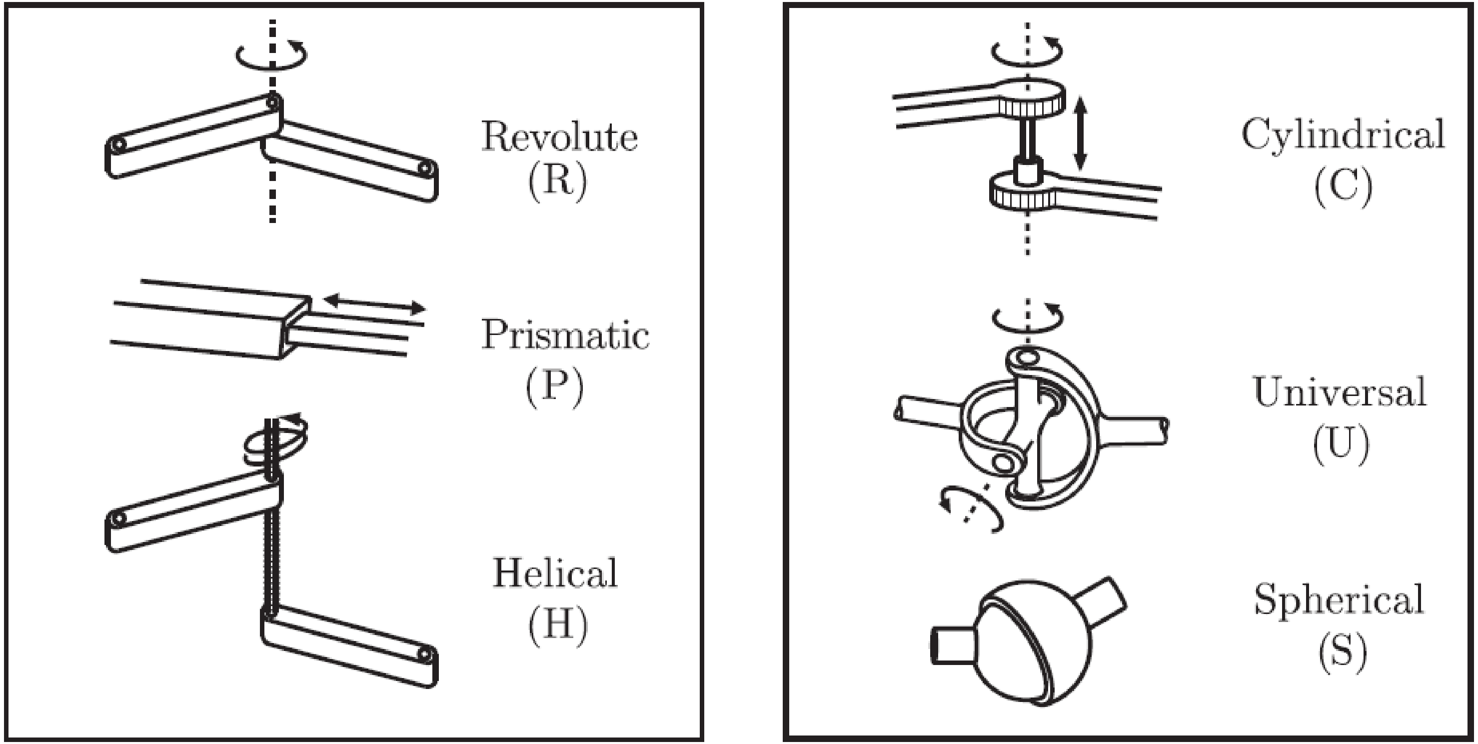
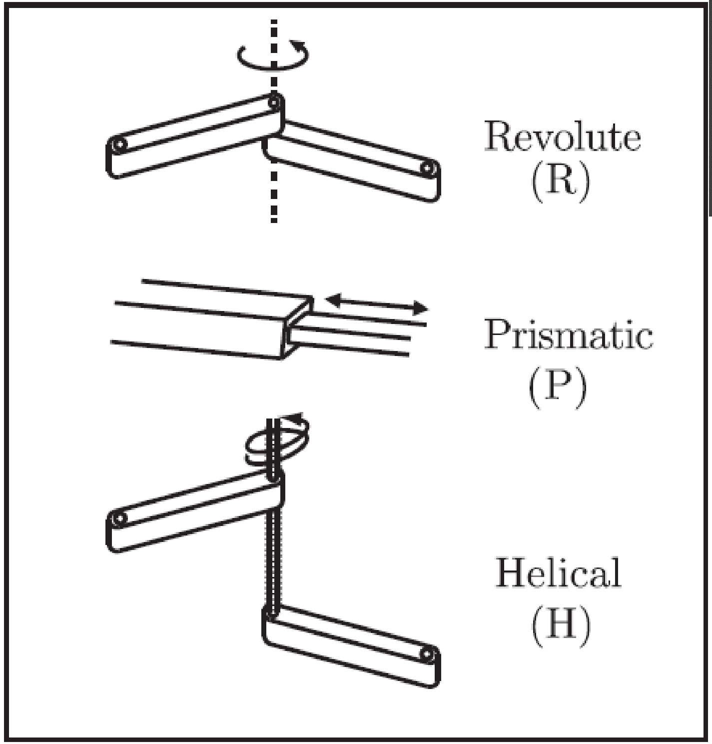
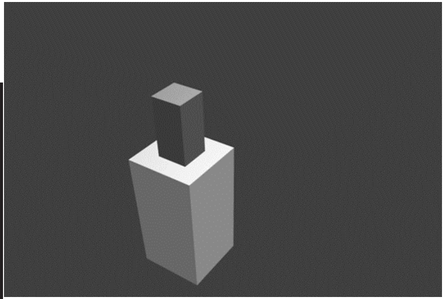
21AIE201-INTRODUCTION TO ROBOTICS

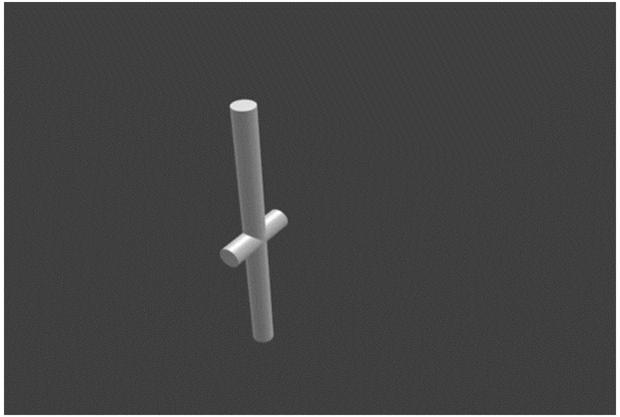
Lecture 6

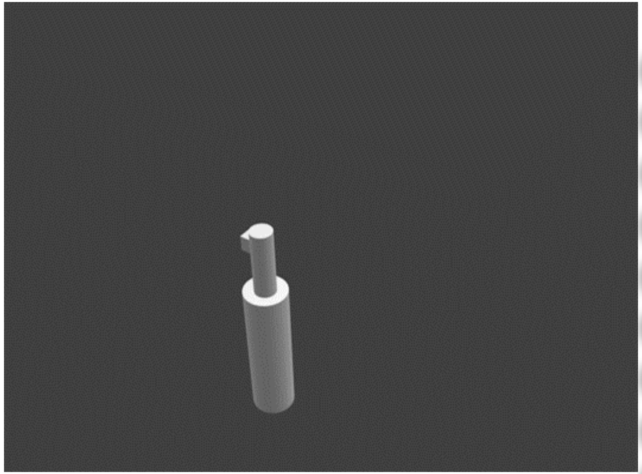



Typical robot joints.


Revolute
(R)
Prismatic
(P)
Helical
(H)

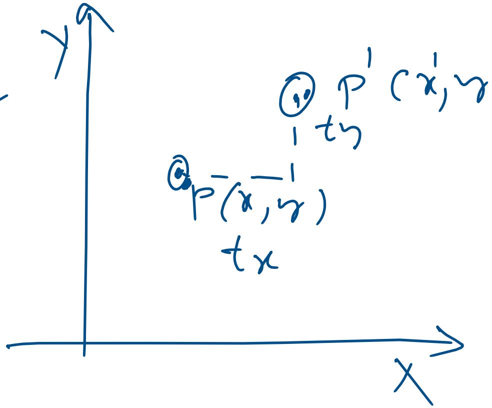






Transformation

1. Translation
2. Rotation
3. Scaling
4. Reflection

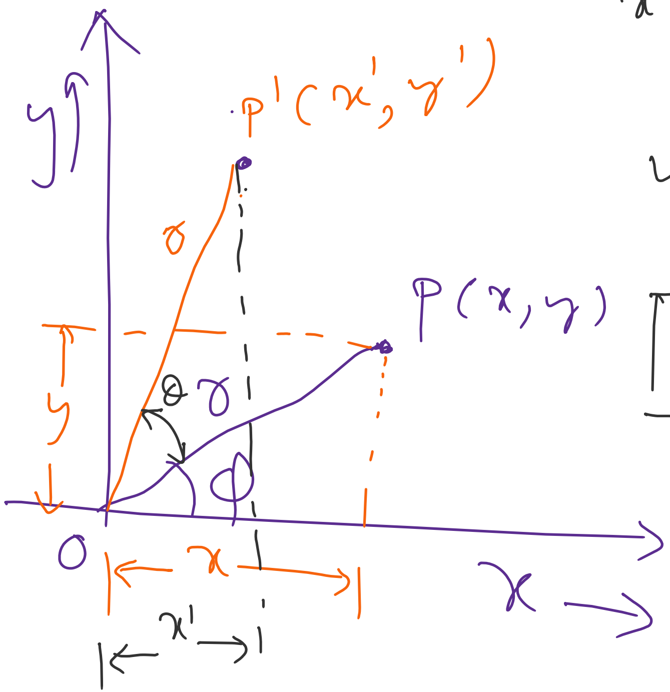


$$x' = x + t_x$$
$$y' = y + t_y$$

$$\begin{bmatrix} x' \\ y \end{bmatrix} = \underbrace{\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t \end{bmatrix}}$$

matrix addition

Rotation



$$x = r\cos\phi \quad y = r\sin\phi \longrightarrow \text{matrix multiplication}$$

$$x' = r\cos(\phi+\theta) = r\cos\phi \cdot \cos\theta - r\sin\phi \cdot \sin\theta$$

$$\boxed{x' = x\cos\theta - y\sin\theta}$$

$$y' = r\sin(\phi+\theta) = \underbrace{r\sin\phi \cdot \cos\theta}_{y\cos\theta} + \underbrace{r\cos\phi \cdot \sin\theta}_{x\sin\theta}$$

$$\boxed{y' = x\sin\theta + y\cos\theta} \quad -(2)$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$[P'] = [R] \times [P] \rightarrow \text{matrix multiplication}$$

Classification of Robots

- Power Source
- Workspace Geometry
- Degrees of Freedom
- Kinematic Structure
- Movement and
- Type of Applications

Based on Power Source[1]

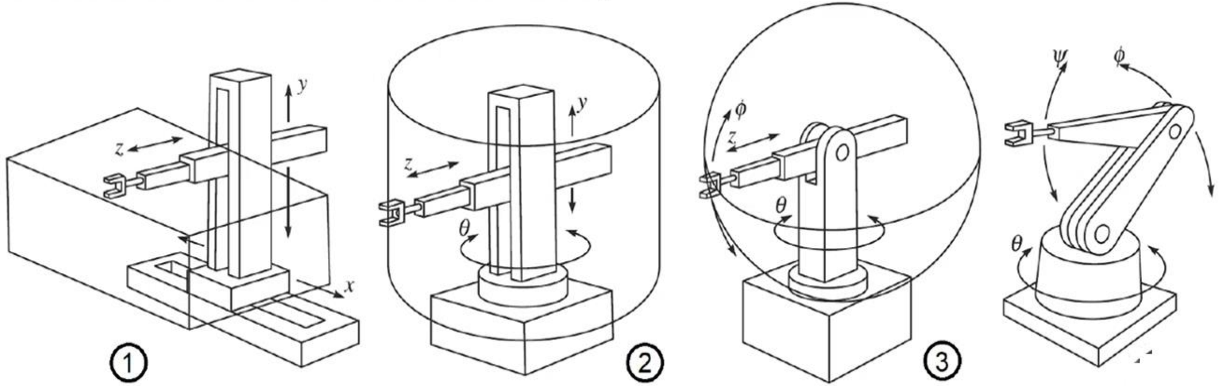
Electrical, Hydraulic, Pneumatic, Non-conventional sources

1. **Electrical**: AC/DC
   DC: Provides higher torque, More maintenance - More parts
   → BLDC, Brushed geared motors, Steppers, etc.
   → Used in Mobile, Aerial, and Underwater robots.
   → AC: Large capacity industrial robots
   → Mostly with synchronous servo motors.
2. **Hydraulic**: Usually in very large capacity robots.
   → Problems - noise, leak, fire hazard, maintenance, etc.
3. **Pneumatic**: High speed robots.
   → Issues of compressibility of gas - lack of precision, drifting, etc.
4. **Non-conventional sources**: Nuclear - Submarines, Deep Space explorations, Solar - Space robots, etc.
   → Mostly runs electrical actuators.

Based on Workspace Geometry [2]

1. **Cartesian (PPP)**: For heavy loads in Industry - Simple, Easy to use and program
2. **Cylindrical (RPP)**: More reachable, large payload, rigid structure.
3. **Spherical/Polar (RRP)**: Large range.
4. **Articulated Arm**: Most common in Industry

The **workspace** of a robot arm is the set of all positions that it can reach.

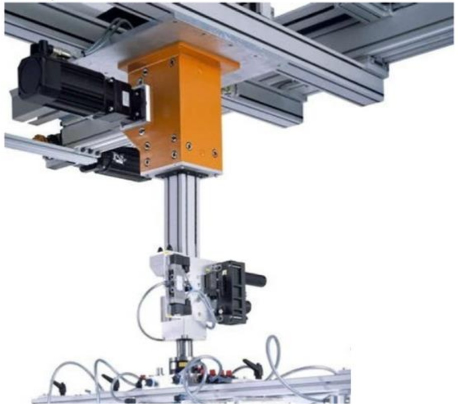


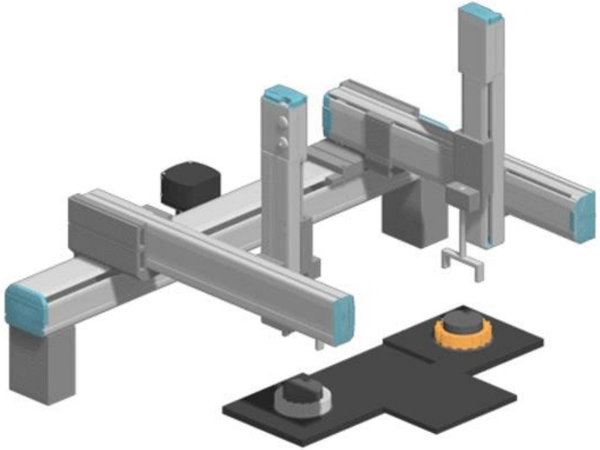
Cartesian Robot

Cartesian/Rectangular Gantry(3P): These Robots have 3-Linear joints that position the end-effector, which ar usually followed by additional revolute joints for controlling orientation.

Makers: *Gudel AG, Martin Lord, Fibro, IAI, PROMOT, MOTEC, BOSCH Rexroth, KUKA, Nordson EFD, Cincinnati Milacron, Parker, Festo Diactic, Mazak, Lucas.*

Applications: CMM, Inspection, Laser Cutting, Pick-and-place, Loaders, etc.





Cylindrical Robot

Cylindrical Robot (R2P or RPP): These Robots have a rotary joint and 2-Linear joints that position the end-effector, and are usually followed by additional revolute joints for controlling orientation.

Makers: (Very Few and Old) *Seiko, Hudson, ST Robotics.*

Applications: Limited operations in hotel industry, tool loaders, pick-and-place, etc.

Spherical Robot

Spherical Robot (2RP): These Robots have 2-rotary joints and a prismatic joint that position the end-effector, and may have an additional revolute joint for controlling orientation.

Makers: (Obsolete) *Unimate-Kawasaki.*

Applications: (Limited) Lack of vertical axis motion, used as tool loaders and specific pick-and-place.

Based on Degrees of Freedom (DoF)[3]

1. Planar - 2/3 DoF
2. Spatial: 3 DoF pure translating/rotating robot
3. 6-DoF: 3 Translation and 3 Rotation
4. Redundant robots
5. Limited DoF: 4 or 5 for special purposes

Based on Kinematic Structure

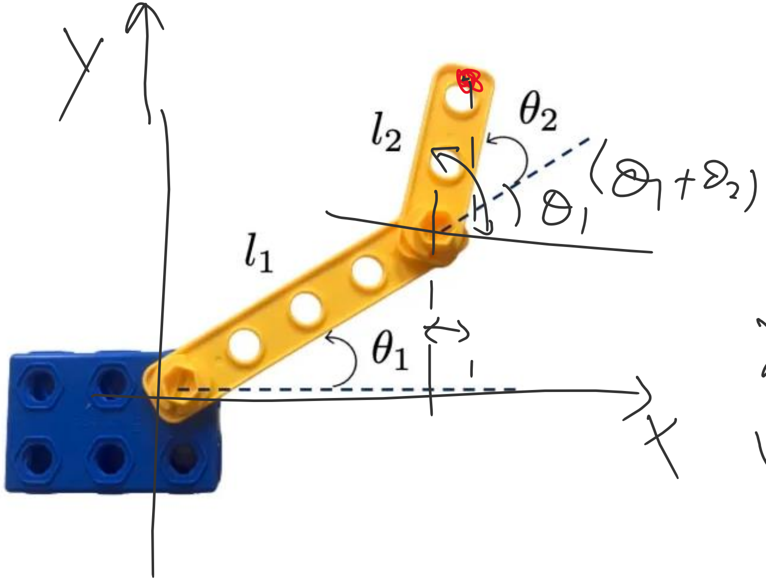
1. Open loop: Serial Robot
2. Closed loop: Parallel structure
3. Hybrid or Tree type systems
4. Anthropomorphic robots


Based on Movement

1. Fixed Robots
2. Mobile robots:
   → Wheeled, Omni wheels, Legged, etc.
3. Swimming robots and Underwater robots
4. Aerial or Flying robot

The Workspace of a Robot

- By definition, the workspace of a robot is a specification of the reachable configurations of the end-effector.
- The workspace of a robot has nothing to do with a particular task.



The robot arm has two revolute joints, and the lengths of the links are as follows:

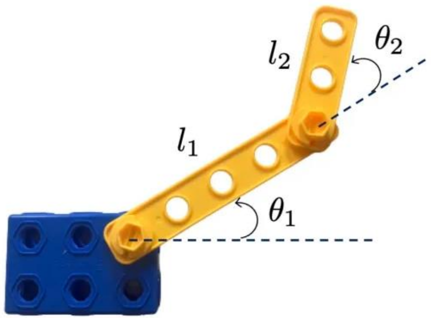
l_1=15.6cm

l_2=9.2cm

$$x = l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2)$$

$$y = l_1 \sin\theta_1 + l_2 \sin(\theta_1+\theta_2)$$

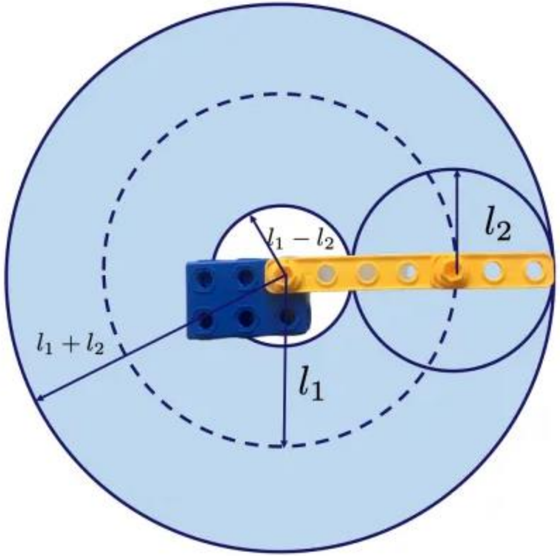
The Workspace of a Robot



The robot arm has two revolute joints, and the lengths of the links are as follows:

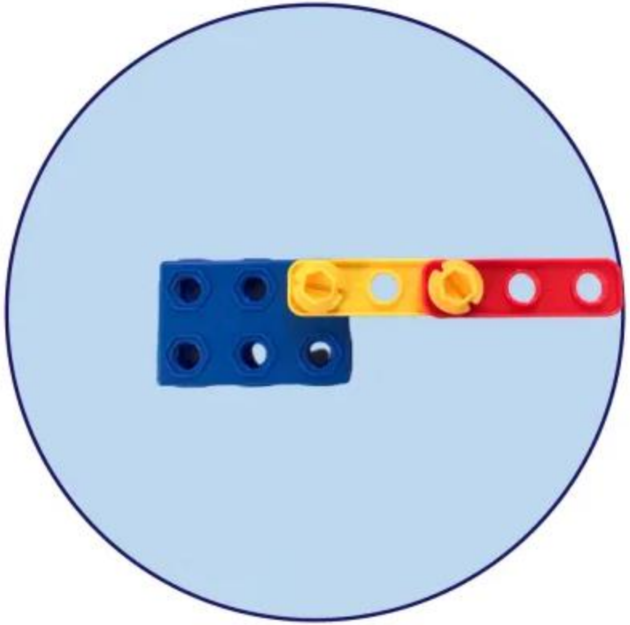
l_1=15.6cm
l_2=9.2cm

The workspace of this robot, if we do not impose any limitations on the joint angles **(both angles can be freely changed from 0 to 360º)**, can be visualized like the figure below:

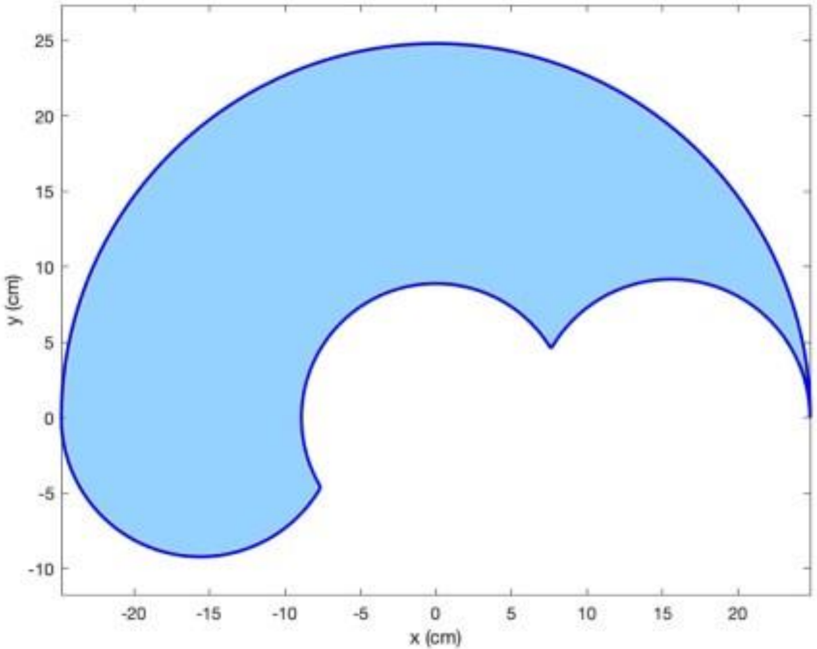


The circle with a radius of $l_1 - l_2$ is the area that the robot end-effector cannot reach.

The Workspace of a Robot



$$\theta_1 \in [0^o, 180^o]$$
$$\theta_2 \in [0^o, 150^o]$$



Time for Discussions

Thank You!