机器人技术与实践

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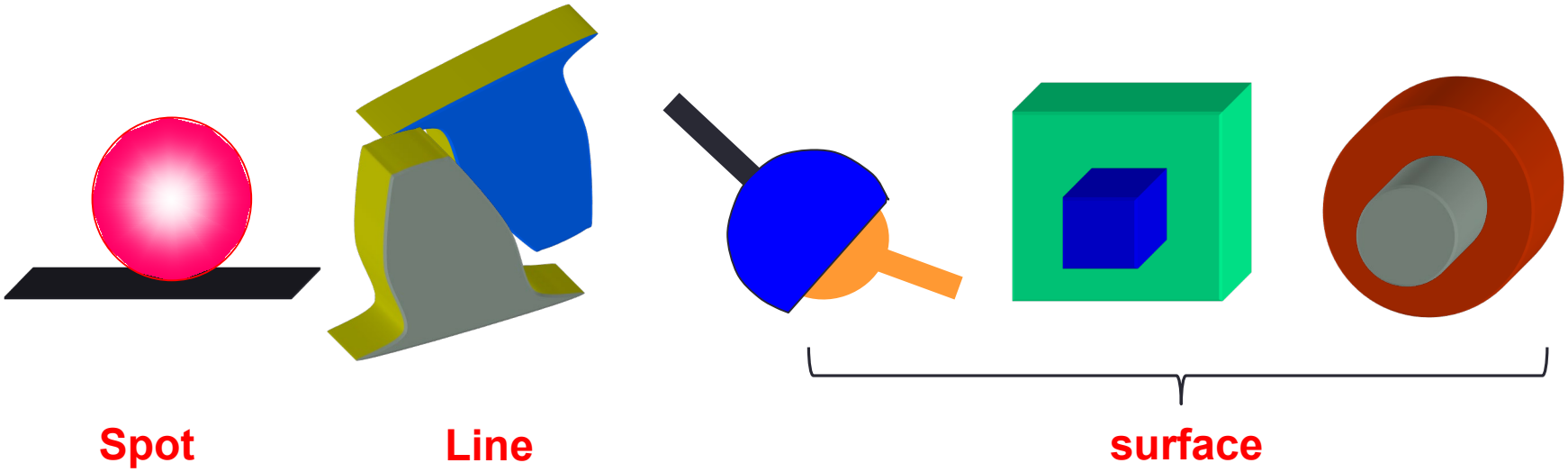
1. MECHANISMS OF ARTICULATED ROBOTS

ABB IRB4400

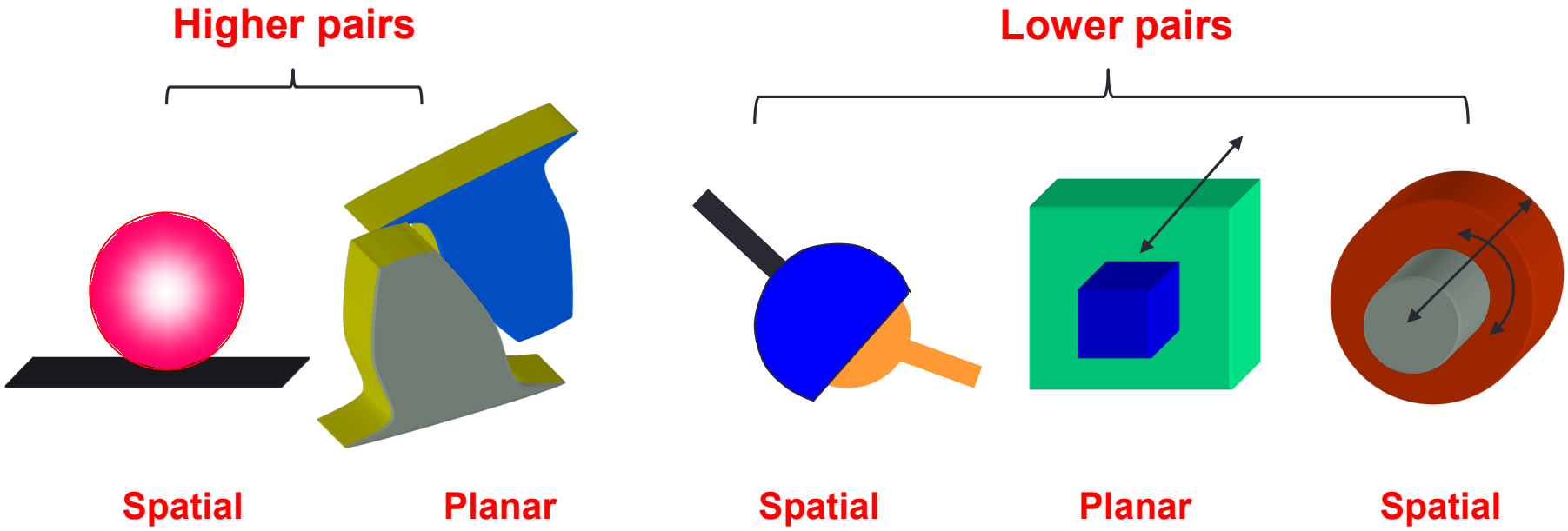
NAO

1.1 Mechanisms

- **Mechanism** – a system of two or more linked machine parts with kinematic pairs
- **Kinematic pairs** – the movable contact between two linked machine parts
- **Elements of kinematic pairs** – contact point, line, or surface



Kinematic pairs



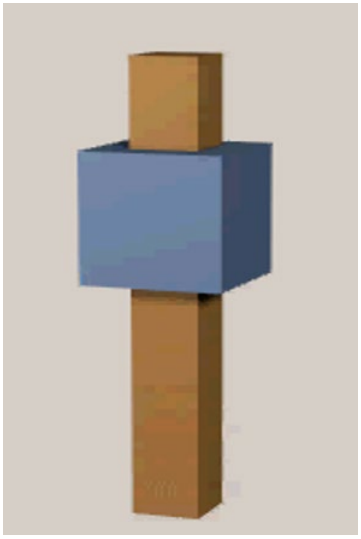
by pressure of contacts:

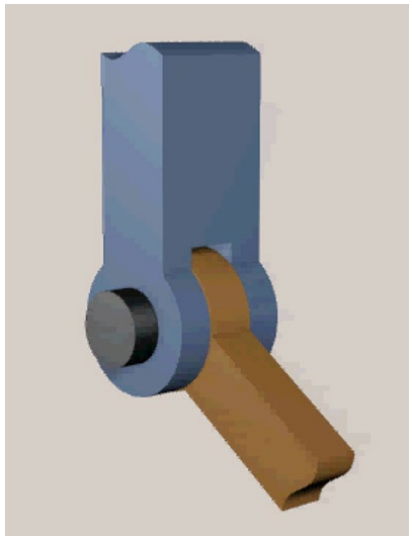
- Lower pairs - surface contact
- Higher pairs – spot or line contact

by relative movements

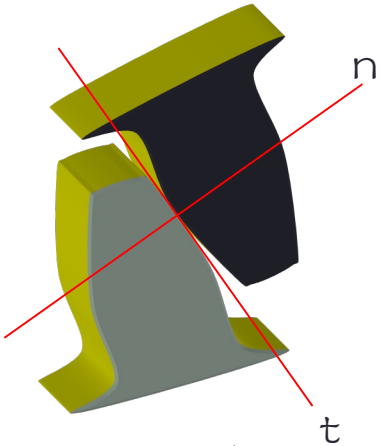
- Planar pairs
- Spatial pairs

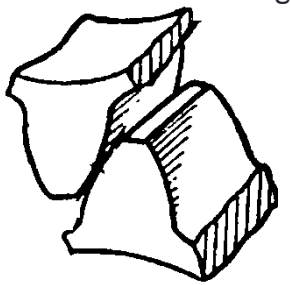
Planar pairs

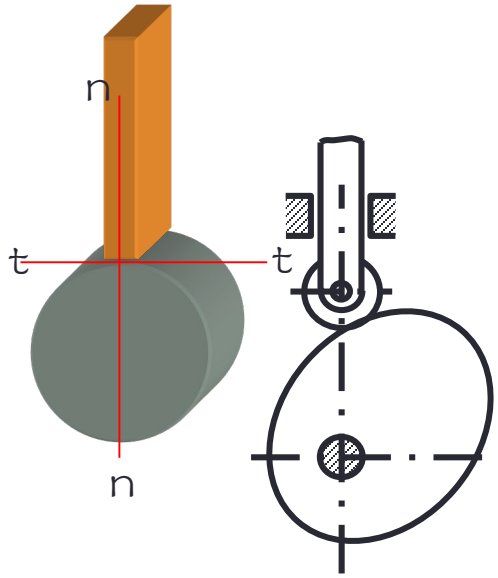




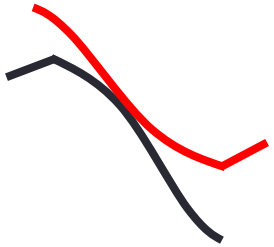
Lower pairs - prismatic and revolute

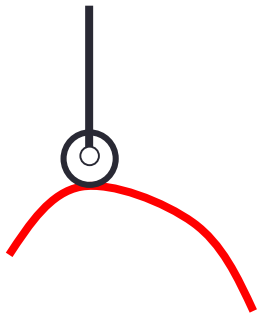




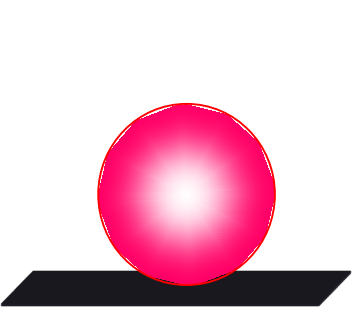


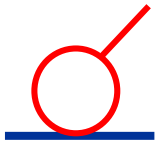
Higher pairs - gear and cam



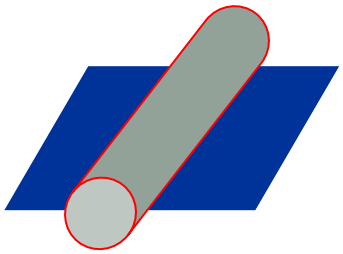


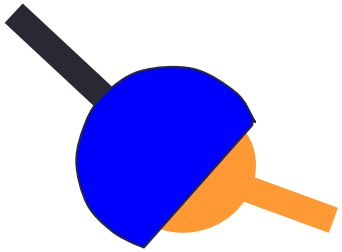
Spatial pairs

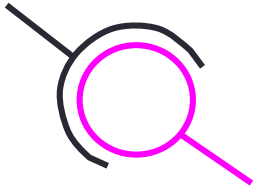




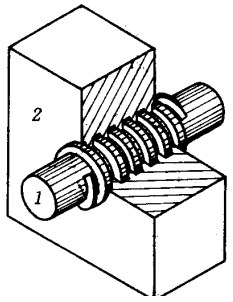
spot or line contact

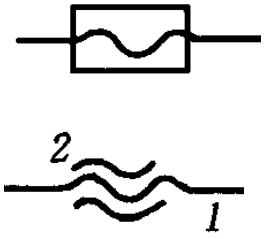




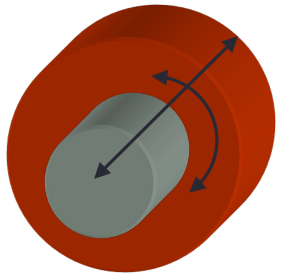


Spherical pair





Helical pair



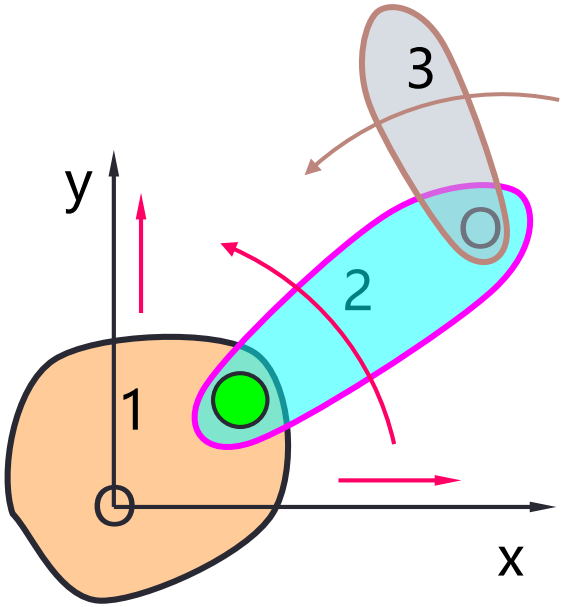
Cylindrical pair

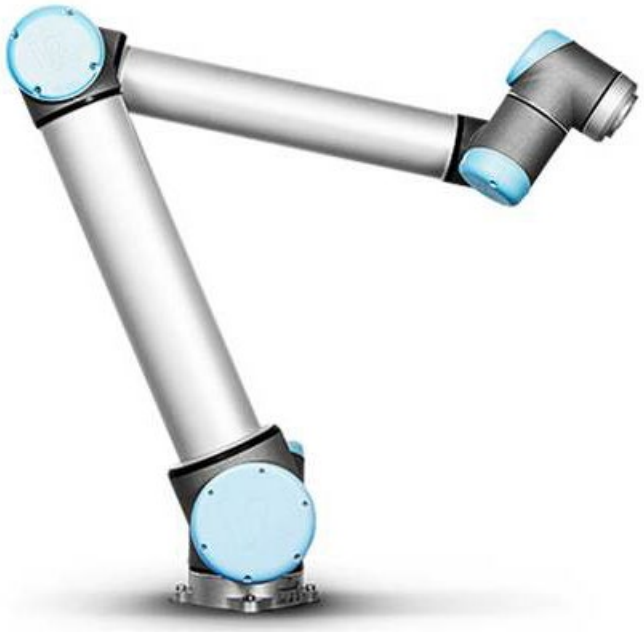
higher pairs

lower pairs

Mechanism

- A system of two or more linked machine parts with kinematic pairs

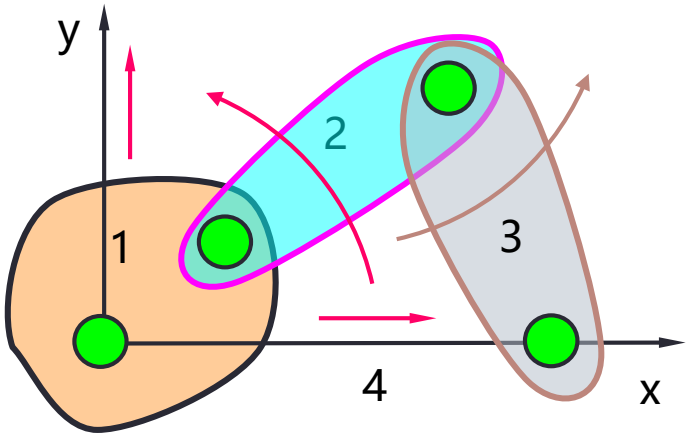


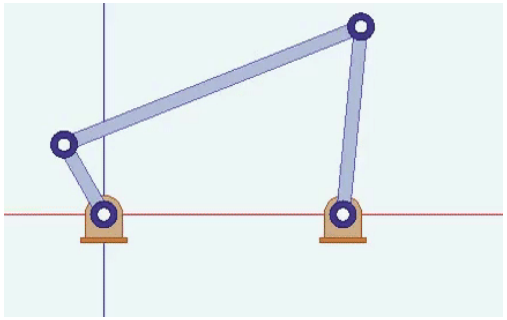


Serially-connected open chain

Serial Close Chain

- **Mechanism** – a system of two or more linked machine parts with kinematic pairs





Serially-connected close chain

Degree of Freedom

A particle: DoF = 3

DoF of a planar particle = ?

- **A particle in the Cartesian Space needs 3 coordinates (x, y, z) to locate its position. A free particle has 3 translational DOFs.**

A rigid body: DoF=6

DoF of a planar rigid body = ?

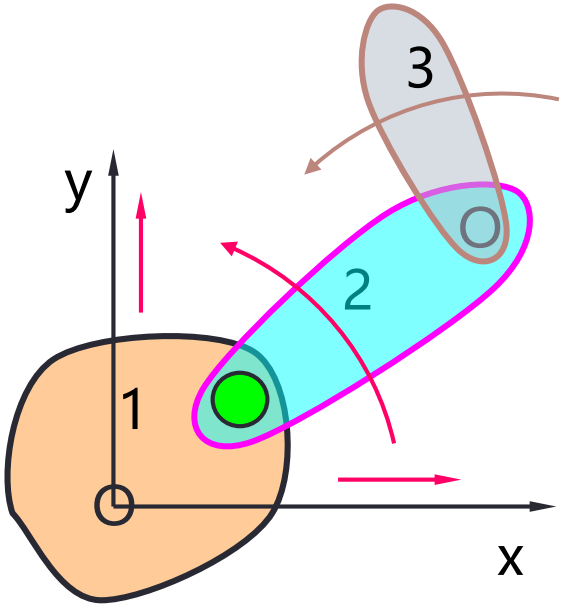
- **A free rigid body has 3 translational DOFs and 3 rotational DOFs. It needs 3 coordinates (x, y, z) to locate the reference point (CG, e.g.) on a rigid body and 3 orientation angle (α, β, γ) to define its pose with respect to the reference coordinate frame.**

A robot: DoF = ?

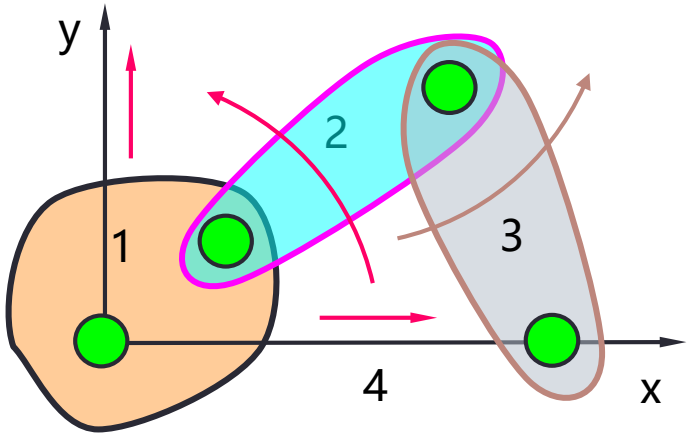
- **In most cases, it is determined by the number of independent actuators in a robot mechanism.**

Degree of Freedom

- If rigid links are connected by kinematic pairs to form a mechanism, total DOFs decrease owing to constraints from kinematic pairs.



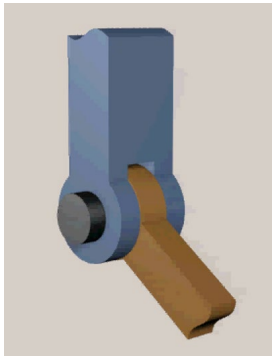
3 DOFs



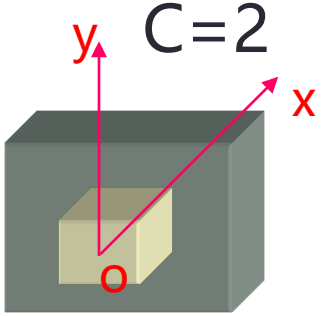
1 DOF

DOF of Planar Mechanisms

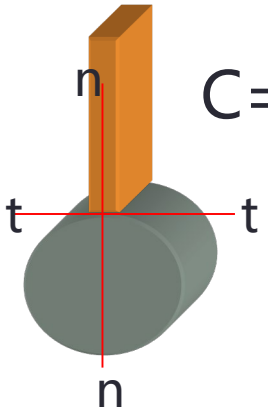
- A planar lower pair brings 2 constraints
- A planar higher pair brings 1 constraint



C=2



C=2



C=1

DOFs of Planar Mechanisms

No. of movable parts: $n = N\text{-}1$ (N is the total No. of parts)

No. of lower pairs: L

No. of higher pairs: H

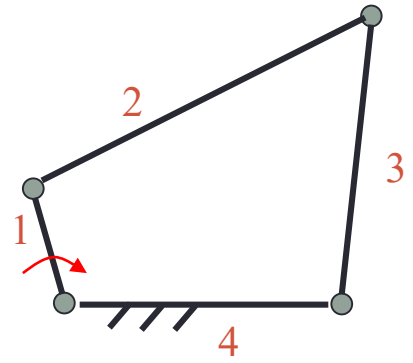
DOF of un-connected links: $3n$ or $3(N\text{-}1)$

No. of constraints from kinematic pairs: $2L+H$

DOF of a mechanism

$$F = 3n - (2\mathrm{L} + H)$$

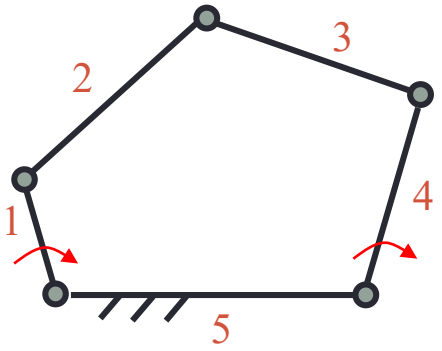
Examples



$F = 3n - 2L - H$

$= 3\times 3 - 2\times 4 - 0$

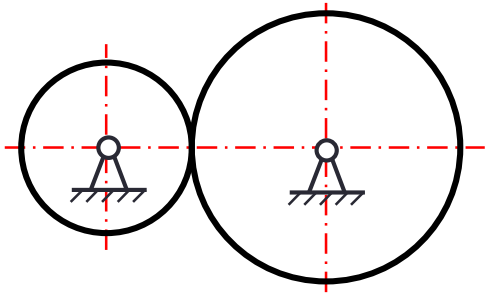
$= 1$



$F = 3n - 2L - H$

$= 3\times 4 - 2\times 5 - 0$

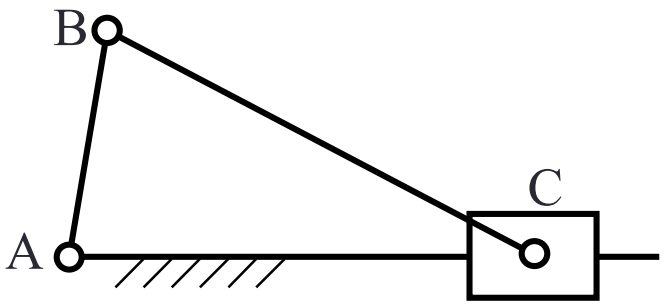
$= 2$



$F = 3n - 2L - H$

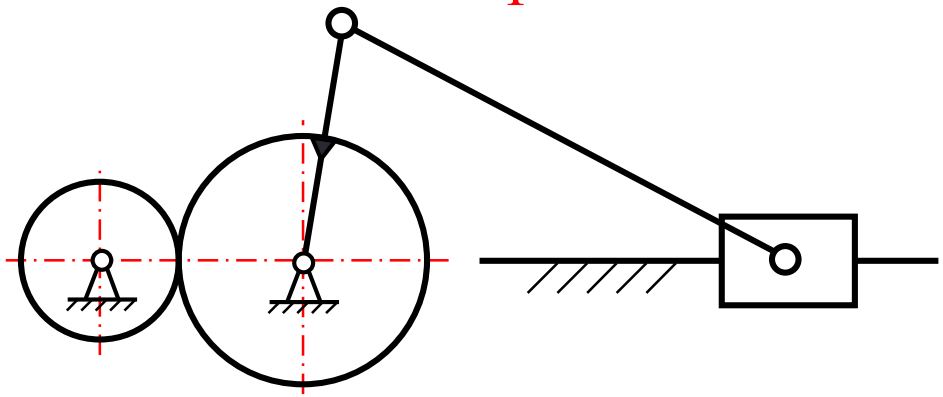
$= 3\times 2 - 2\times 2 - 1$

$= 1$



$F = 3n - 2L - H$

$= 3\times 3 - 2\times 4 - 0 = 1$



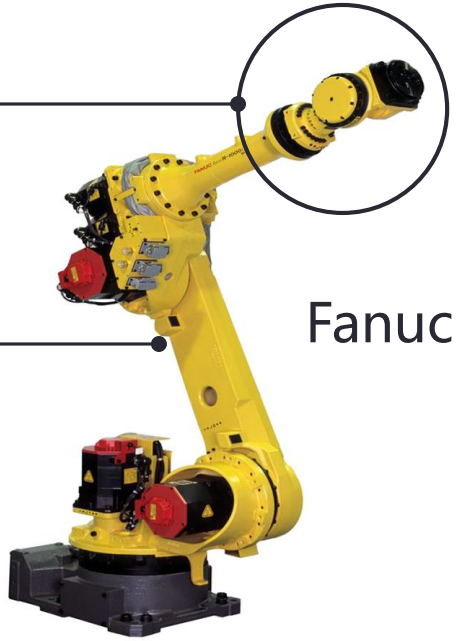
$F = 3n - L - H$

$= 3\times 4 - 2\times 5 - 1 = 1$

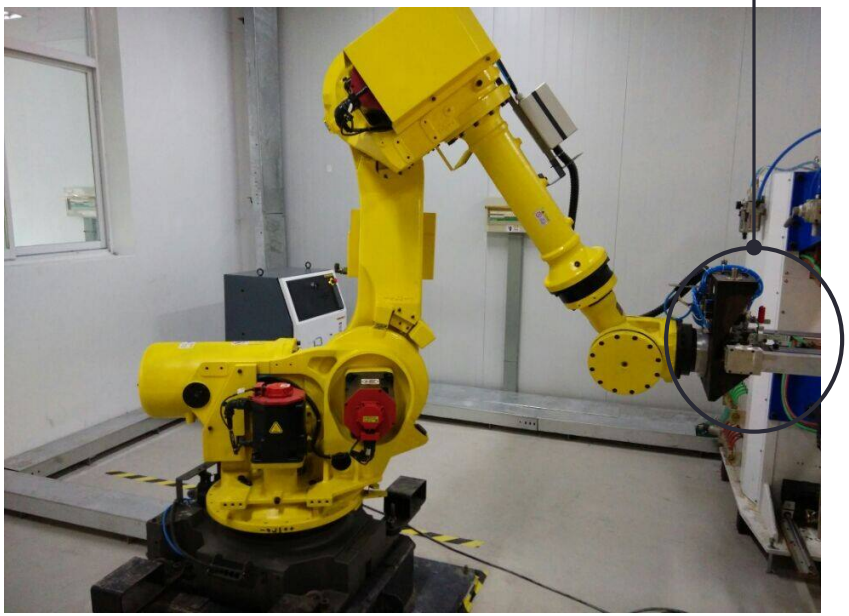
1.2 Robot Manipulators

A robot manipulator - a sequence of rigid bodies (links) interconnected by means of articulations (joints)

- ✓ **Arm -** ensures mobility
- ✓ **Wrist -** confers dexterity
- ✓ **End-effector -** performs the task required of the robot



Fanuc R-2000iB

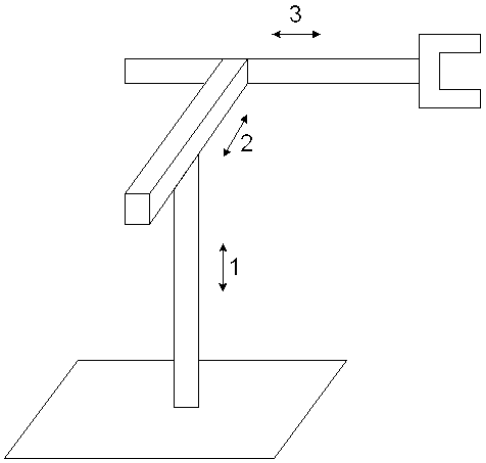


Structure of Manipulators

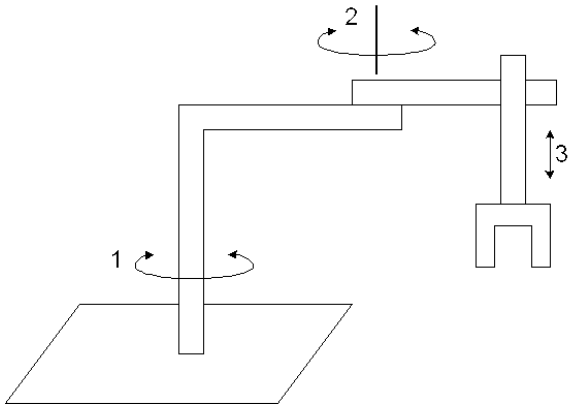
- ✓ The fundamental structure of an articulated manipulator is **the serial or open kinematic chain.** One end of the chain is constrained to a base, while an end-effector is mounted to the other end.
- ✓ The articulation between two consecutive links can be realized by means of **prismatic** or **revolute** joints.
- ✓ Using the two types of joints, there are mathematically **72 different industrial manipulator configurations**, simply because each joint can be P or R, and the axes of two adjacent joints can be parallel (||), orthogonal (⊢), or perpendicular (⊥).
- ✓ Two perpendicular joint axes become parallel if one axis turns 90 deg about the common normal. Two perpendicular joint axes become orthogonal if the length of their common normal tends to zero.

Structure of Manipulators

- ✓ The type and sequence of the arm’ s DOFs, starting from the base joint, allows a classification of manipulators as Cartesian, cylindrical , spherical , SCARA, and anthropomorphic (articulated).



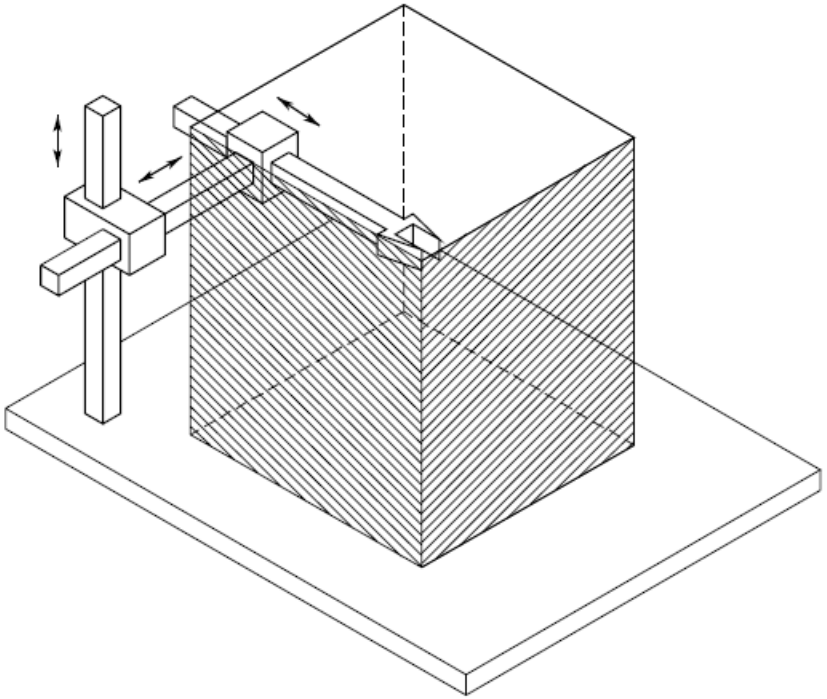
Cartesian, P⊢P⊢P

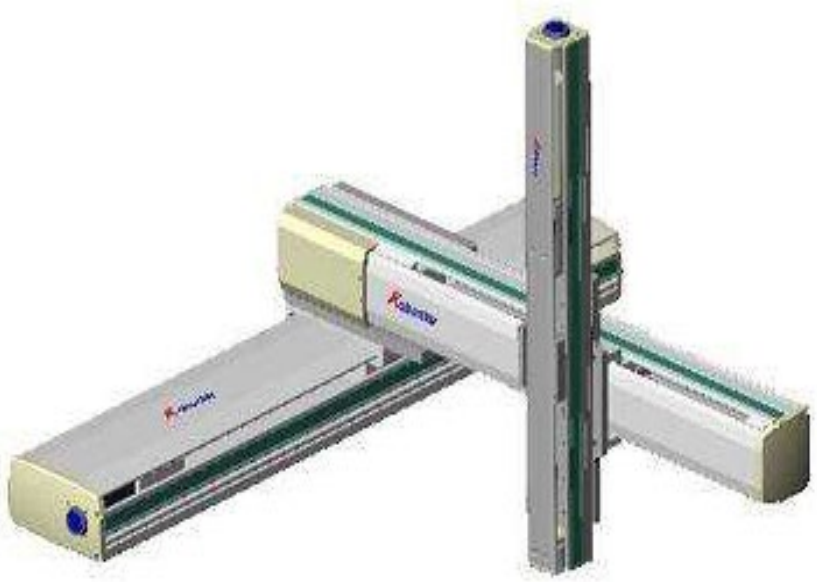


SCARA, R||R||R||P

Selective Compliant Articulated Robot for Assembly

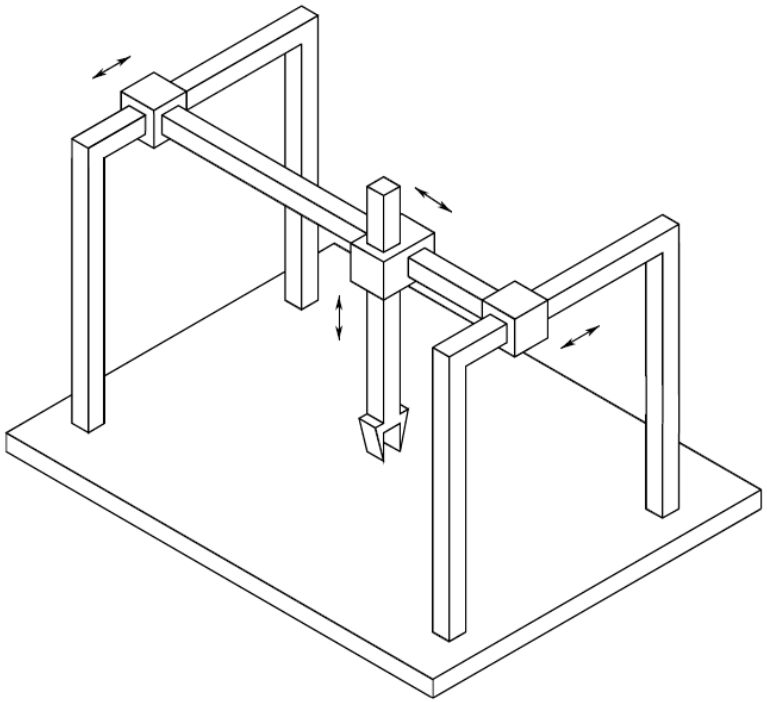
Cartesian Manipulator

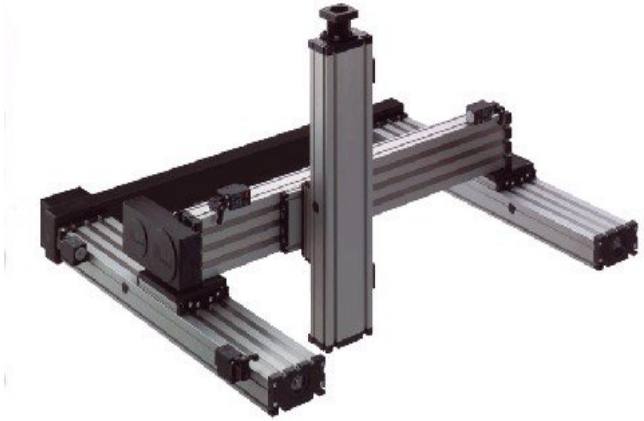


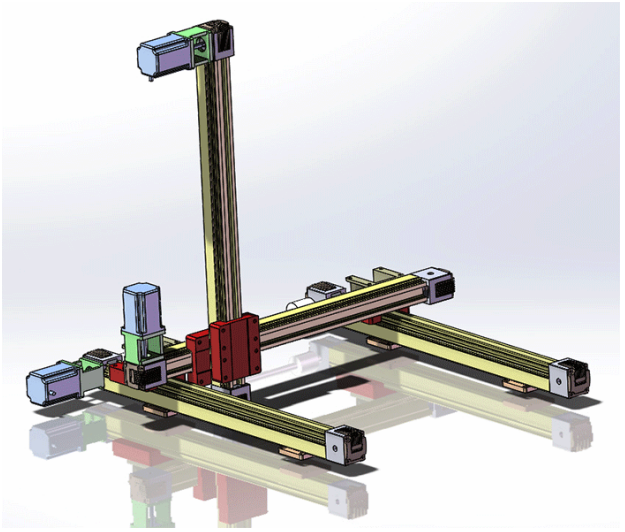


The workspace - portion of the environment the manipulator's end-effector can access

Gantry manipulator

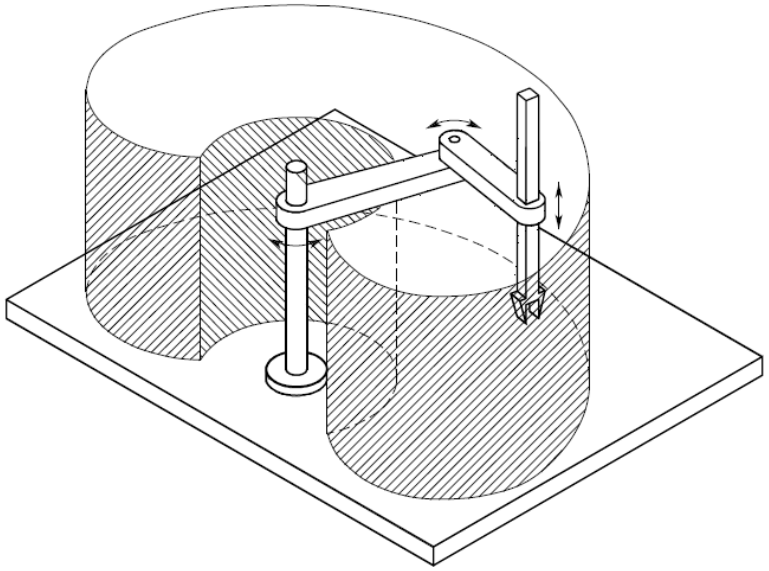


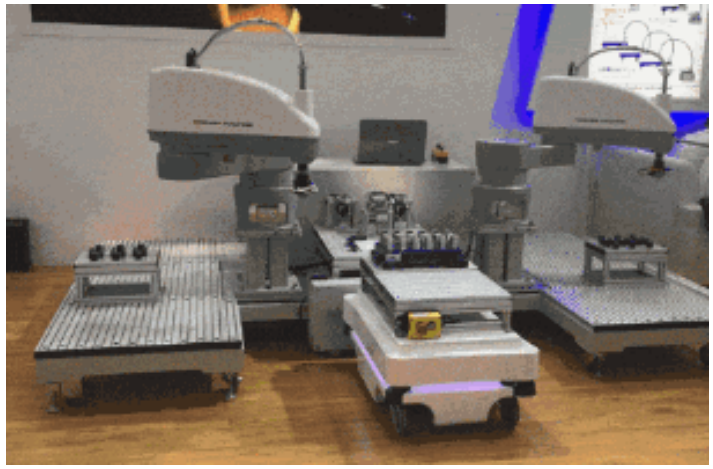


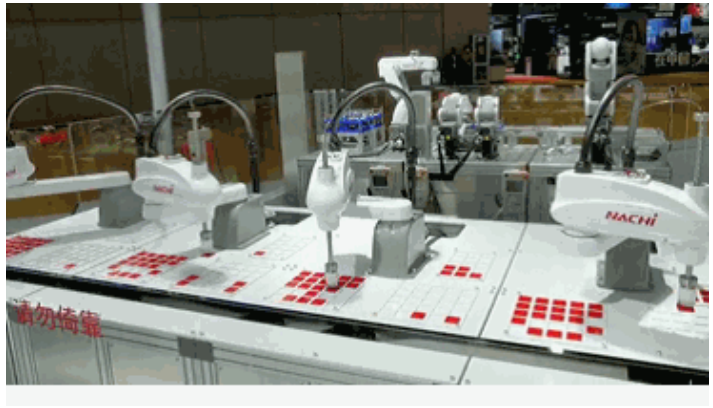


Stronger Cartesian

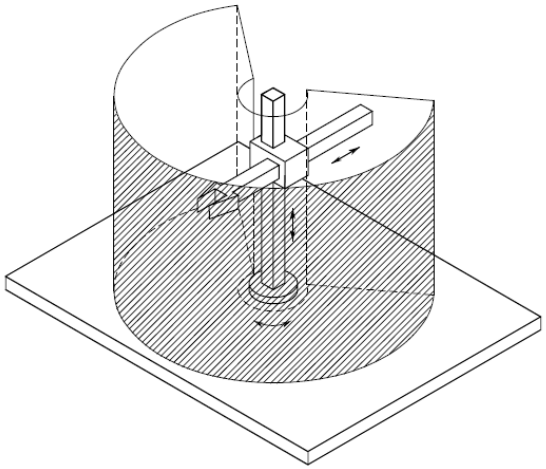
SCARA Manipulator





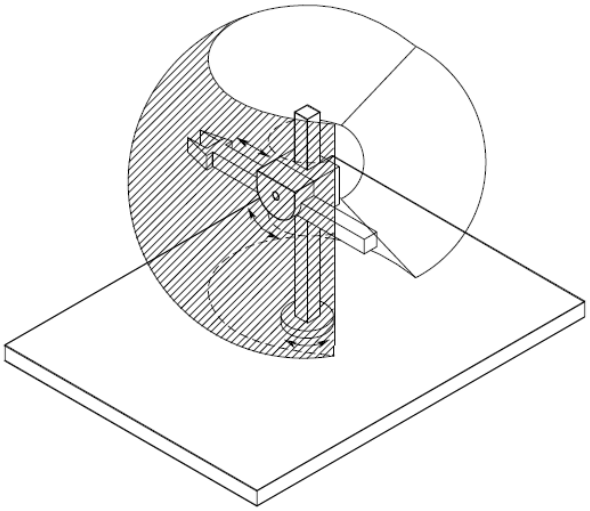


Others



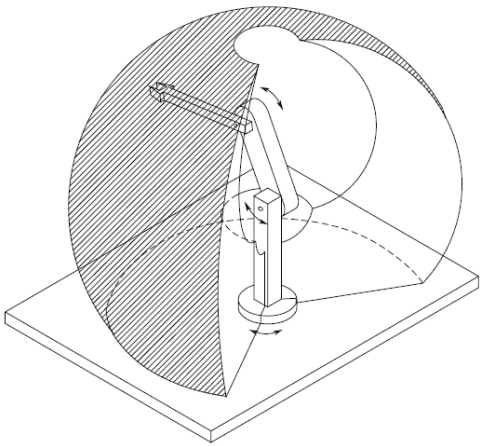
Cylindrical manipulator

$\mathrm{R}\|\mathrm{P}\vdash\mathrm{P}$



Spherical manipulator

$\mathrm{R}\vdash\mathrm{R}\perp\mathrm{P}$

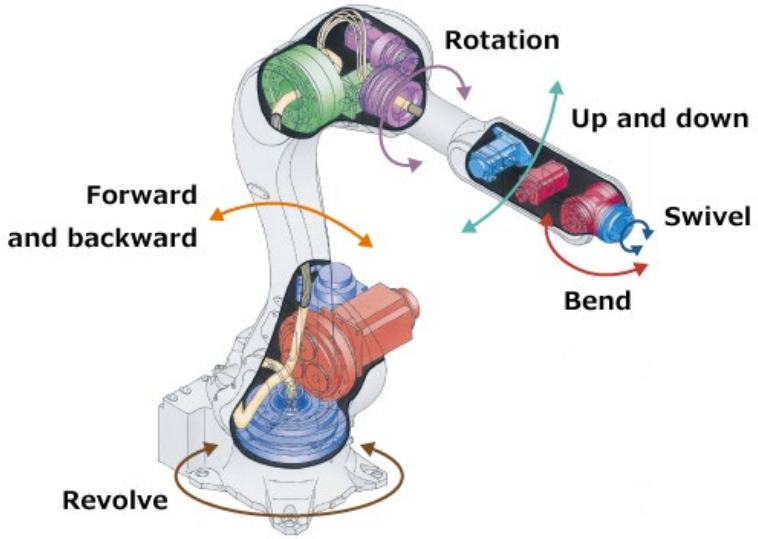


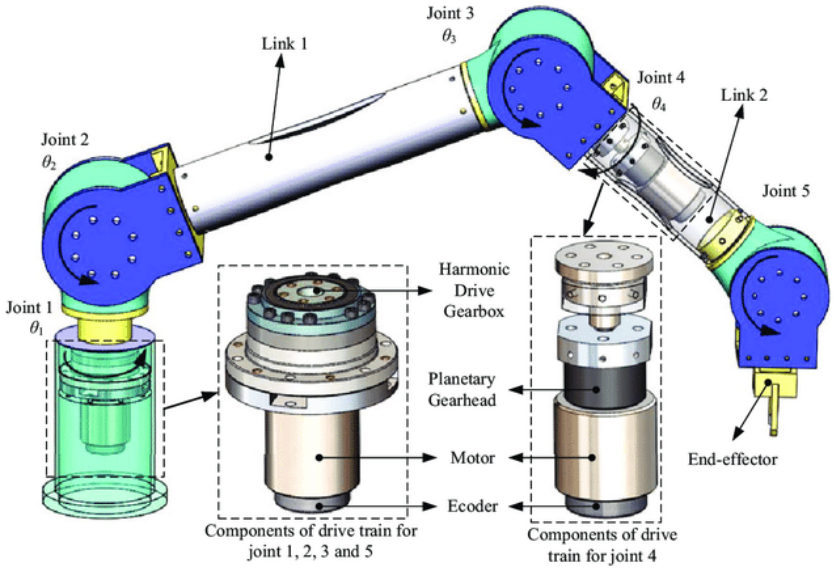
Anthropomorphic manipulator (elbow, revolute, or articulated)

$\mathrm{R}\vdash\mathrm{R}\|\mathrm{R}$

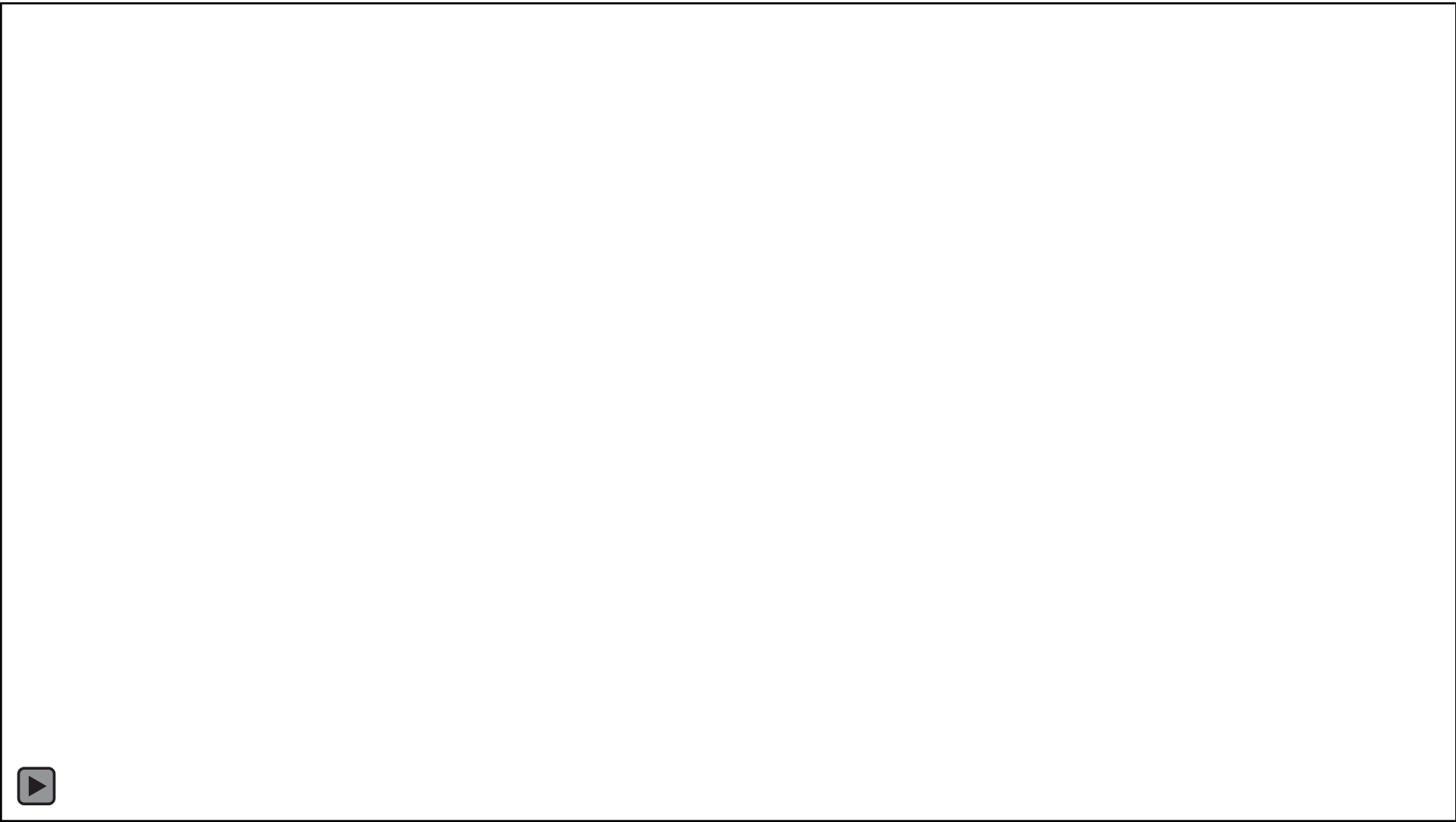
Standard 6-Axis Manipulator

- ✓ In the most general case of a task consisting of **arbitrarily positioning and orienting an object** in three-dimensional (3D) space, **six DOFs are required**: three for positioning a point on the object and three for orienting the object with respect to a reference coordinate frame.
- ✓ If more DOFs than task variables are available, the manipulator is said to be **redundant** from a kinematic viewpoint.



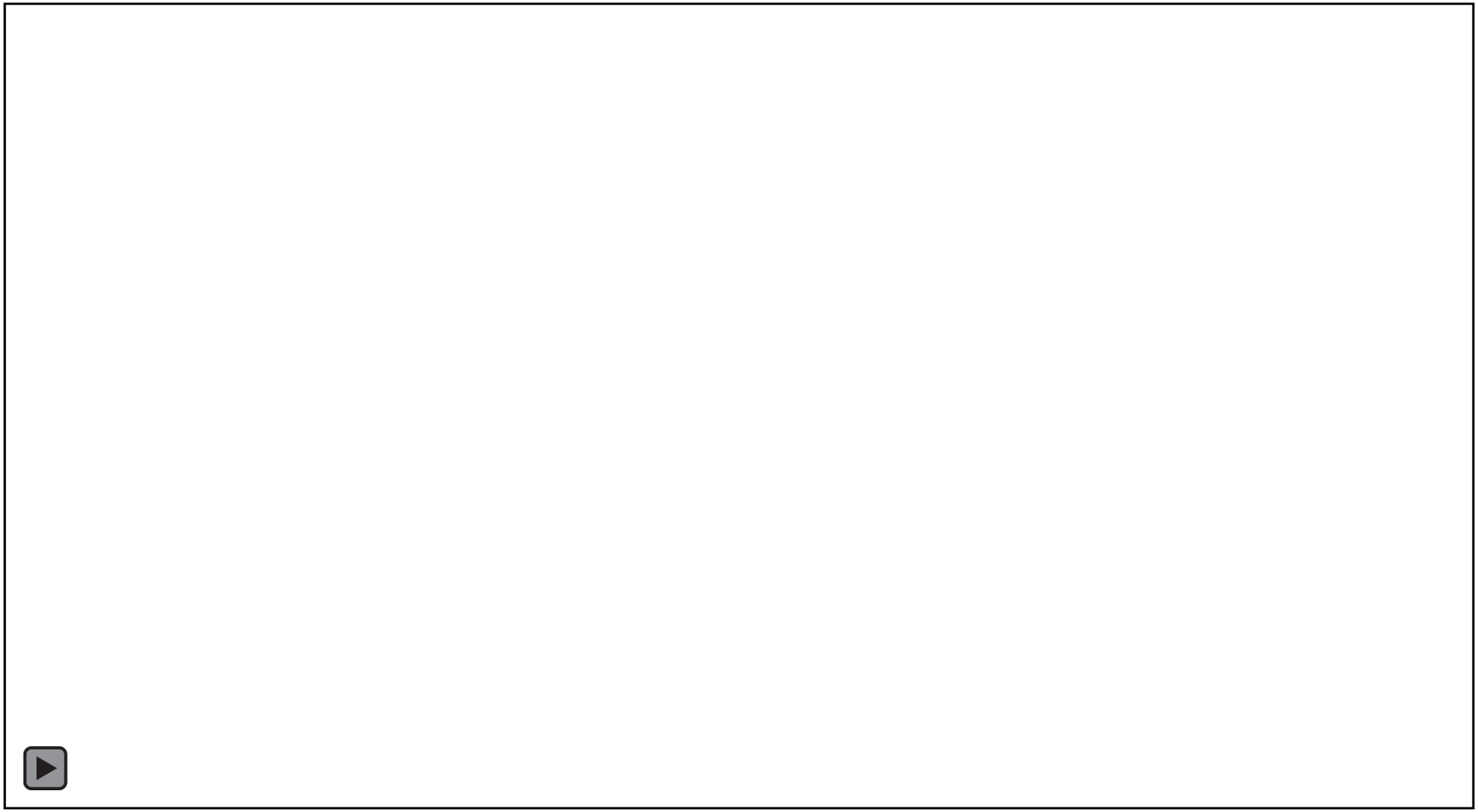


Standard 6-axis Manipulator



Examples

Standard 6-Axis Manipulator

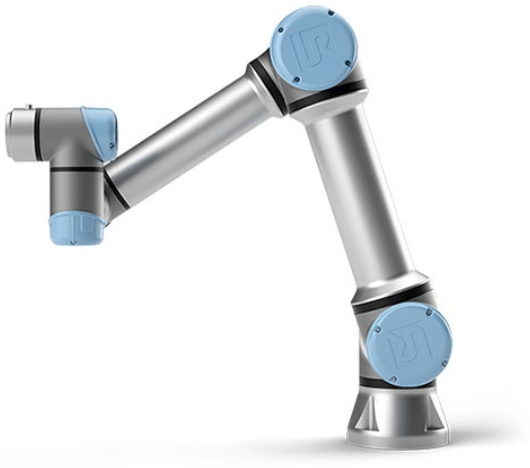


More axis, more dexterity, more security , more sophisticated control

Examples

Different systems and more than industrial senarios

Cooperative robot



UR

Dual-arm robot

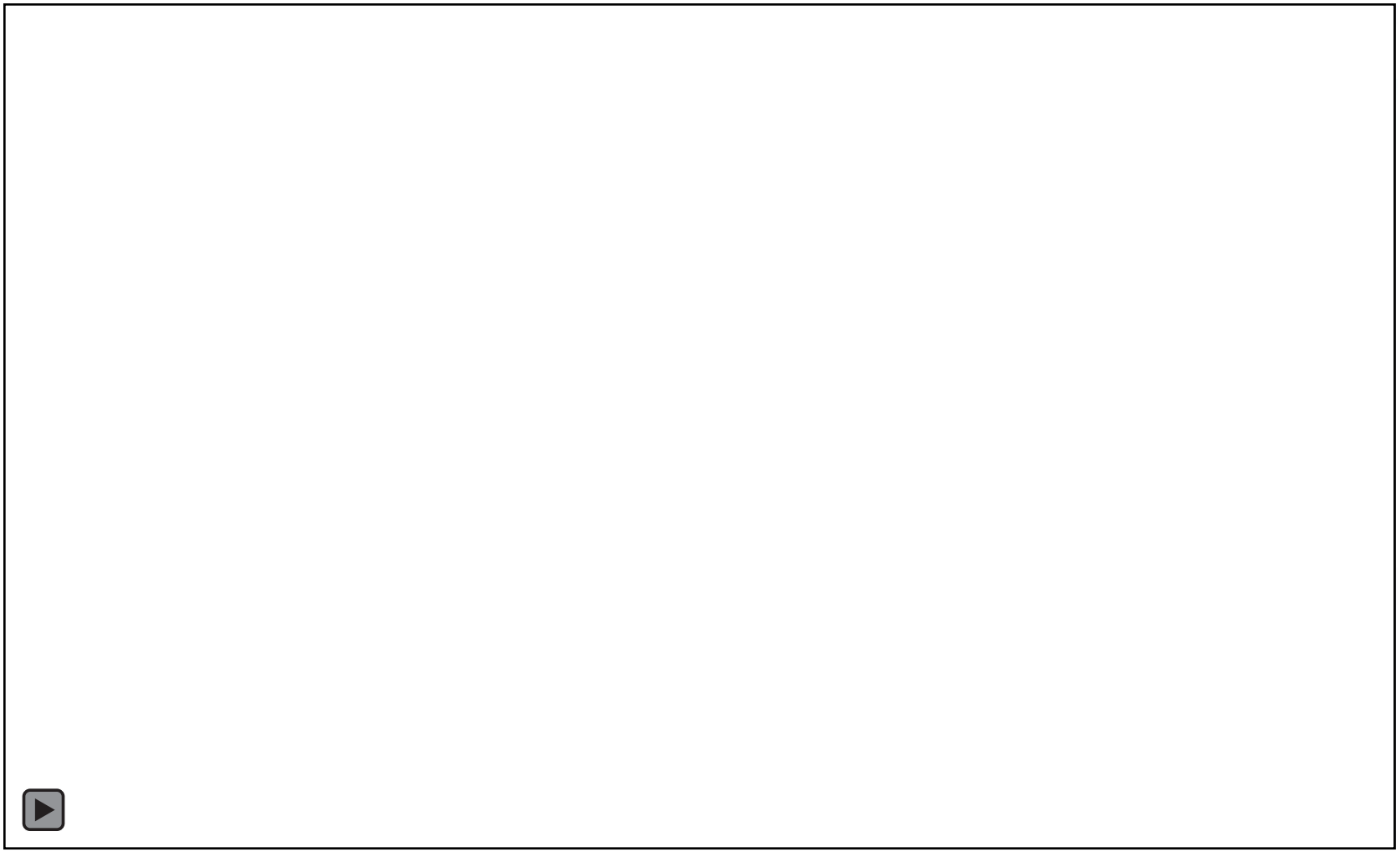
Baxter

Remotely controlled robot

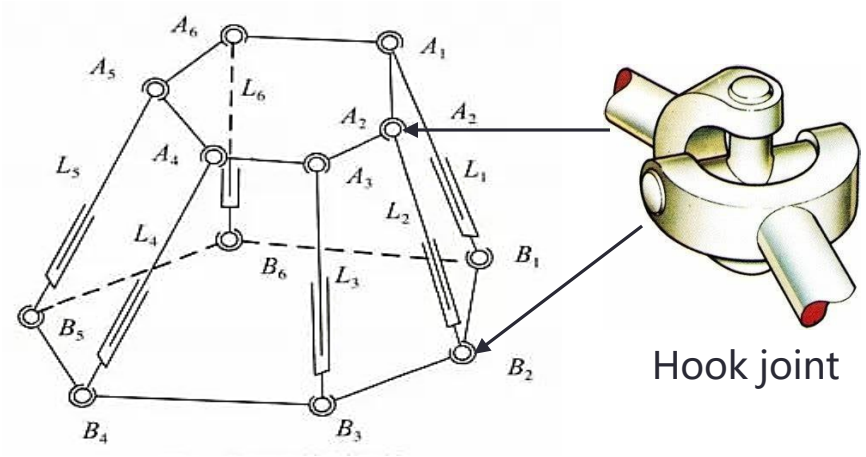
Davinci Surgical Robot

Examples

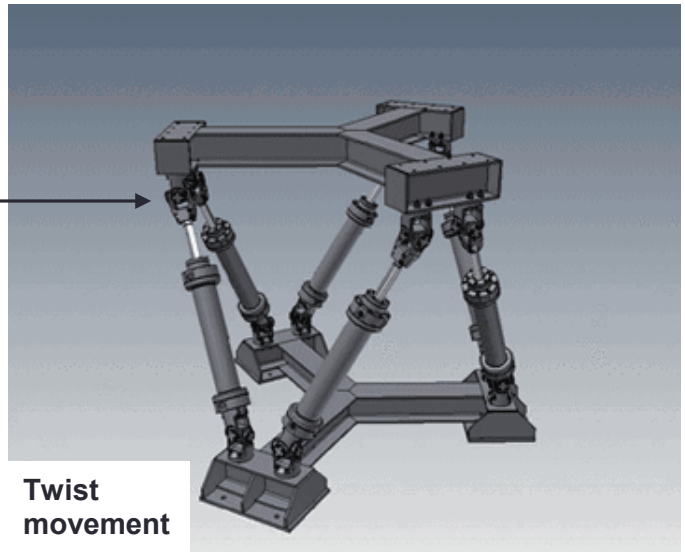
Remotely controlled robot



Stewart Platform

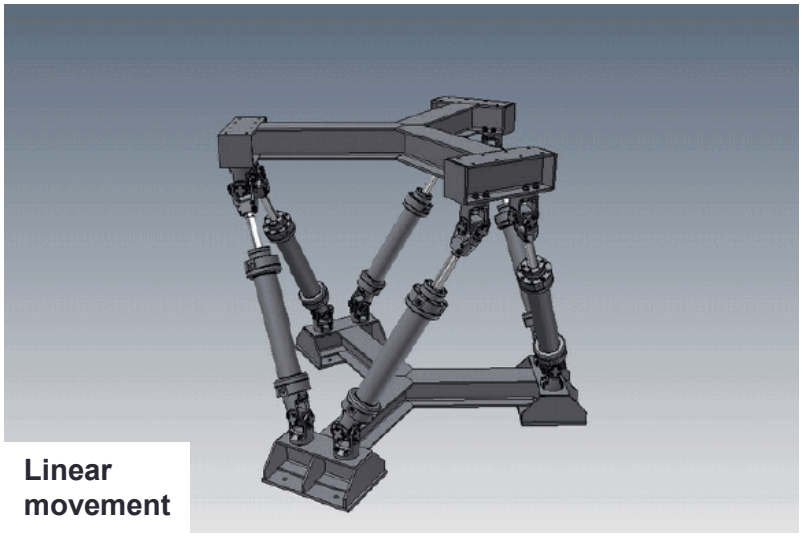


Hook joint

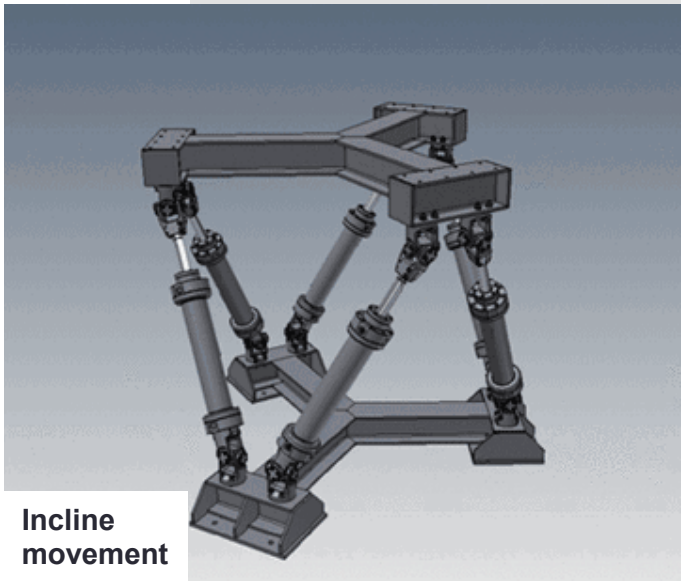


Twist movement

Parallel closed kinematic chain

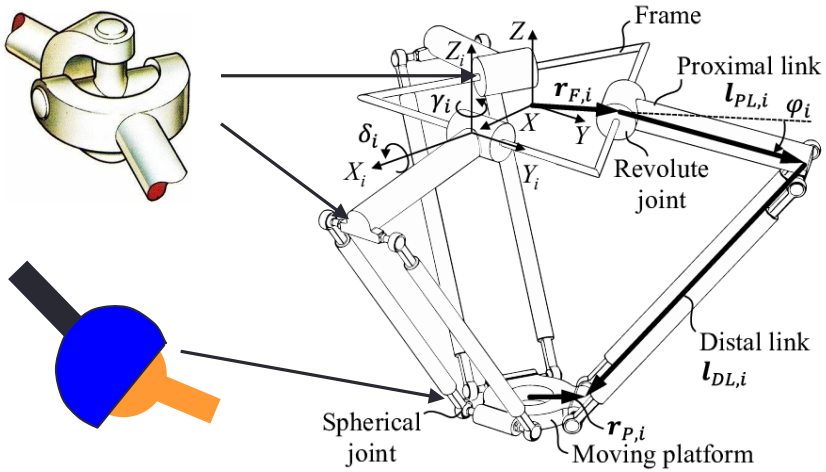


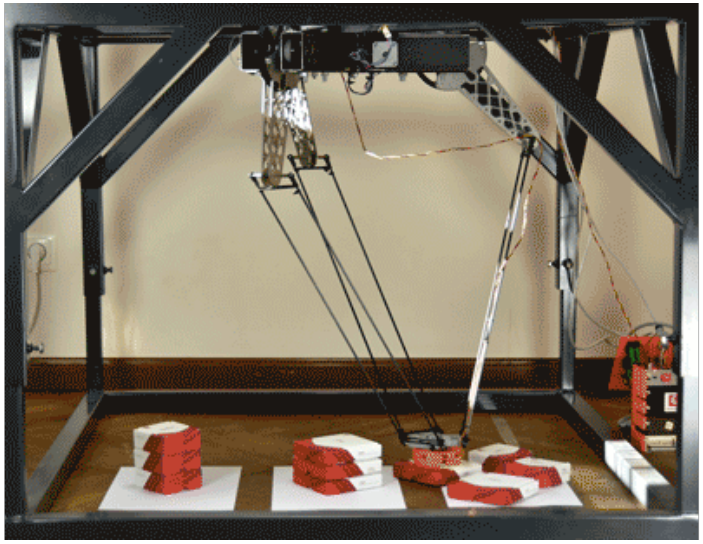
Linear movement

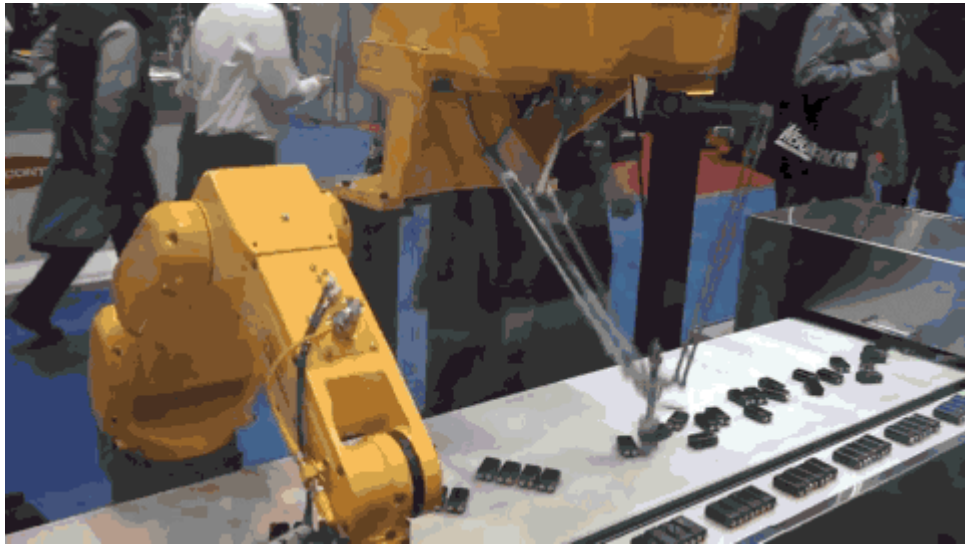


Incline movement

Delta Manipulator

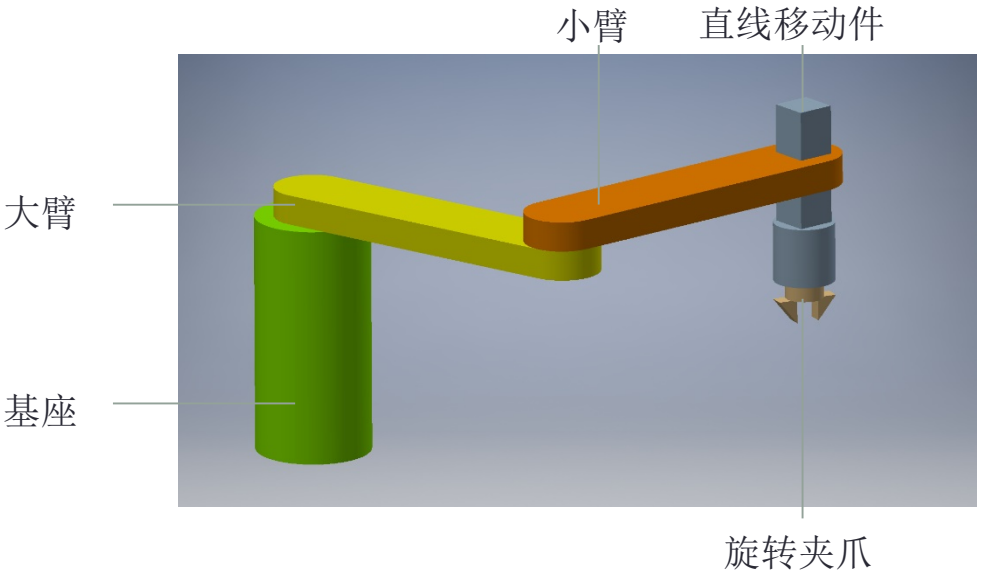






实验1 ： SCARA机械臂CAD建模

1. 使用一种CAD建模软件，构建SCARA机械臂的简化模型，如图所示。
2. 该机械臂机构中包含4个关节：关节1、2为平面转动副，关节3为直线移动副，关节4为平面转动副
3. 模型中包含5个零件，分别为：1）基座；2）大臂；3）小臂；4）直线移动件；5）旋转夹爪
4. 基本尺寸：基座高400mm，大臂长400mm，小臂长400mm，直线移动距离200mm
5. 提交*.stl格式装配文件；
6. 提交实验报告，命名规则为：学号-1-姓名.docx；



实验器材

1. ZJU-I型桌面机械臂
2. 机器人关节模组
3. SolidWorks
4. CoppeliaSim
5. Python、Matlab、VSCode