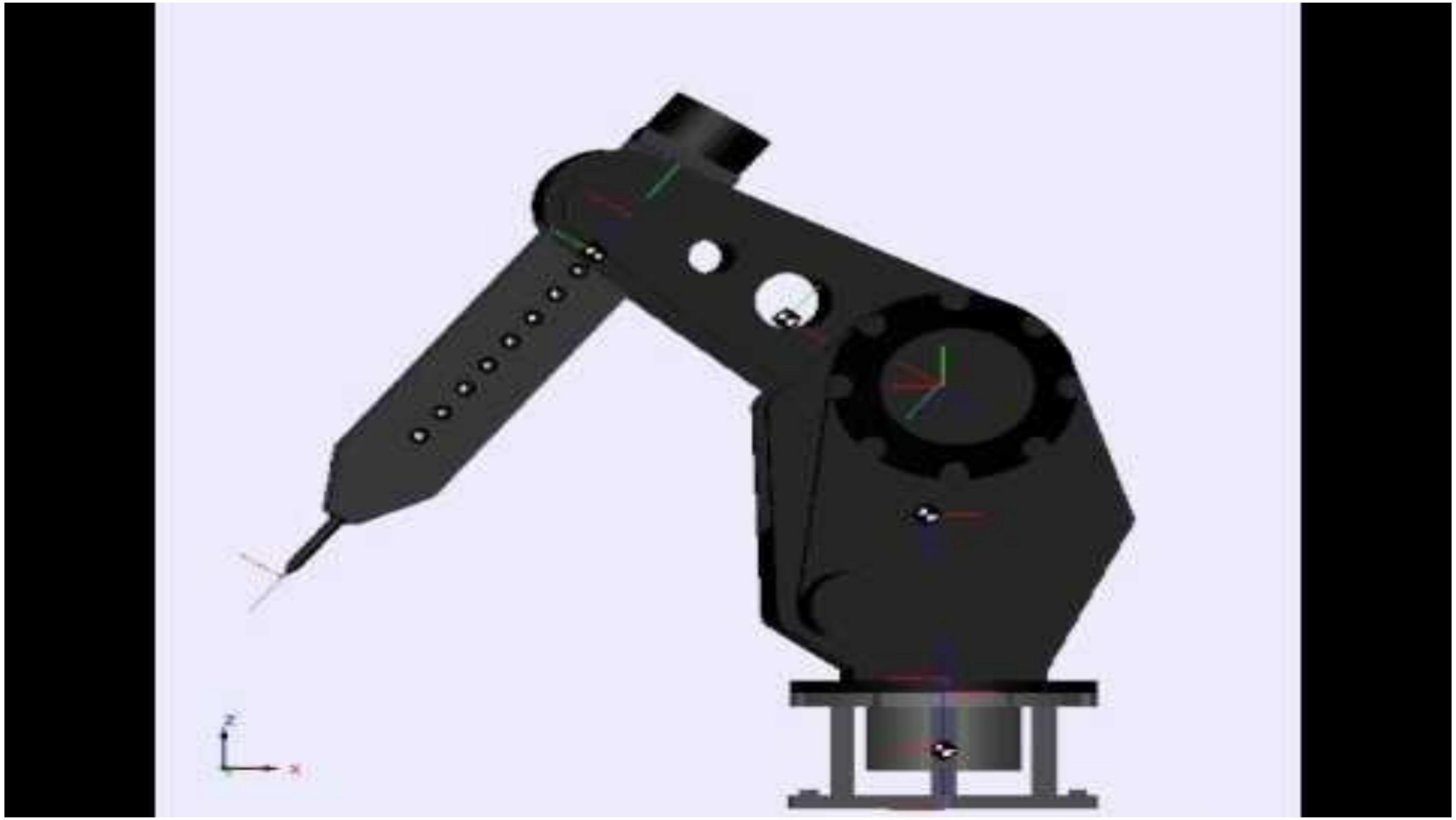
Work Envelope of Cylindrical Robot



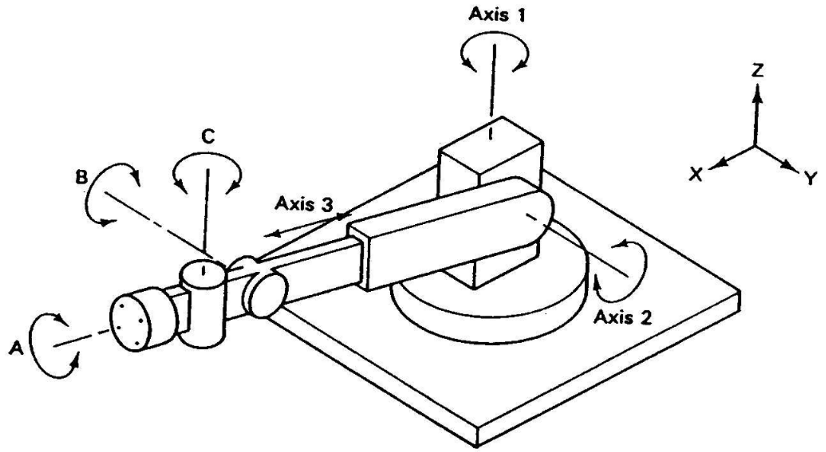


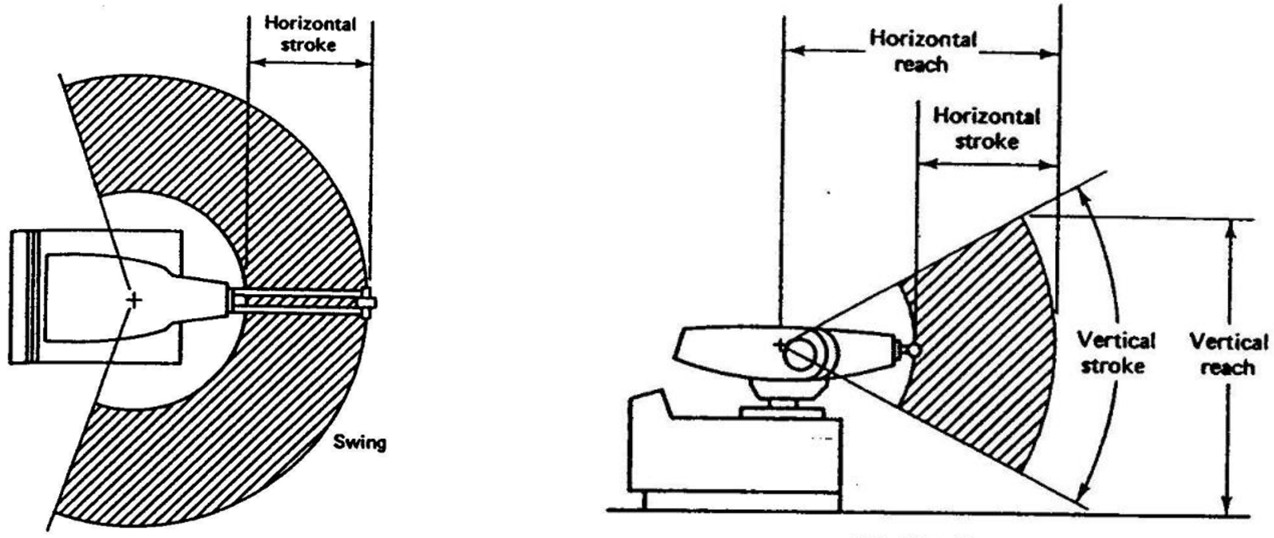


Spherical - RRP



Work Envelope of a Spherical Robot



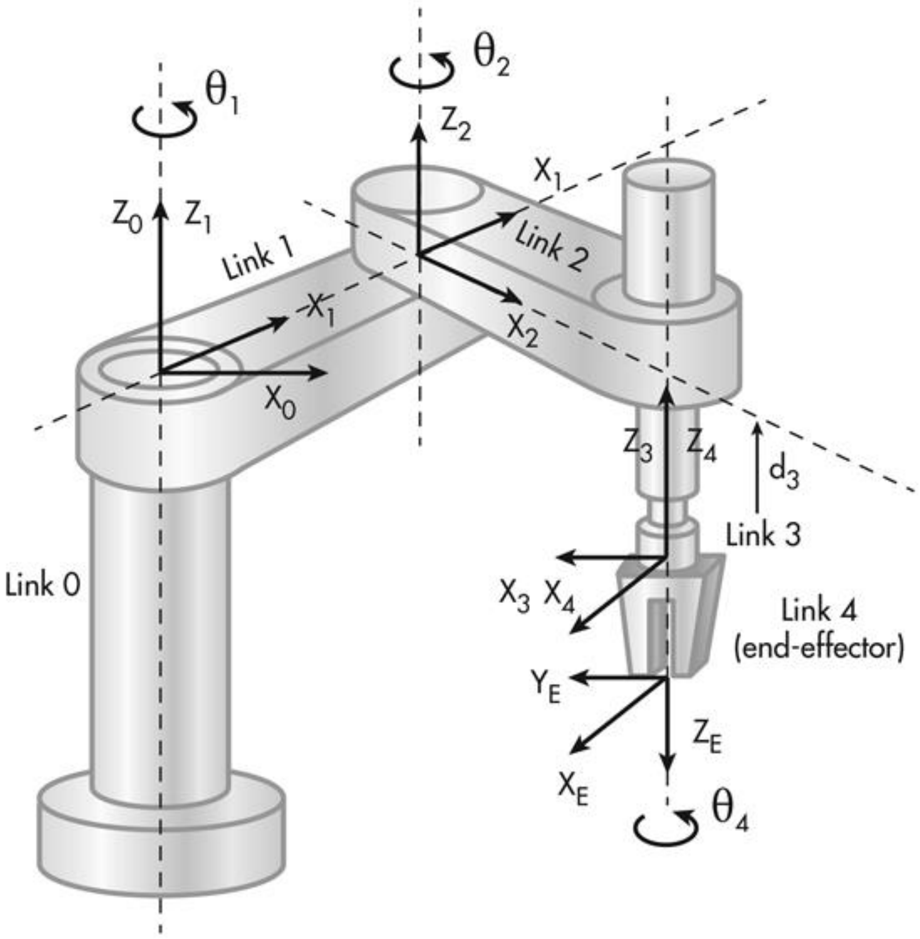


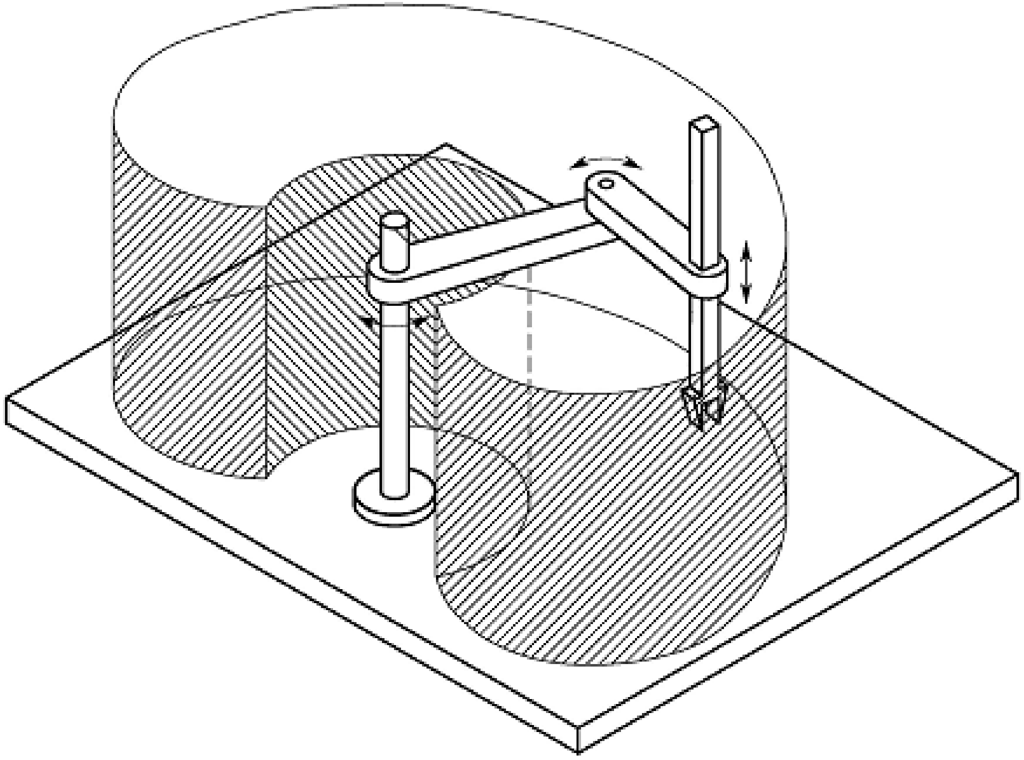
(a) Plan (b) Elevation

SCARA (RRP) (Selective Compliance Assembly Robot Arm)

Compliant robot

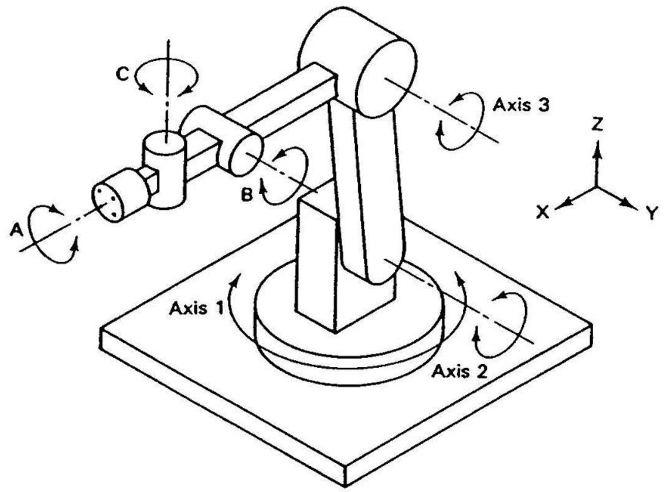
Work Envelope of a SCARA Robot

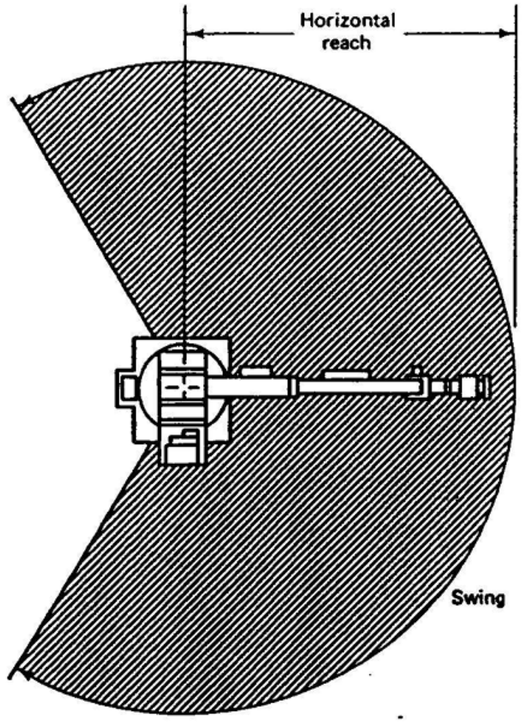




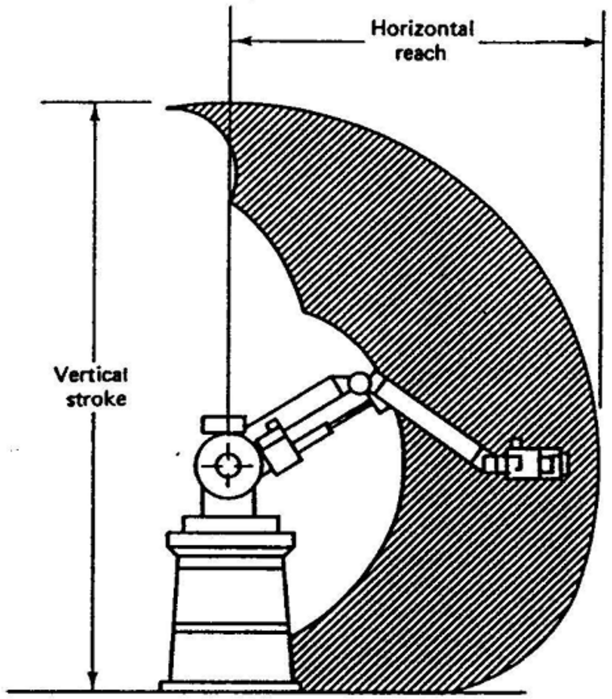
Articulated (RRR)

Work Envelop of an articulated robot



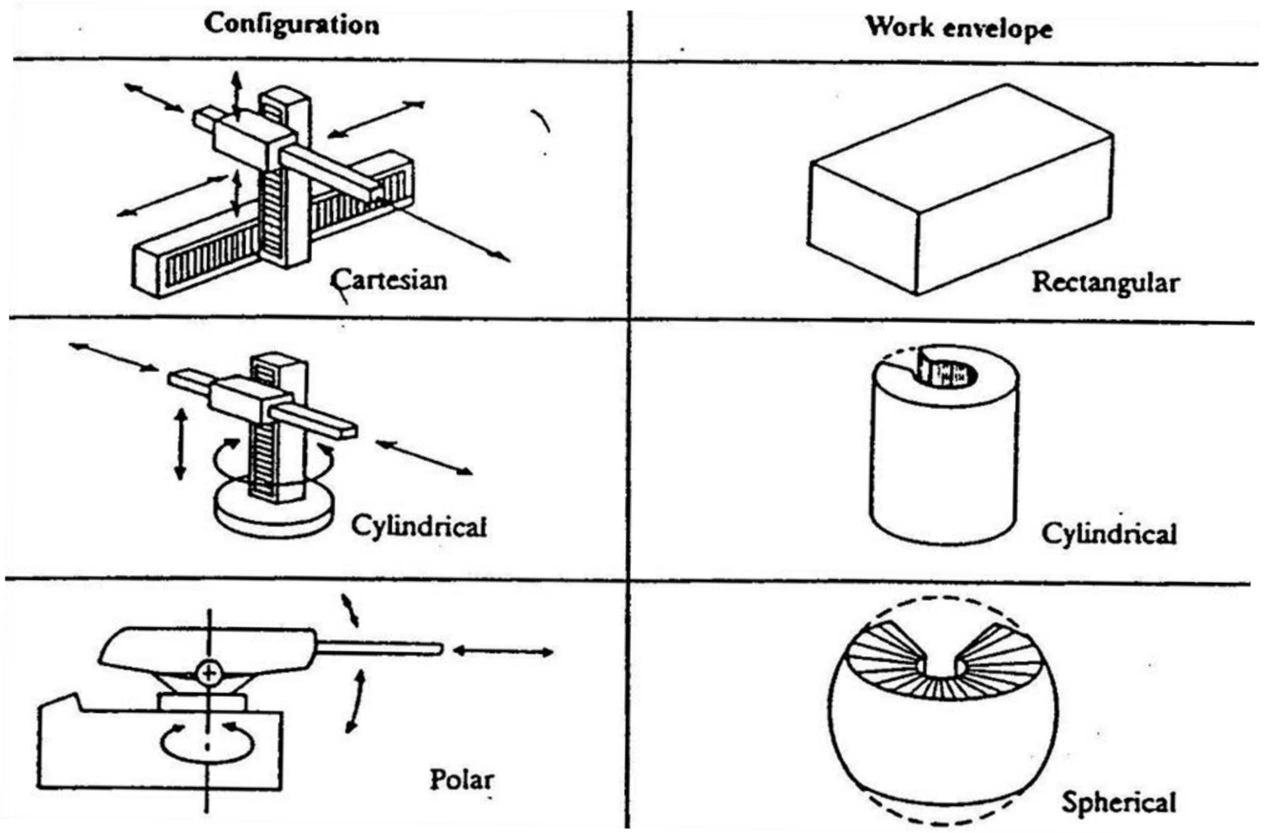


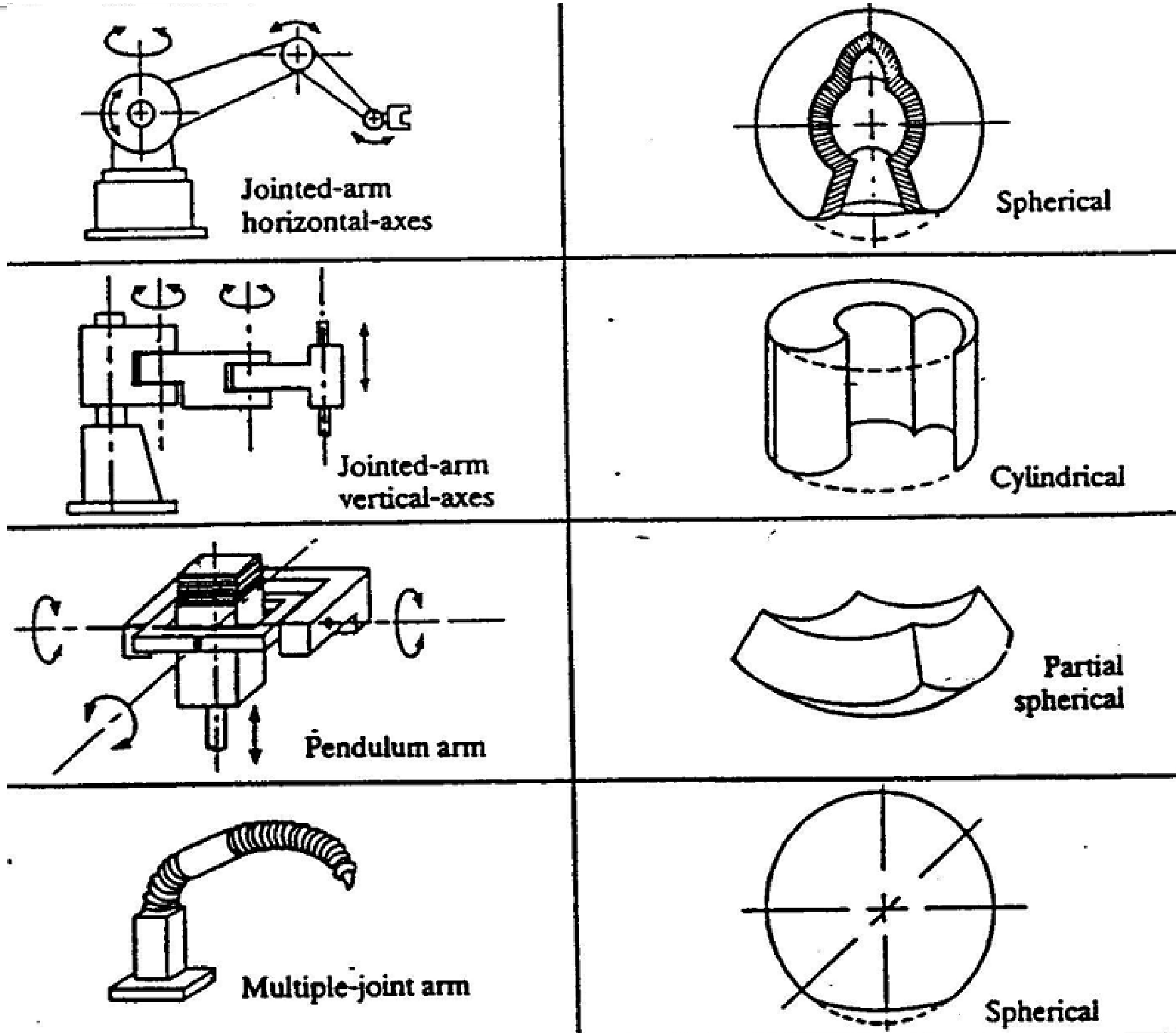
(a) Plan



(b) Elevation

Robot classification by work envelop





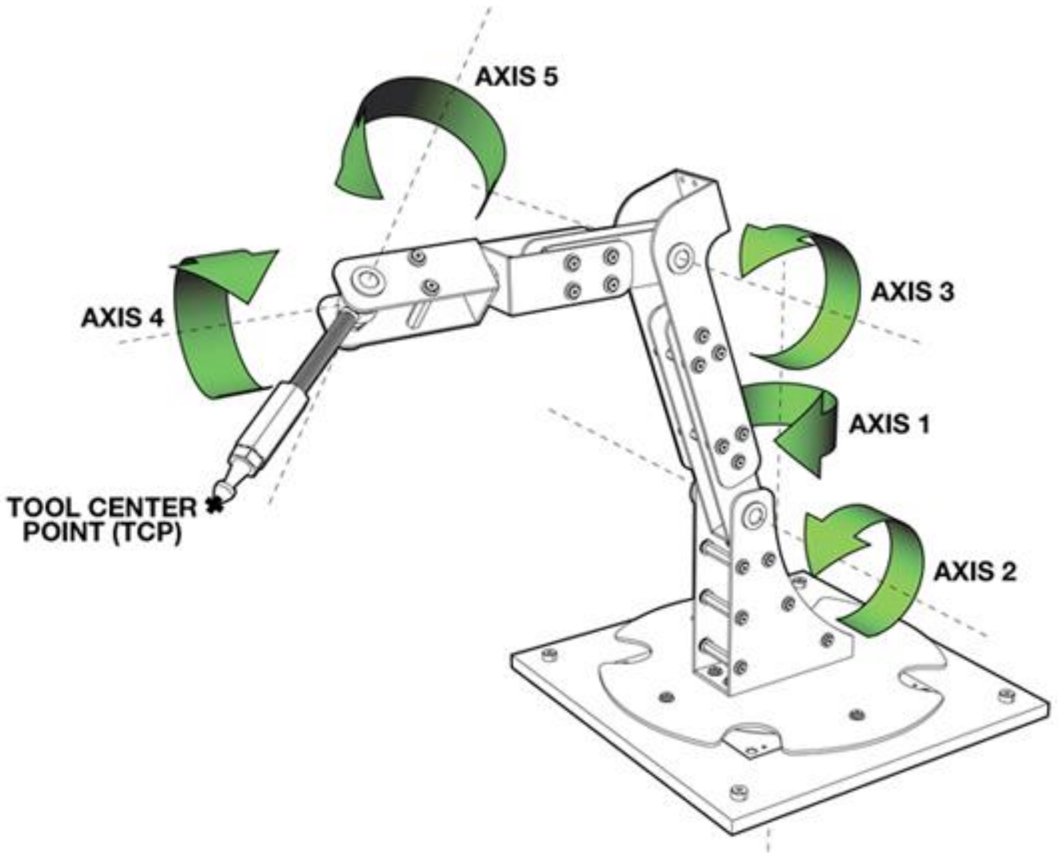
Consideration for choosing robot

- Design:
  - Desire large work envelope
  - Good performance:
    - Payload, speed, precision/accuracy, workspace, reach, repeatability
- Usage:
  - Need to know the design layout / configuration
  - Interface with other machines / robots
- Purchasing:
  - Need to consider complete cost
  - Necessary space
  - Tooling / end effectors
  - Maintenance

Next
Analysis of robot kinematics

Robot kinematics

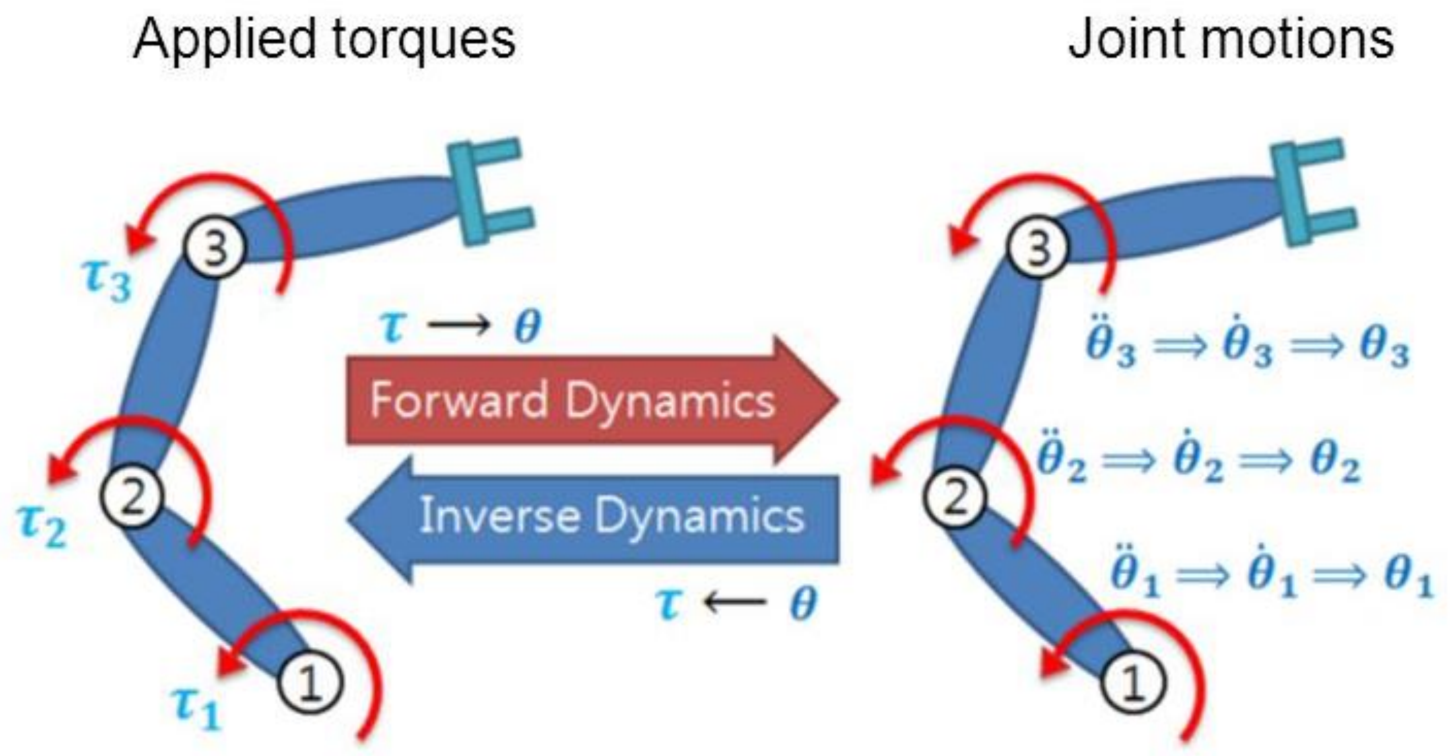
- Kinematics analysis
  - Study robot motion (position, velocity, acceleration) without considering the force/torque that cause the motions



- Forward/inverse kinematics

Robot dynamics

- Study robot motion caused by force/torque



Assignment

- Refresh your linear algebra
  - Vector and matrix operations

  - Practice with Matlab

http://www.cyclismo.org/tutorial/matlab/matrix.html

End