NYU TANDON SCHOOL OF ENGINEERING

NSF

Promoting robotic design and entrepreneurship experiences among students and teachers

Lesson 16: Links and Joints of of a Robotic Arm

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CONTENTS

- Introduction to robotic arm
- Degrees of freedom (DOF)
- Joints and links

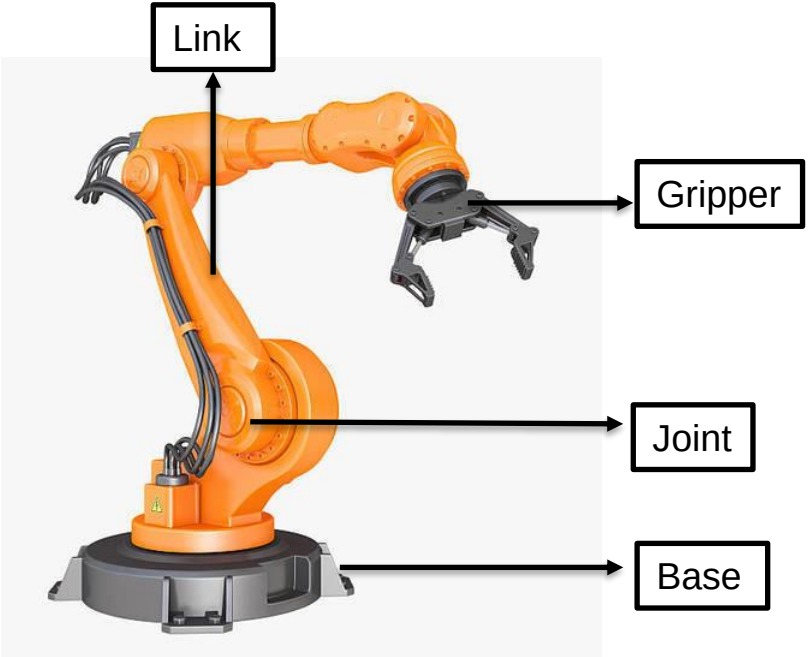
- **TASK/ACTIVITY:** DOF for VEX Clawbot activities

INTRODUCTION TO ROBOTIC ARMS

What is a robotic arm?

- A **robotic arm**, which is usually **re-programmable**, is a type of mechanical arm which functions similar to a human arm

- It is a system made of **links** and **joints** with multiple degrees of freedom (**DOF**) with a **manipulator** at the end to perform various dexterous tasks like **gripping**, **picking** and **placing** objects, etc.



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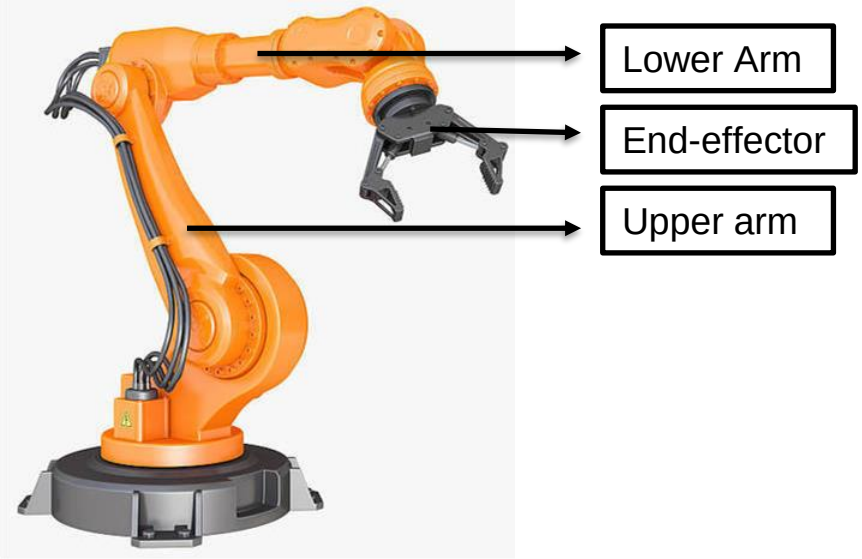
PARTS OF ROBOTIC ARMS

- Basic skeleton of an arm contains **upper arm**, **lower arm** and the **end-effector (gripper)**
- **End-effector**: It is the attached at the end of lower arm which will **perform tasks** like gripping, digging, etc.



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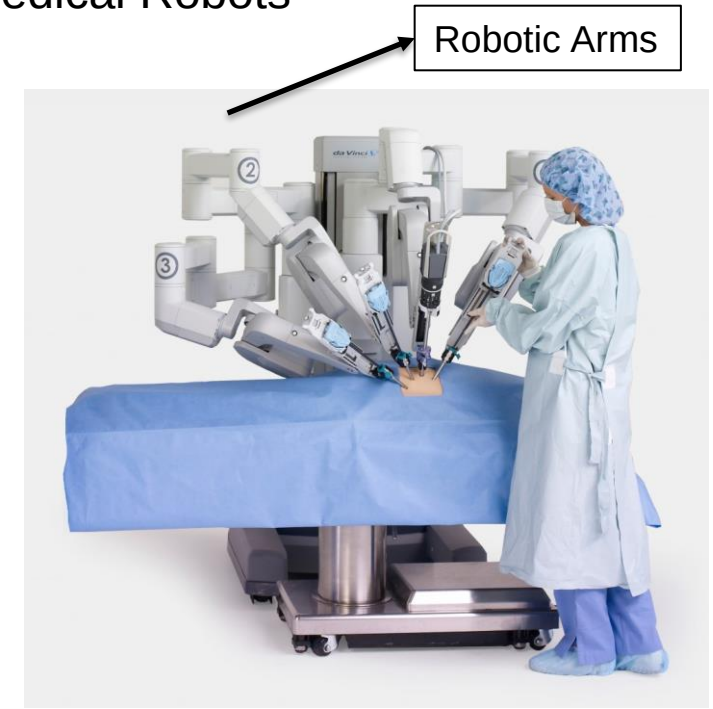
A FEW APPLICATIONS OF ROBOT ARMS

- Medical Robots



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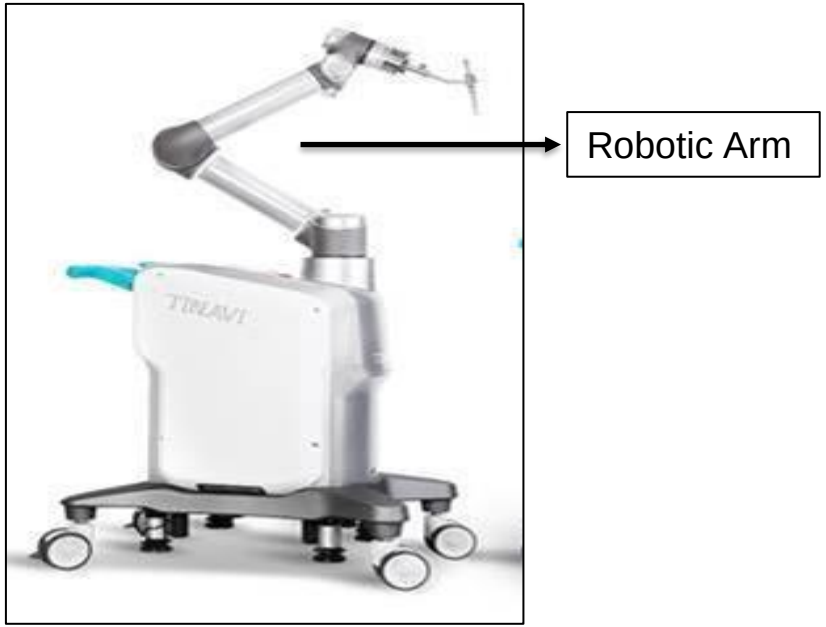

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A FEW APPLICATIONS OF ROBOT ARMS

- Military robots

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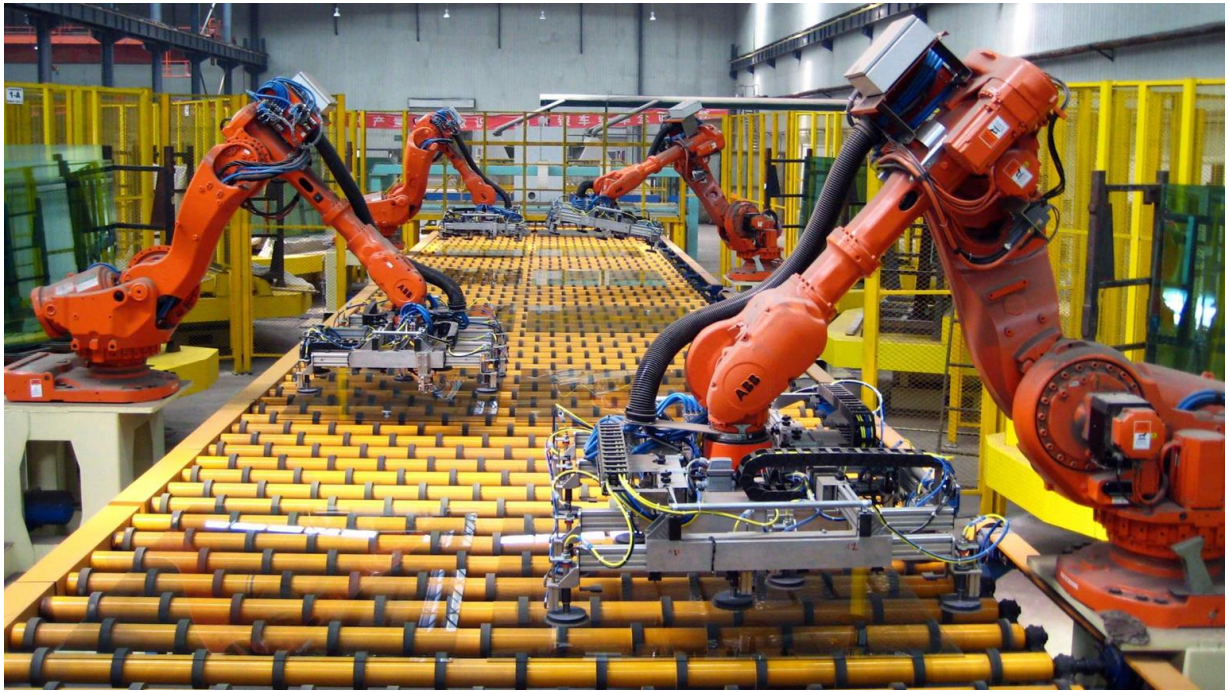
A FEW APPLICATIONS OF ROBOT ARMS

- Automobile Industry



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A FEW APPLICATIONS OF ROBOT ARMS

- Domestic Robots

Video

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A FEW APPLICATIONS OF ROBOT ARMS

- Space and exploration industry

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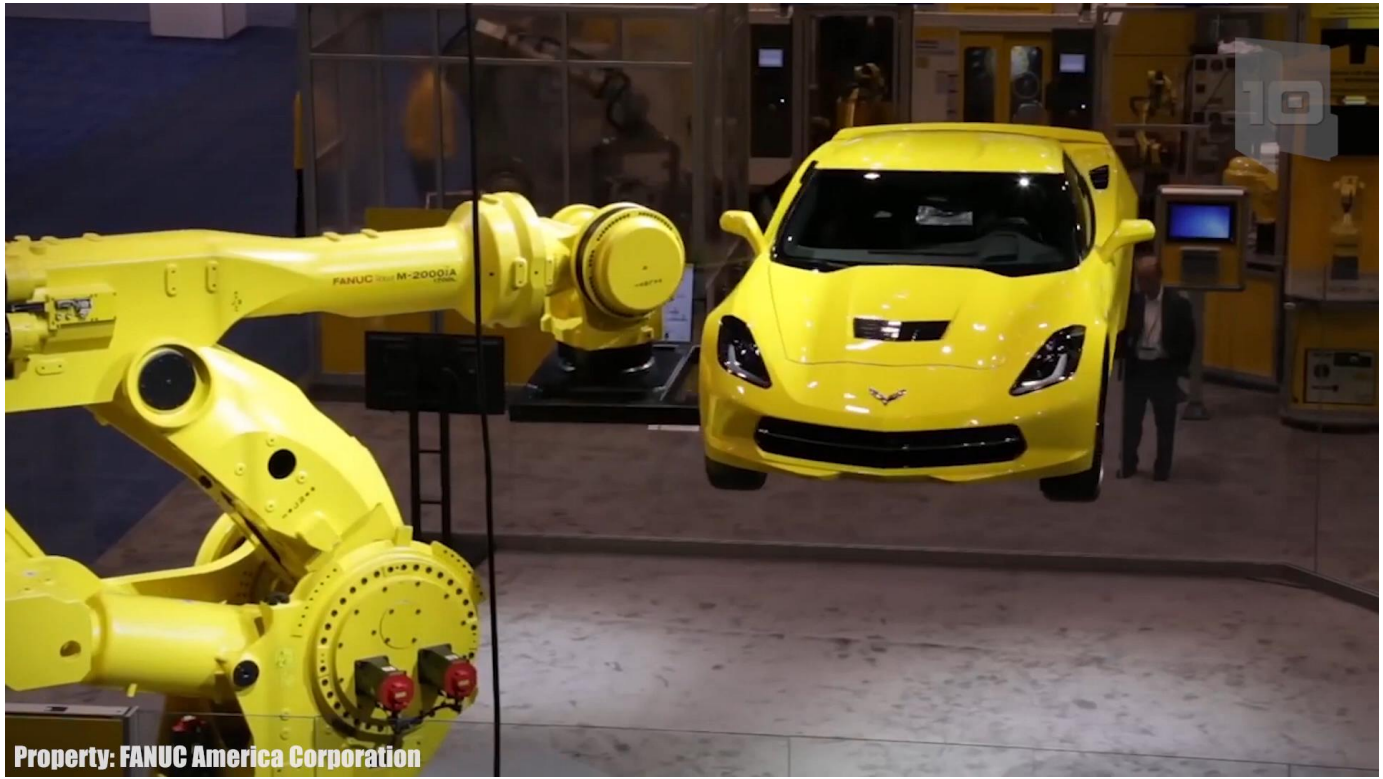
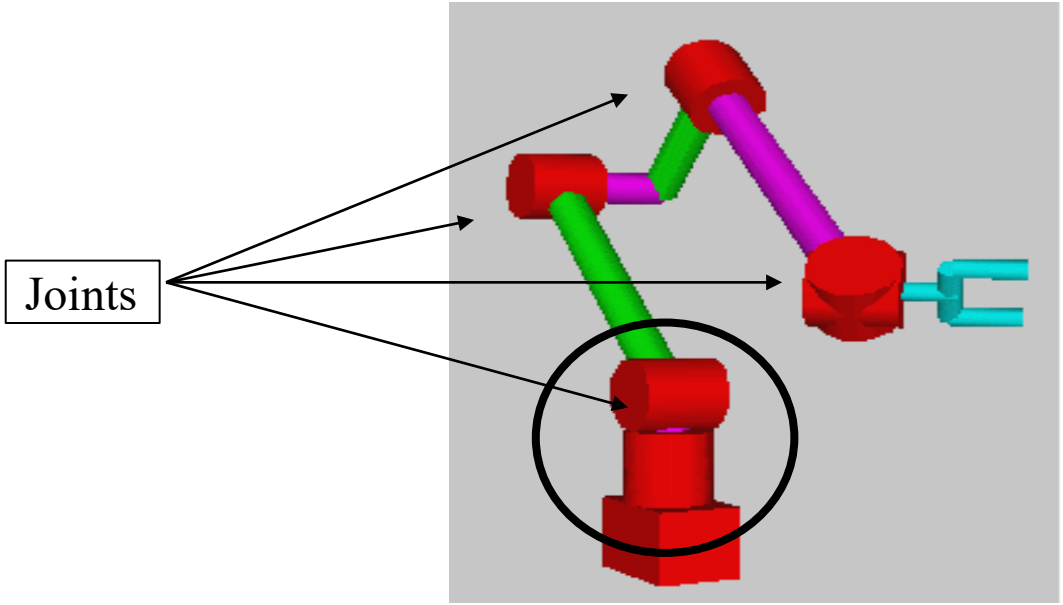
APPLICATIONS OF ROBOT ARMS



Video

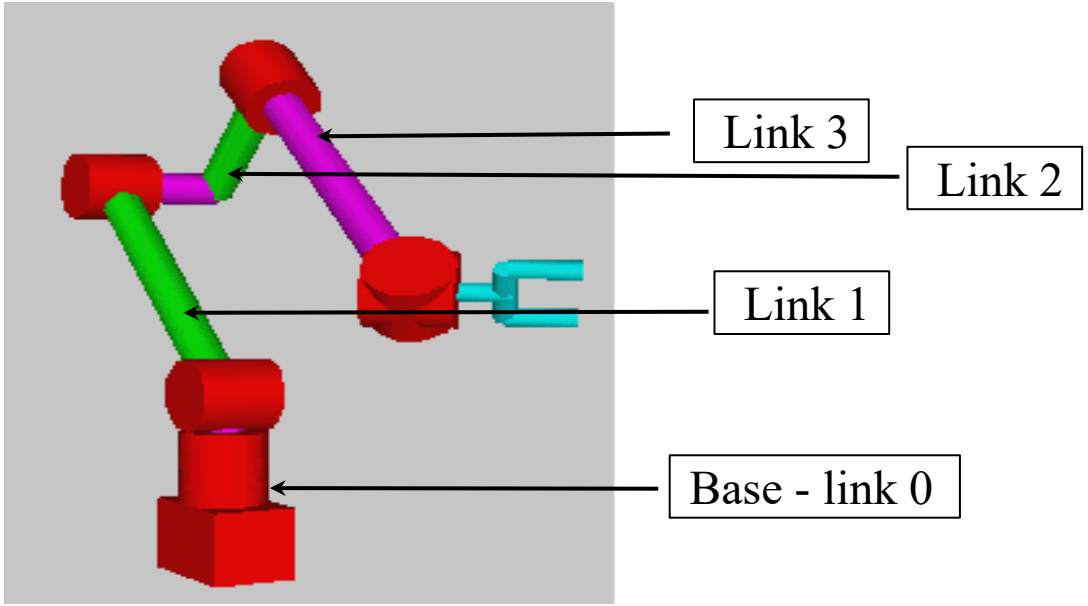
JOINTS

- **Joints**, also called **axes**, are the movable components of the robotic arm that result in relative motion between adjacent links
- The numbering of the joints start from 1 to n



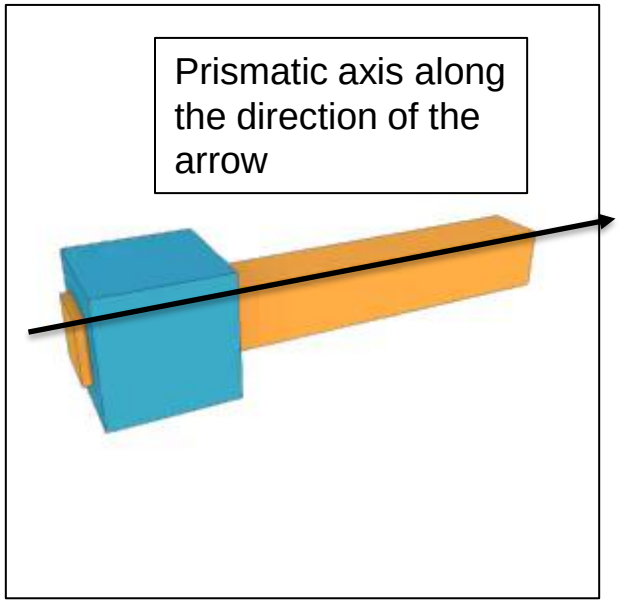
LINKS

- **Links,** also called as **arms,** are the rigid structures connecting the joints
- The ground/base is also called the base link and considered as link 0
- The no. of links will be 0 to n-1 where n = no. of joints



TYPES OF JOINTS

- **Prismatic joints:**
  - They are also called as linear or translational joints
  - The type of motion between the links is linear along the prismatic axis of the joint
  - One degree of **translational** freedom (DOF) along a prismatic axis



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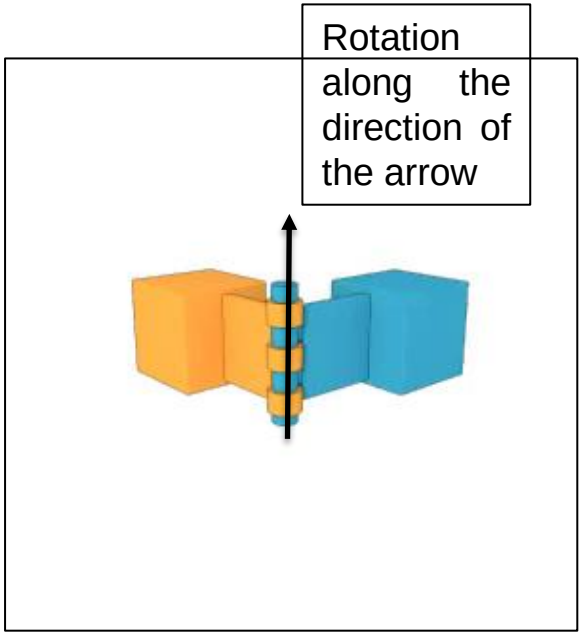
TYPES OF JOINTS

- **Revolute joints:**
  - They are also called as hinge joints which allow rotation along a single axis
  - Driven by electric motors and chain/belt/gear transmissions, or by hydraulic cylinders
  - One degree of **rotational** freedom (DOF) about a revolute axis



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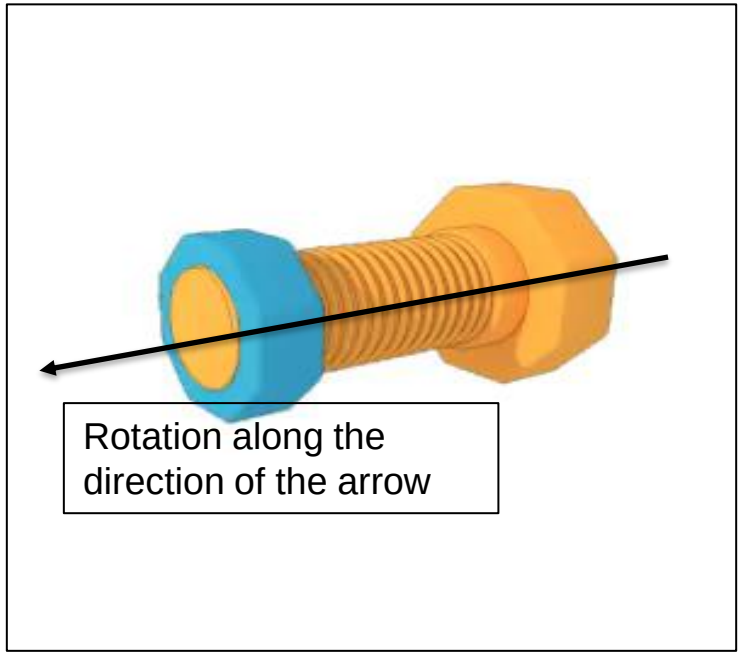
TYPES OF JOINTS

- **Helical joints:**
  - They are also called as screw joints
  - Its motion is similar to a screw motion which rotates freely but cannot translate freely restricting its translational motion
  - One degree of rotational freedom (DOF) along the axis



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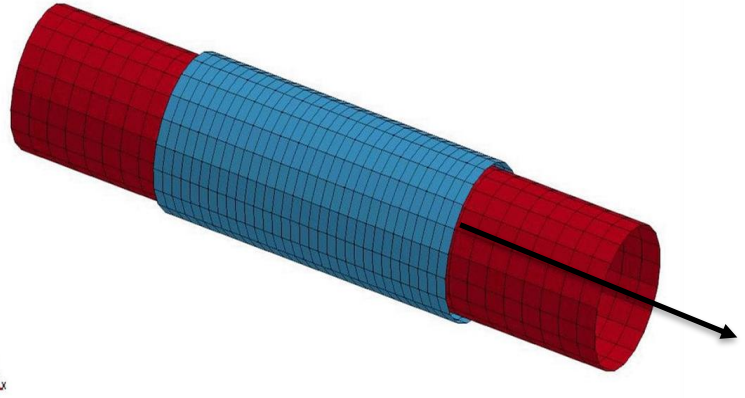
TYPES OF JOINTS

- **Cylindrical joints:**
  - Its motion is similar to a revolute joint in series with a prismatic joint
  - Two degrees of freedom (DOF) with one being rotational and the other translational along the same axis



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Translation and rotation along the direction of the arrow

TYPES OF JOINTS

- **Spherical joints:**
  - They are also called as ball and socket joints
  - Three revolute joints intersecting at a point called the pivot with rotation in 3 directions
  - Three degrees of **rotational** freedom (DOF) about the pivot point

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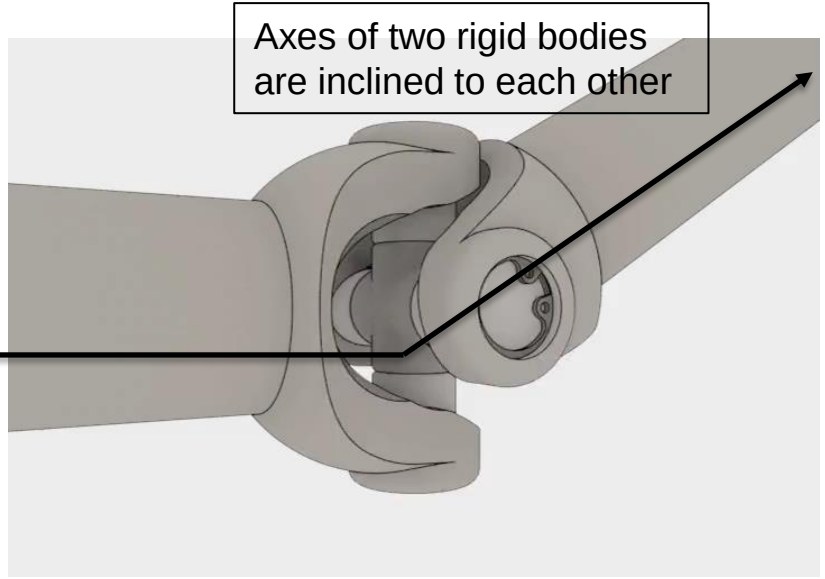
TYPES OF JOINTS

- **Universal joints:**
  - They are also universal coupling or Hooke joints
  - Two hinges joining at a point at 90^{o} to each other with their axes inclined to each other
  - Two degrees of **rotational** freedom (DOF) about the intersecting joint



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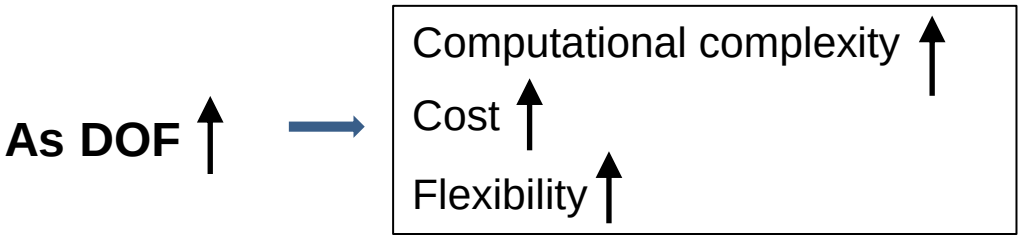
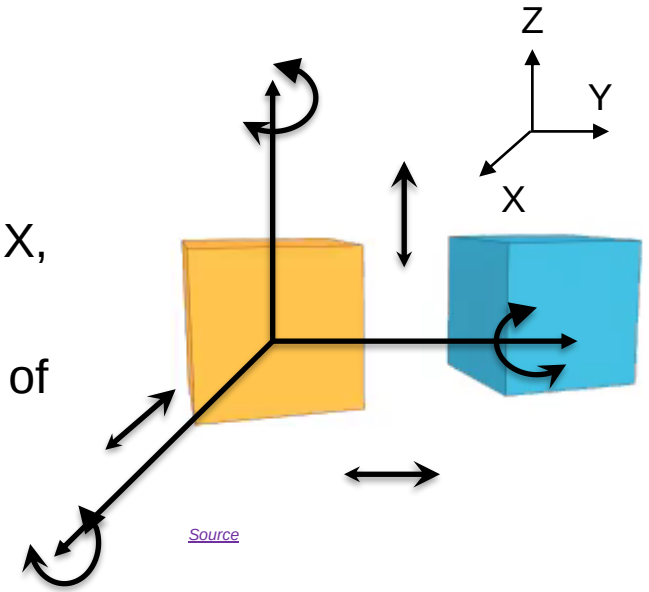
DEGREES OF FREEDOM (DOF)

- **Degrees of Freedom (DOF):** It is generally used to define the motion capabilities of a system
- It is the total number of independent motions a joint can perform
- In most manipulators, containing rotational and linear joints only, DOF is usually the number of joints, performing rotational and linear movements
- **DOF = number of independently driven joints**



DEGREES OF FREEDOM (DOF)

- In general, a free body in space has 6 DOF:
  - Three translation degrees of freedom along X, Y and Z axes
  - Three orientational/rotational degrees of freedom called roll, pitch, and yaw



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NOTE: Any free object in 3D space (e.g., the hand, a fingertip, a car, a plane, etc.) can have at most 6 DOF

DEGREES OF FREEDOM (DOF) OF A HUMAN ARM

ACTIVITY 1

REMEMBER!

- **Degrees of freedom:** Number of ways (rotation, translation about axes) in which the motion of the system can be actuated (motors, linear actuators)

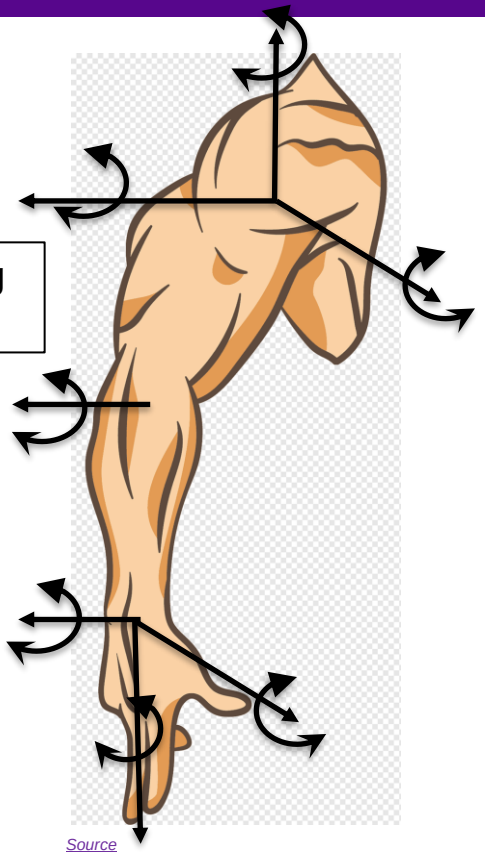
How many degrees of freedom are there in human arm?

DEGREES OF FREEDOM (DOF) OF A HUMAN ARM

ACTIVITY 1 - SOLUTION

- A human arm has 7 DOF, of which:
  - 3 rotations are in the shoulder
  - 1 rotation is in the elbow
  - 3 rotations are in the wrist
- All the degrees of freedom can be controlled

Rotation along the axes



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DEGREES OF FREEDOM (DOF)

- How to calculate degrees of freedom for a robot?

$$DOF = m(N-1) - \sum_{i-1}^{J} c_i$$

  - ***m*** is number of degrees of freedom of a rigid body (***m*** = 3 for planar mechanisms and ***m*** = 6 for spatial mechanisms)
  - ***N*** is number of links in a mechanism, including the base link
  - c_i is the number of constraints provided by joint ***i***, for example, the constraints for a spatial rotation joint is 5, since there is only one degree of freedom for this joint

CONSTRAINTS ON JOINTS

- **Joint constraints**: They are used to restrict the relative motion between the two components at a **joint**

  - They result in the decrease of the degrees of freedom (DOF) of rigid body system

- **Types of Constraints:**

1. **Planar:** Motion constraint placed by one body on another in 2 - dimensional space

1. **Spatial:** Motion constraint placed by one body on another in 3 - dimensional space

CONSTRAINTS ON JOINTS

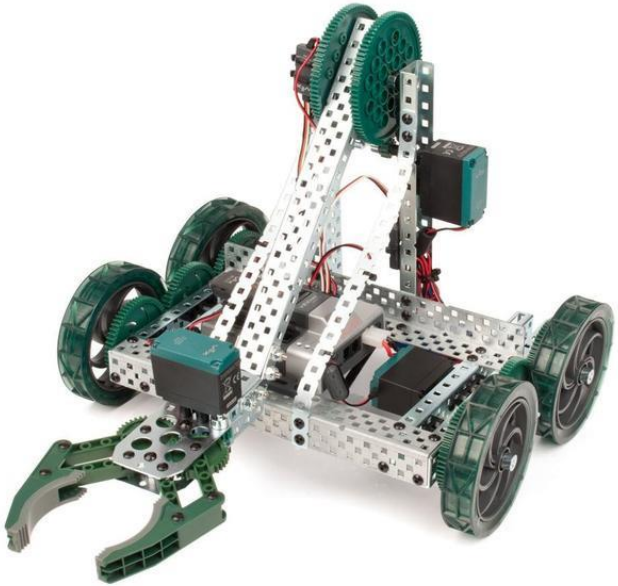
Joint type	DOF	Planar Constraints	Spatial Constraints
Prismatic	1	2	5
Revolute	1	2	5
Helical	1	-	5
Cylindrical	2	-	4
Universal	2	-	4
Spherical	3	-	3

ACTIVITY - 2

How many degrees of freedoms are there for mechanical arm in Clawbot?

Use:

$$DOF = m(N-1) - \sum_{i-1}^{J} c_i$$



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ACTIVITY 2 - SOLUTION

How many degrees of freedom for mechanical arm in Clawbot?

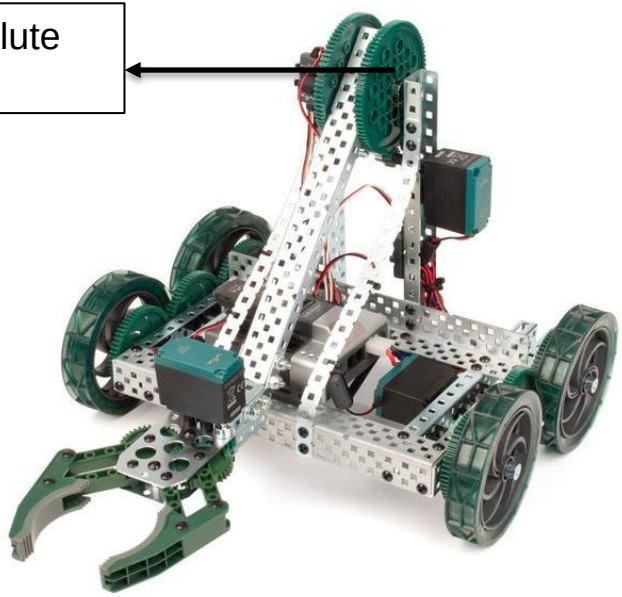
Using:

$$DOF = m(N-1) - \sum_{i-1}^{J} c_i$$

- We have on revolute joint:

  - m = 3
  - N = 3
  - c = 5 (spatial constraints)
  - i = 1

- ***DOF*** = 3 (3-1) – 5 = **1**



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Thank You!

Questions and Feedback?