Kinematics
(of robot arms)

Kinematics

science of **motion**

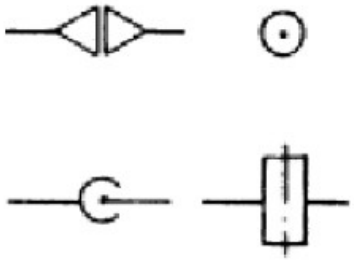
without regarding the underlying **forces**

- link: rigid component
- joint: moving parts
  - revolute: rotation
  - prismatic: translation

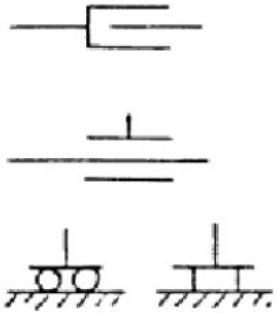
Kinematics

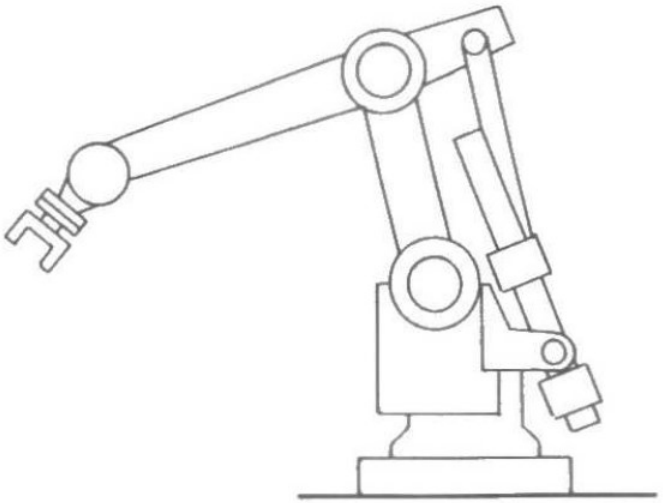
joints symbols

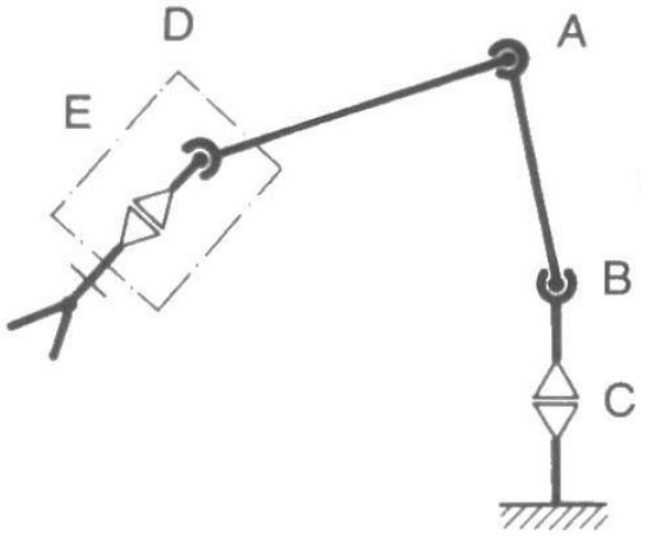
rotation



translation





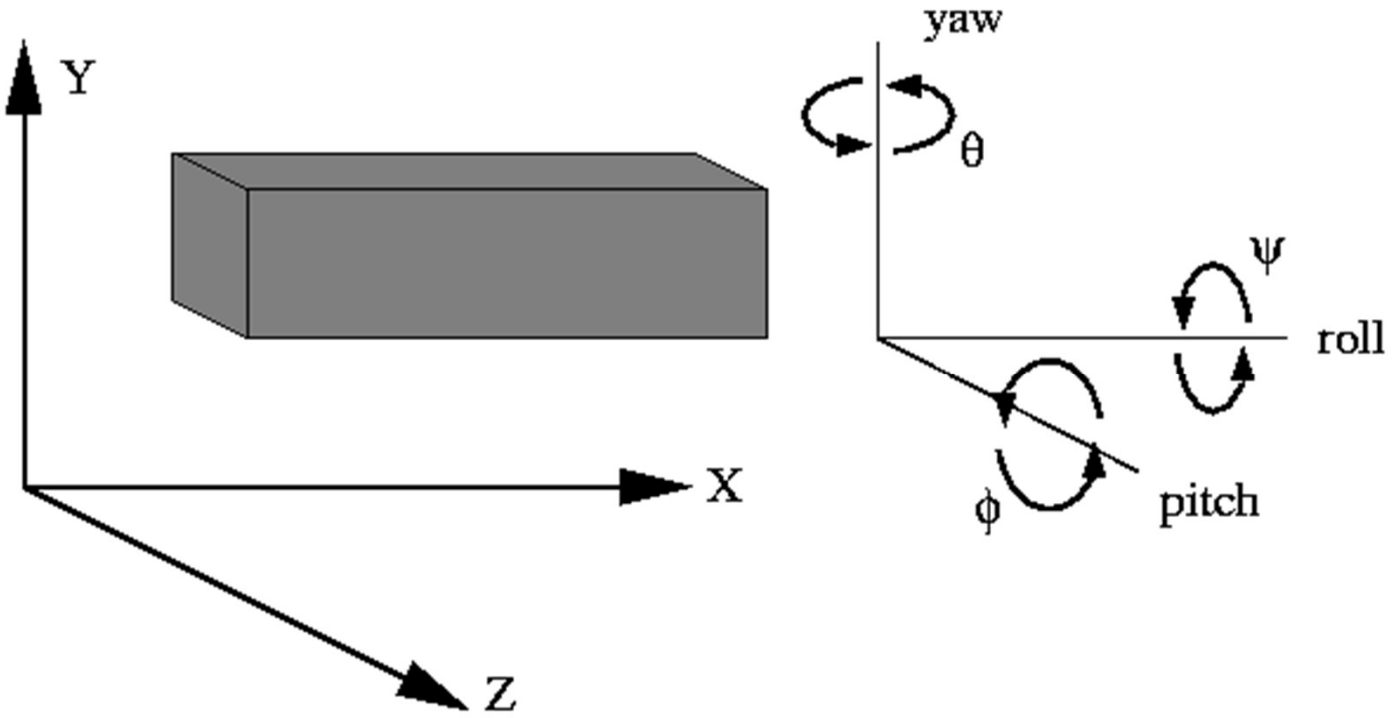


Kinematics

degree of freedom (DOF):

- number of variables
- needed to describe the motion
- of a system

3D Kinematics Rigid Body



6-DoF Pose: Position and Orientation

Kinematics

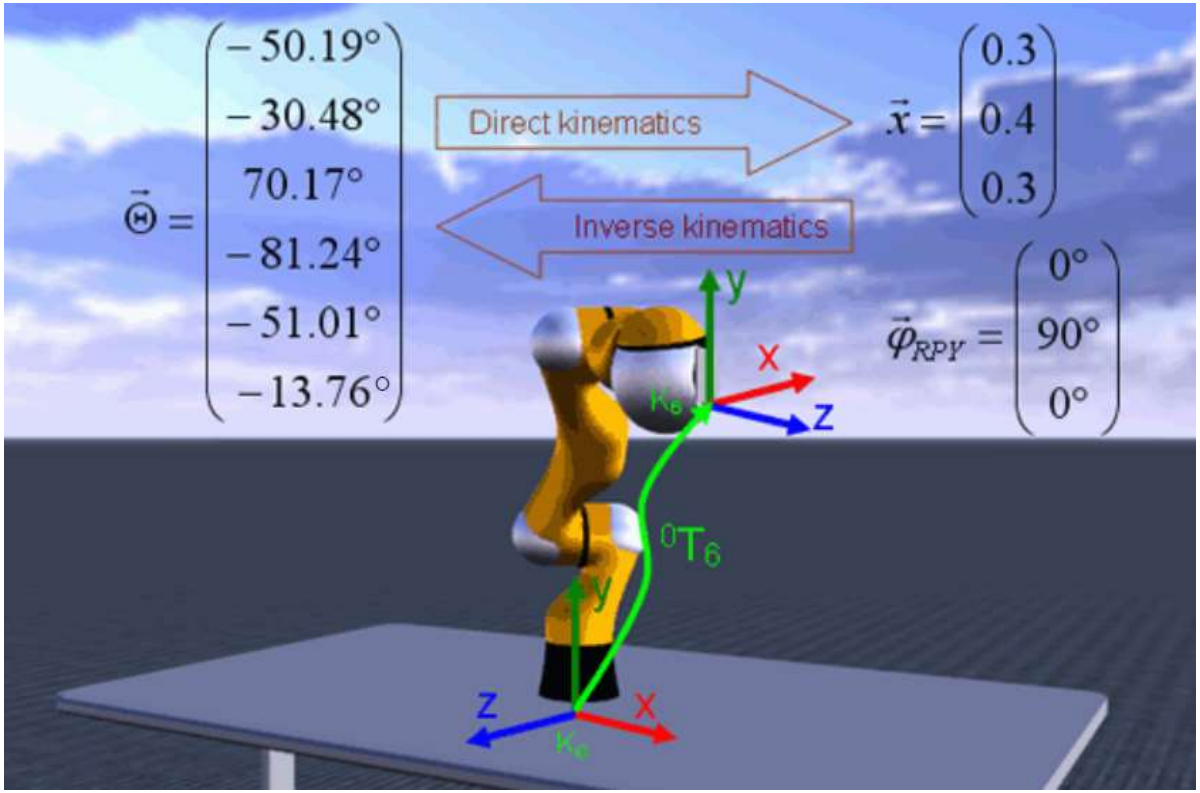
forward kinematics

- given joint values
- determine pose

inverse kinematics

- given desired pose
- find joint values

often:
not whole system
but only end-effector
pose of interest



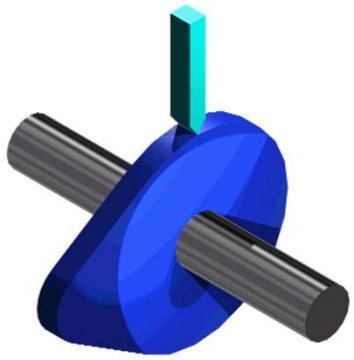
Kinematic Chain

kinematics topology as a graph

- link (rigid): edge between joints
- joint: vertex
  - revolute aka hinged: 1 DoF rotation
  - prismatic aka sliding: 1 DoF translation
  - screw: turning & sliding, but 1 DoF
  - cylindrical: revolute and sliding with 2 DoF
  - spherical aka ball joint: 3 DoF rotation
  - …

Kinematic Chain

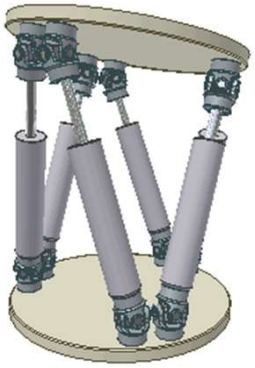
- joints can get complex
  - e.g., cam & follower



- but mainly revolute & prismatic
- especially in combination with actuators
  - active joint: driven by motor
  - passive joint: following through mechanical linkage

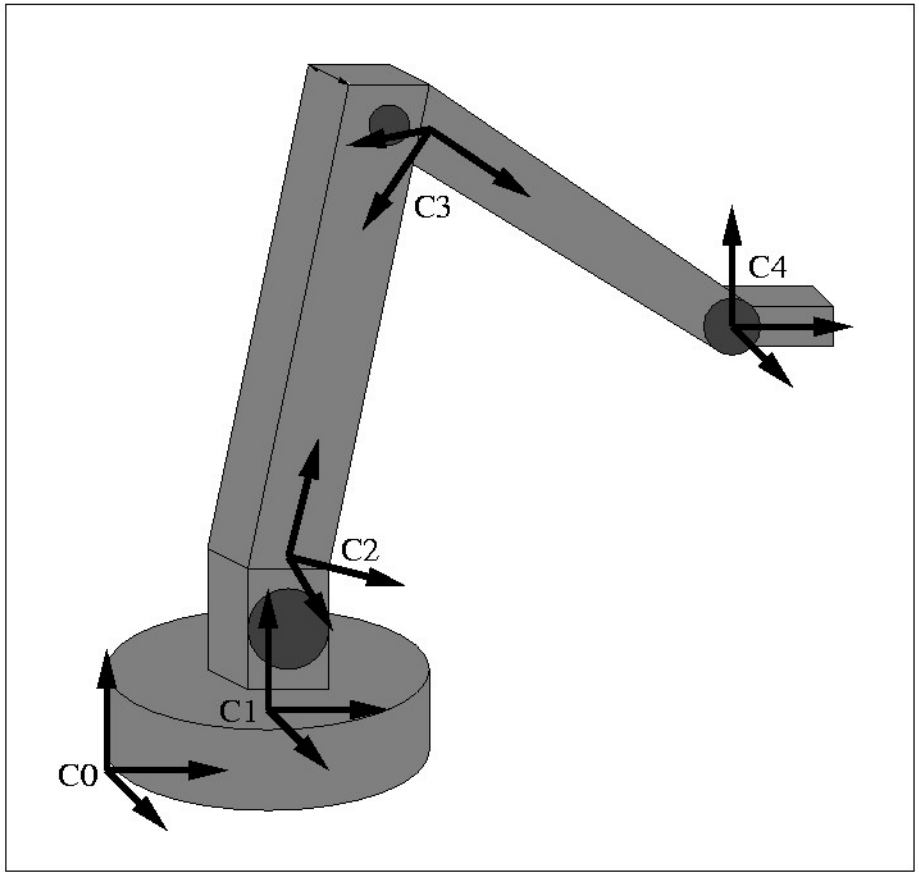
Kinematic Chain

- closed vs open chain
  - contains loops or not
- standard robot arm: serial chain
  - open chain as "tree" with branching factor 1
  - only revolute or sliding joints, all active
- parallel robot arms: closed chains
  - e.g., Steward platform (active prism. joints) or low-DoF pick'n'place robots

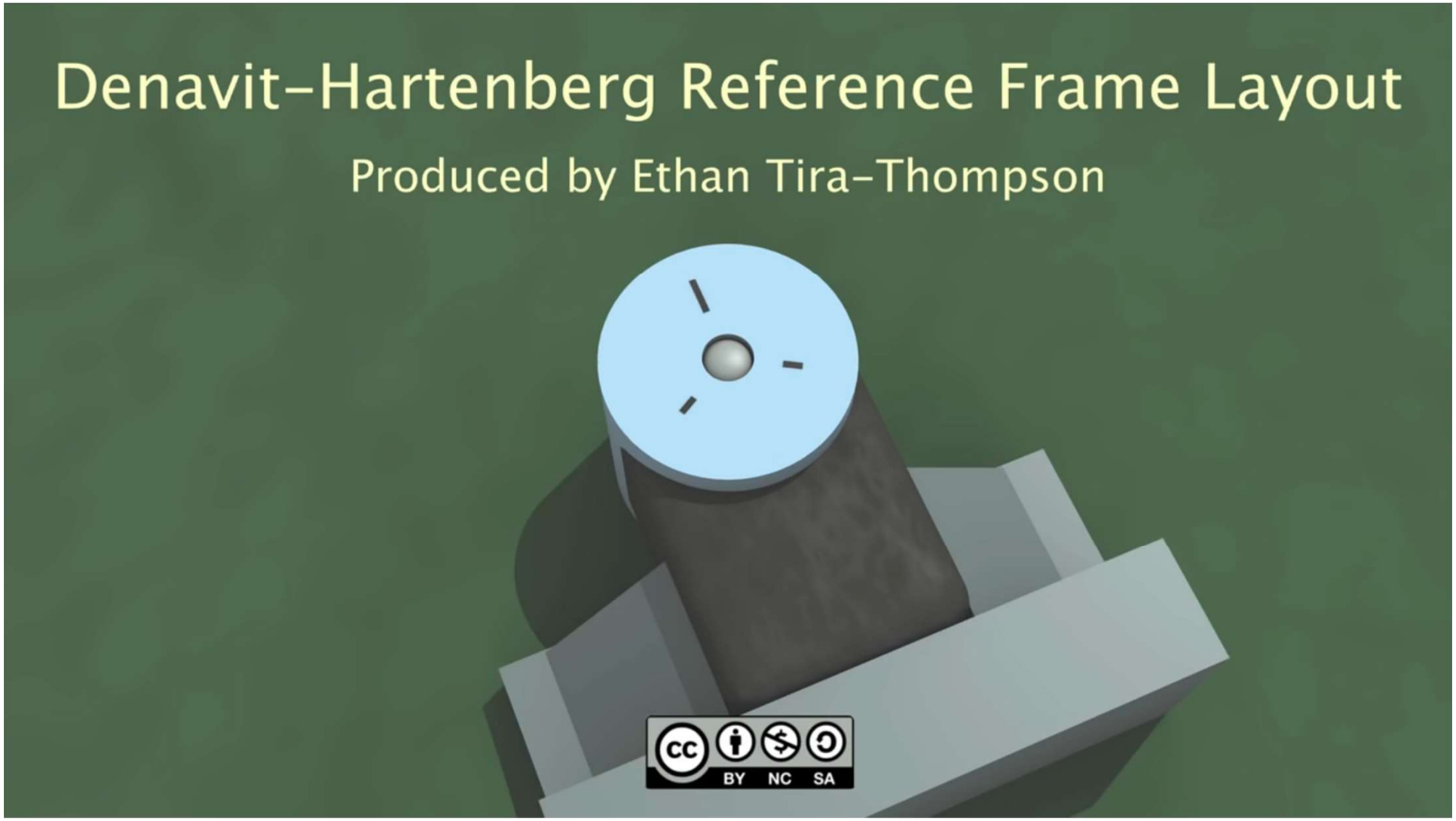


Robotarm Forward Kinematics

- transformation between coordinate systems (frames)
  - world-frame
  - base-frame
  - manipulator-frame
- kinematics becomes easy
  - determining manipulator-pose
  - through standardized matrix operations (or quaternions for rotation)
- conventions
  - Denavit-Hartenberg Rules
  - how to attach frame to link



Denavit-Hartenberg Rules



http://www.youtube.com/watch?v=rA9tm0gTln8

Denavit-Hartenberg Rules

short summary

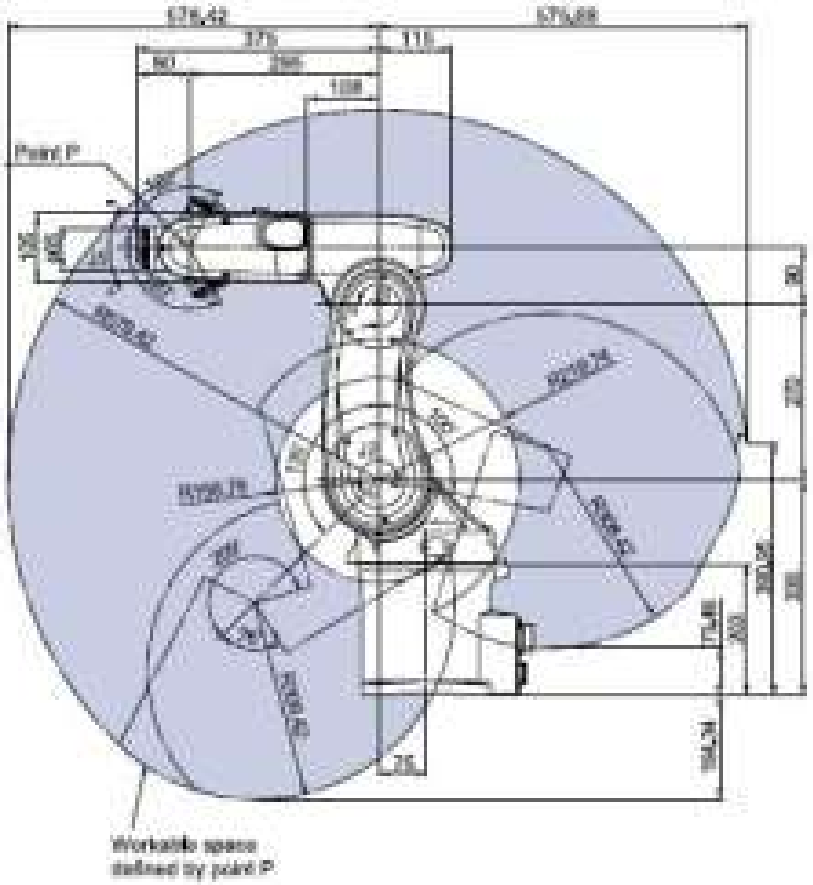
- z-axis of each joint: along its axis of motion
- x-axes: along the common normals between z-axes
- y-axes follow from right-hand-rule
- only four parameters for each transformation between frames:
  - d : "depth" along the previous joint's z axis
  - θ : rotation about the previous z (the angle between the common normal and the previous x axis)
  - r : radius of the new origin about the previous z (the length of the common normal)
  - α : rotation about the new x axis (the common normal) to align the old z to the new z

Work Space (WS)

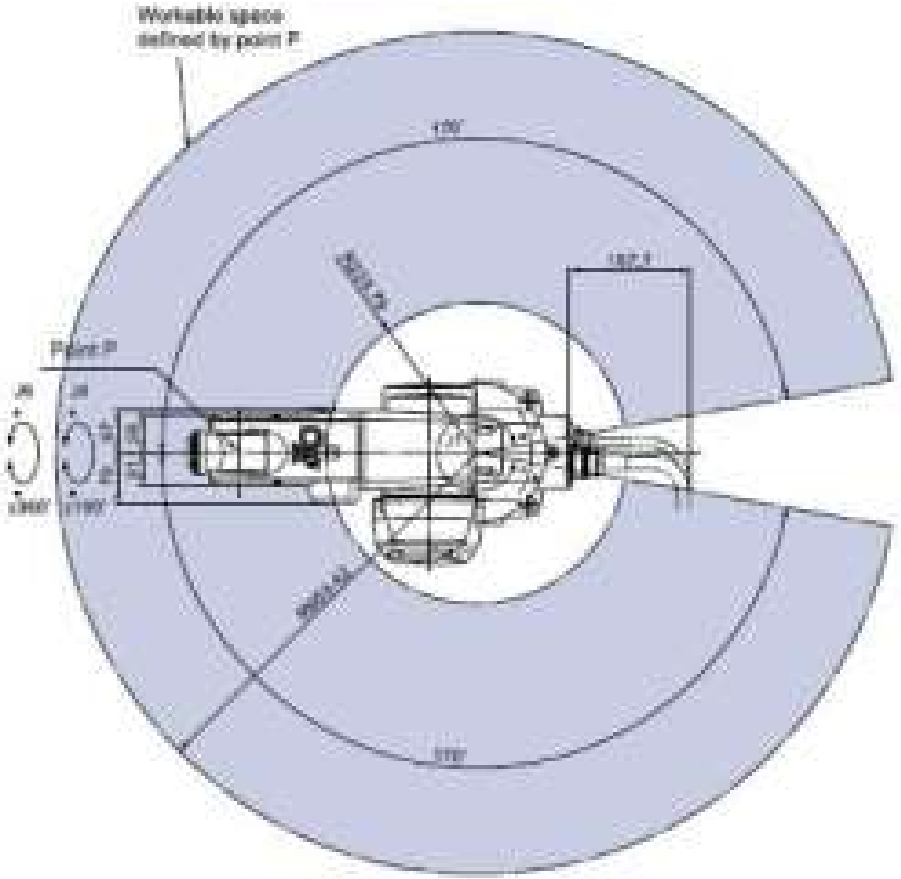
- aka work envelope, reach envelope
- space of poses the end-effector can reach
  - dexterous ws: reach with arbitrary orientation
  - reachable ws: reach with at least 1 orientation

Work Space

example

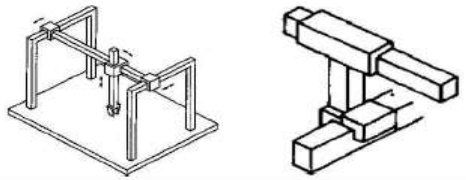
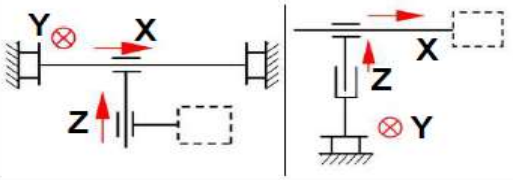
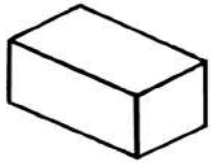
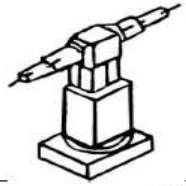
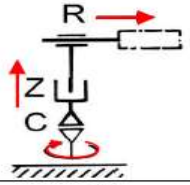
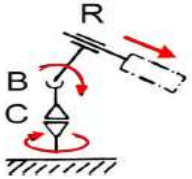
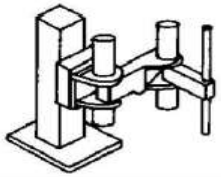
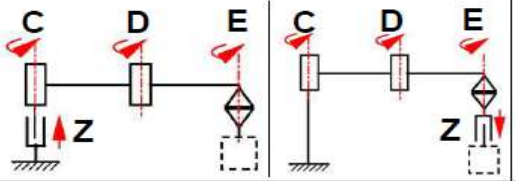
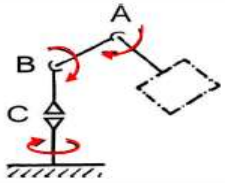


Side Dimensions and Work Envelope



Top Dimensions and Work Envelope

Arm Types & Workspaces

type	robots	kinematic chains	workspace
Cartesian			
cylindrical			
spherical			
horizontal articulated			
vertical articulated			

Forward Kinematics

- more ***Forward Kinematics***
  - later on in the context of locomotion
- ***Inverse Kinematics*** soon
  - first: how are active joints implemented
  - i.e., how are DoF physically actuated