MTS- 417 Introduction to Robotics

WELCOME TO THE COURSE OF INTRODUCTION TO ROBOTICS

Lecture 01
(Introduction to Robotics)

SUBJECT: **MTS 417: Introduction to Robotics**

CREDIT HOURS: **3-1**

CONTACT HOURS: 6 Hours per Week

TEXT BOOKS: ***Introduction to Robotics*** by JJ Craig, Latest Edition

REFERENCE BOOKS: ***A Mathematical Introduction to Robotic Manipulation*** by R. M. Murray, Z. Li, S. S.Sastry

PREREQUISITE: ME-210: Engineering Dynamics

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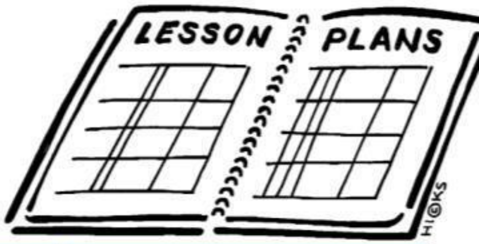


S.No	Topic	Week/Lecture
1	Types of robots	1
2	Types of joints used in robots	2
3	Spatial descriptions	3-5
4	Manipulator Kinematics	6-8
5	Jacobians	9-11
6	Inverse kinematics	12
7	Dynamics of Robots	13-14
8	Path Planning and Trajectory Analysis	15
9	Control	16

Learning Objectives

S.No	Outcomes	Learning Level	PLO
1	Analyze a serial manipulator and develop geometric descriptions of the position and orientation of the robot’s linkages	C4	1
2	Apply forward/inverse kinematics equations for serial mechanism	C3	2
3	Apply force and velocity analysis/ transformations on mechanisms	C3	2
4	Understand and able to solve basic robotic dynamics, path planning and control problems.	C2	2
5	Use modern analytical tools, test equipment and computer aided design to assemble different types of robotic systems and measure performance.	P3	5

1921 - The word robot was introduced to the English language by Czechoslovakian playwright Karel Capek. introduced the word in the play RUR (Rossum's Universal Robots). The word comes from the Czech/Robota, which means forced labor.

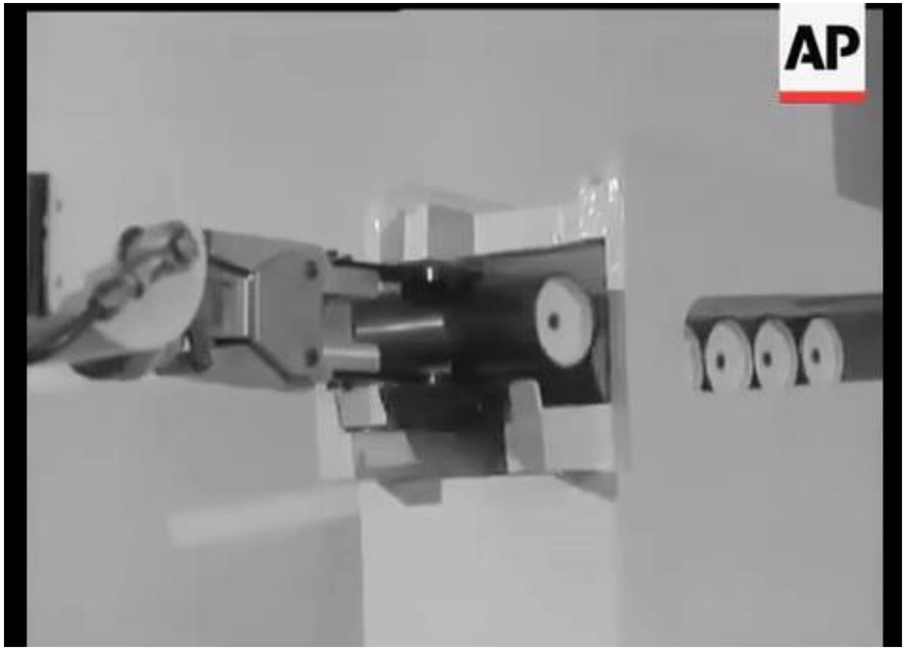
1942 – Isaac Asimov’s three laws of robotics

First Law: A robot may not hurt a human being or, through inaction, allow a human being to come to harm.
Second Law: A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
Third Law: A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

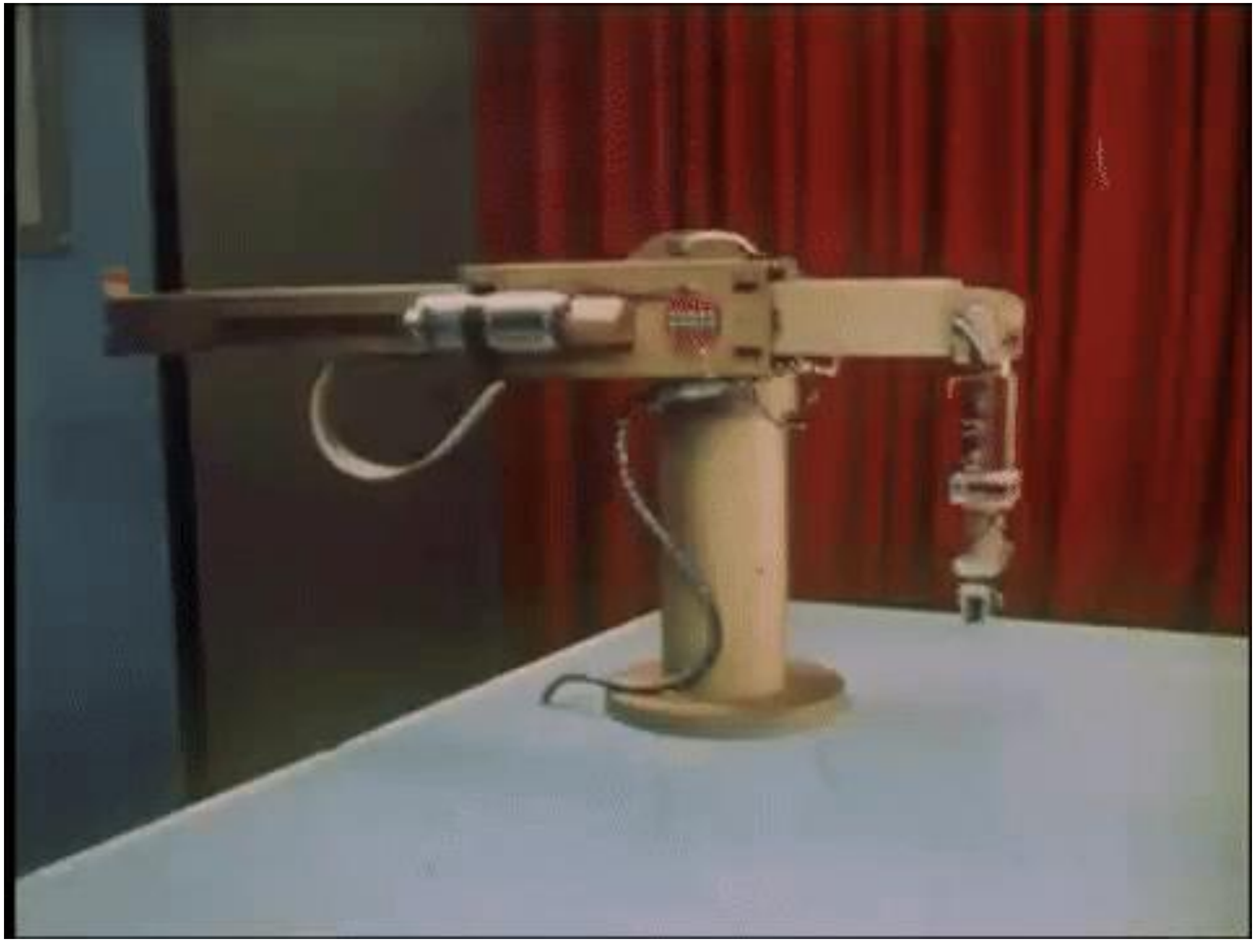
MTS- 417 Introduction to Robotics

1954 - First programmable Industrial Robot was Developed by George Devol.

The robot was programmed using teach mode and could store 200 steps.



1969 – Stanford Arm



Why do we need robots?

- Efficiency
- Precision
- Safety
- Repetition
- Scalability
- Exploration
- Accessibility

Industrial Robots

Sensors for Welding Robot

1. Vision System
2. Laser Sensor
3. Force/Torque Sensor
4. Gas Sensor
5. Temperature Sensor
6. Current Sensor

Sensors for Paint Robot

1. Vision System
2. Proximity sensor
3. Flow Sensor
4. Temperature Sensor
5. Humidity Sensor

Collaborative Robots

Not collaborative

Autonomous Robots

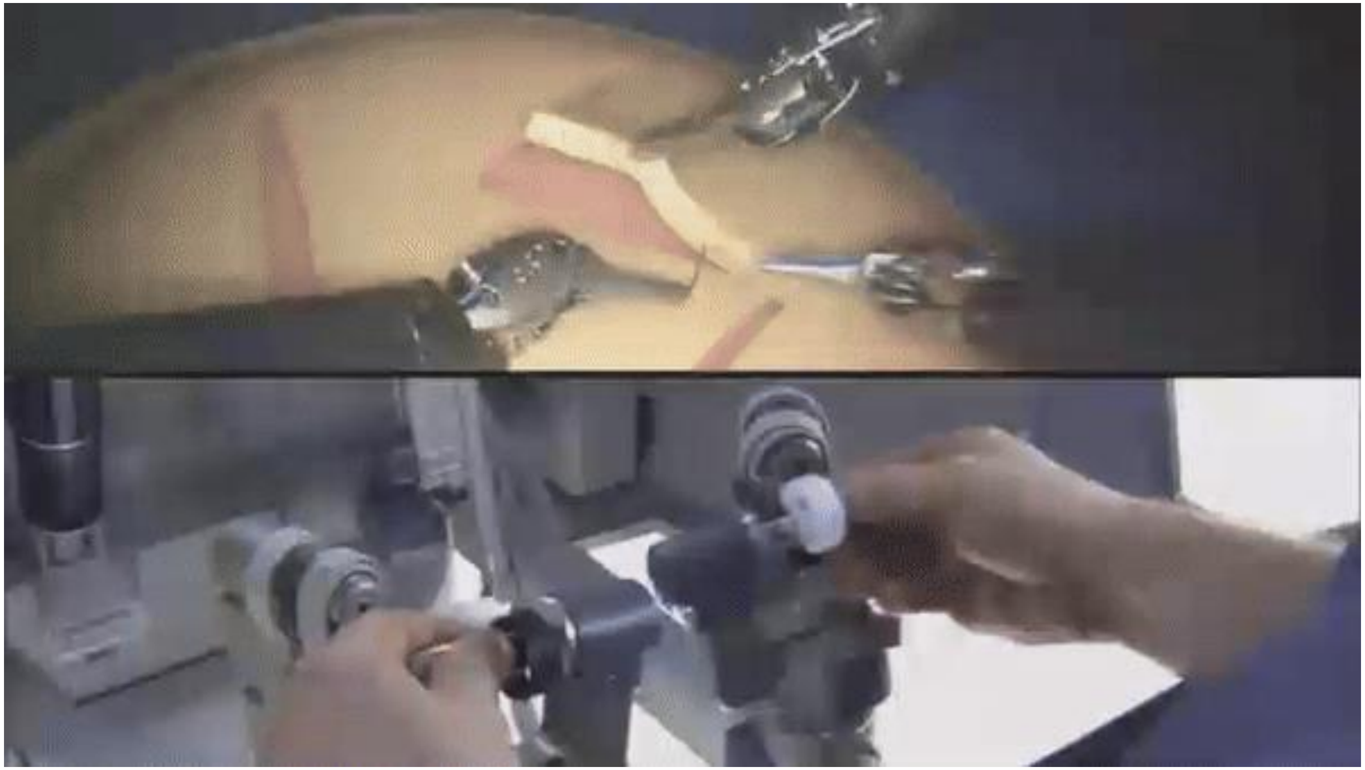
Humanoids

Sensors required in a humanoid

Vision sensors to allow the robot to navigate and recognize objects.
Inertial Measurement Units for robot's orientation and acceleration.
Force/Torque Sensors to measure force exerted on the limbs of the robot and in grasping objects.
Tactile Sensor to detect pressure touch and perceive texture.
Range sensors to avoid collisions.
Microphone for robot's communication

Healthcare Robots

Da Vinci surgical robot



Domestic Robots

Moley Robotics Home Kitchen

Robotic arms available at EME

UR5

CR5

SJ602A

Rhino XR4

Definition of a robot

A robot is a mechanical device controlled by a computer program and electronic circuitry, that uses sensors to guide end effectors to perform autonomous or semi-autonomous tasks

Components of a Robot Manipulator

1.Base: The base is the stationary part of the robotic arm that provides stability and support. It is usually mounted on a fixed surface or platform.

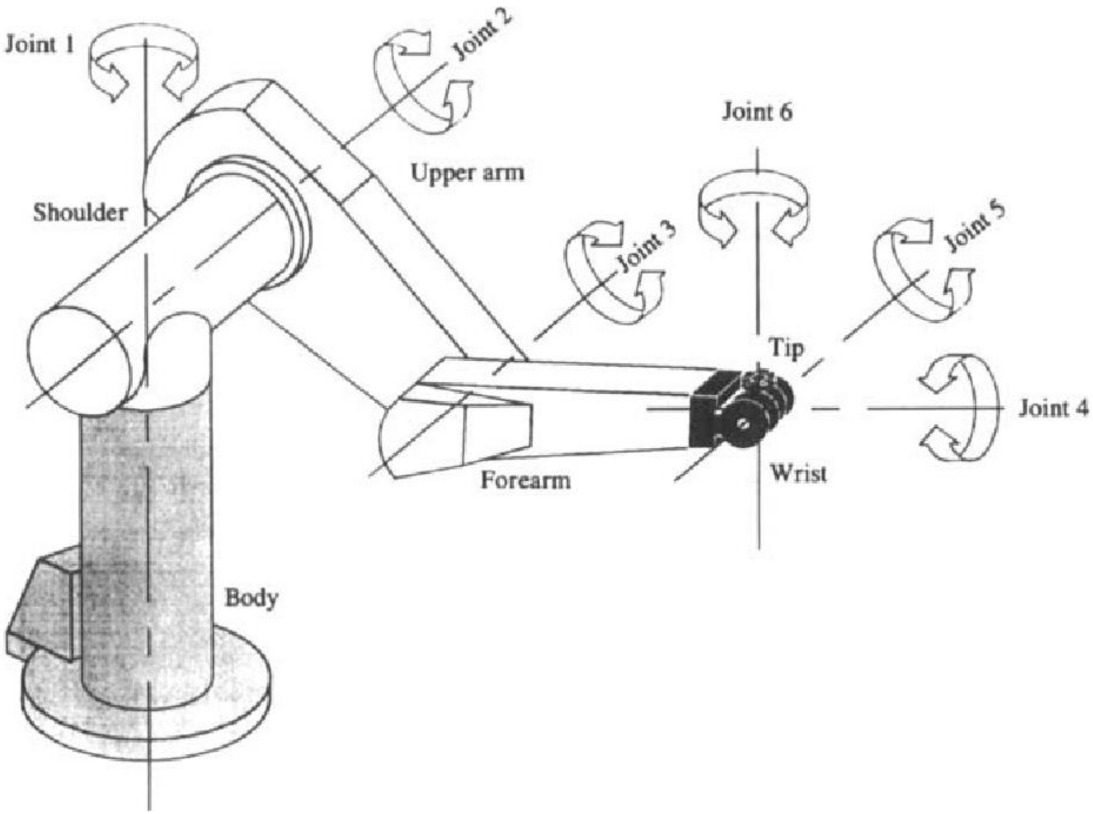
2.Joints: Joints are the movable connections between different links of the robotic arm. There are various types of joints used in robotic arms, including revolute joints (rotational), prismatic joints (linear), and spherical joints.

3.Links: Links are the rigid components that connect the joints of the robotic arm. The length and shape of these links determine the reach and workspace of the arm.

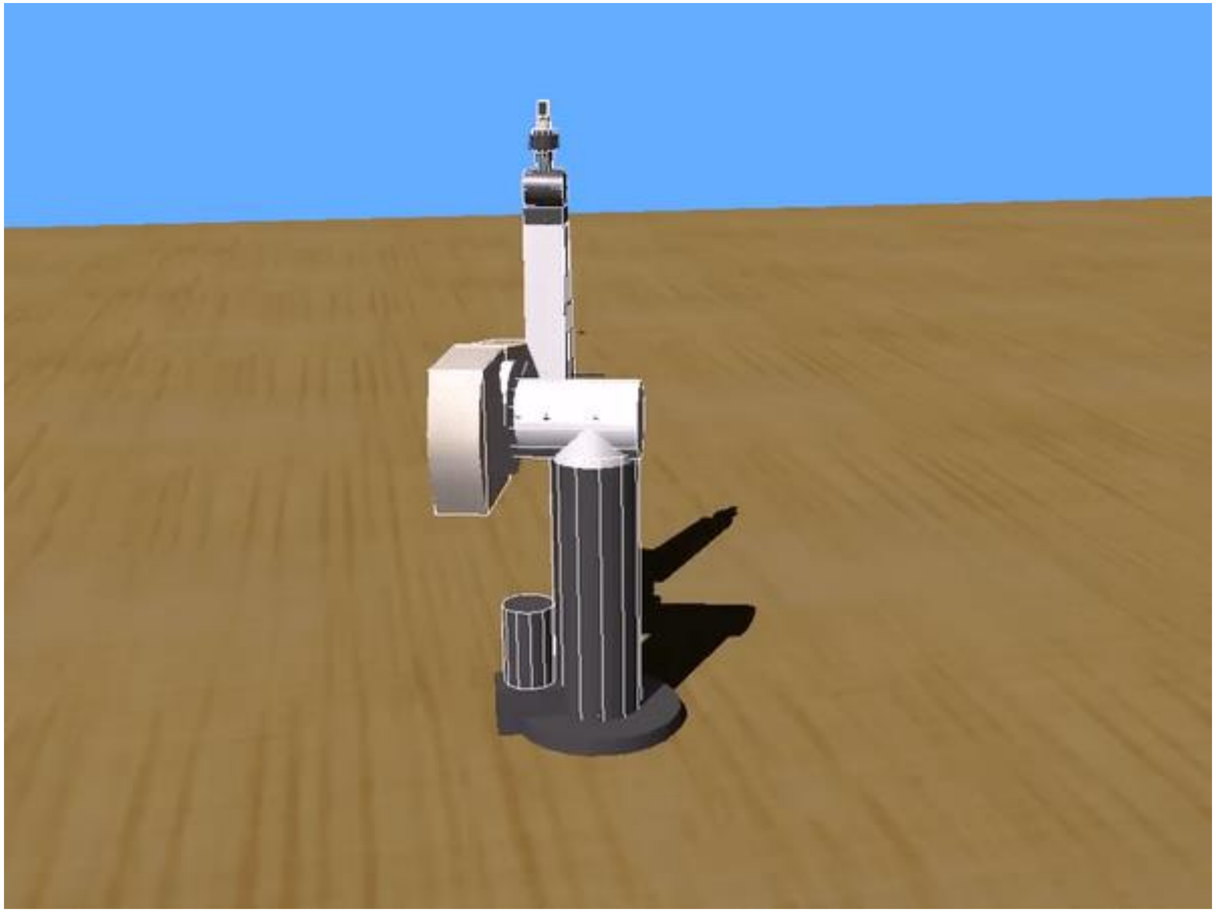
4.Actuators: Actuators are the motors or mechanisms responsible for moving the joints and links of the robotic arm. They provide the necessary torque and force to articulate the arm and perform tasks.

PUMA 560

PUMA (Programmable Universal Machine for Assembly) was developed and used in many research labs today



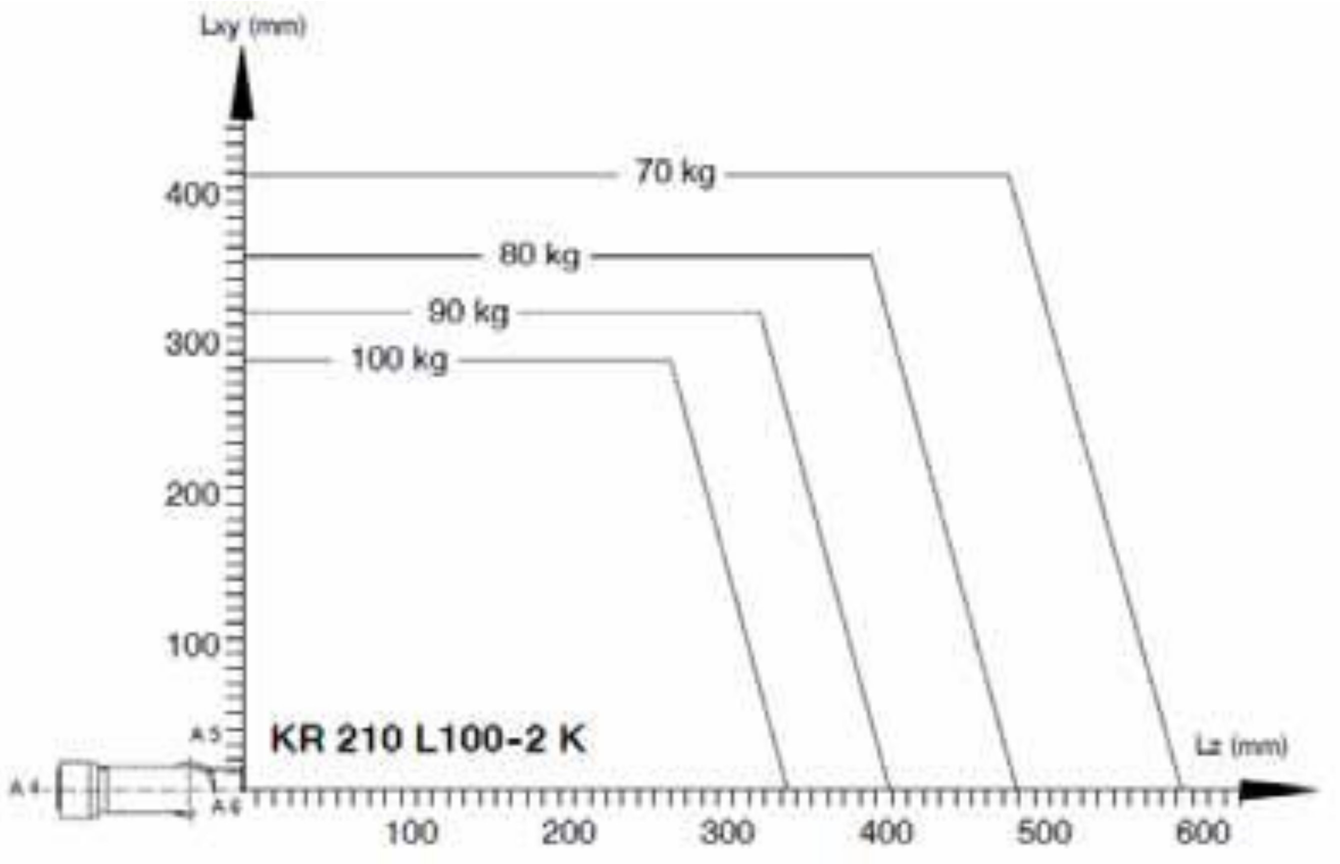
PUMA 560



Specifications to look for in a robot

1. Dimensions of the robot
2. Weight of the robot
3. Degrees of Freedom
4. Payload Capacity
5. Joint speed and acceleration
6. Joints' range
7. Robot's maximum and dexterous reach
8. Repeatability

Payload Capacity Graph



Pick and place a marker

Things to observe:

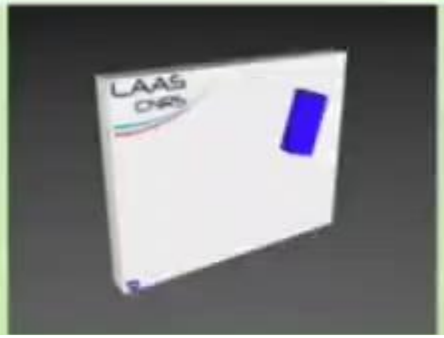
1. Identify objects. What to pick?
2. Marker location?
3. Is marker part of table?
4. Pick marker using hand. Hand location?
   Joint angles?

Types of Joints & DOF

Spherical

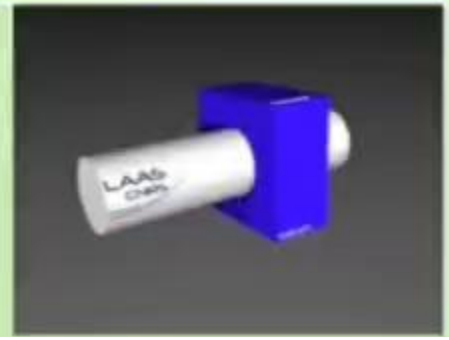
3 DOF

Planar



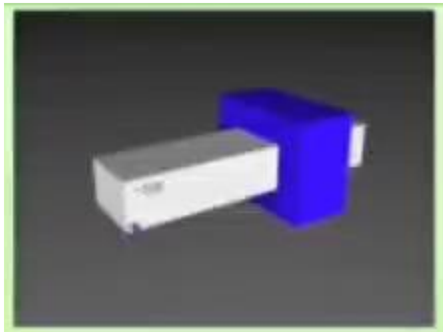
2 DOF

Cylindrical



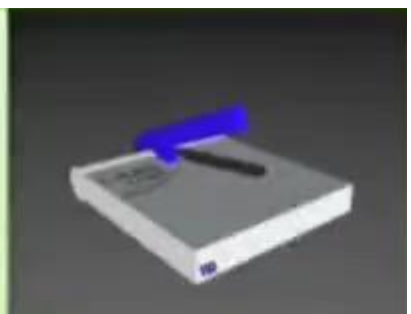
2 DOF

Prismatic



1 DOF

Revolute



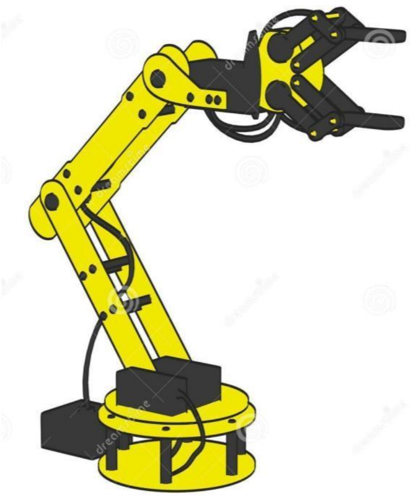
1 DOF

Required DOF in a Manipulator

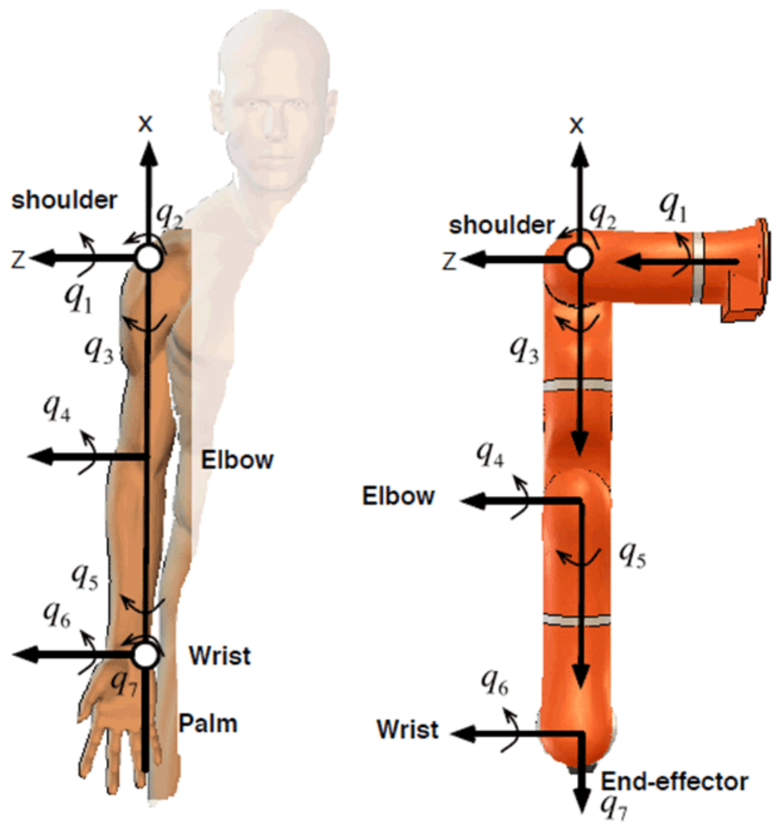
- **It is concluded that to position and orient a body freely in a space, a manipulator with 6- DOF is required**
- **Such a manipulator is called a spatial manipulator. It has three joints for positioning and three for orienting the end effector**
- **A manipulator with less than 6-DOF has constrained motion in the 3-D space**
- **There are many industrial manipulators that have five or fewer DOF that are useful for specific applications that do not require 6-DOF**

Modeling the Human Arm

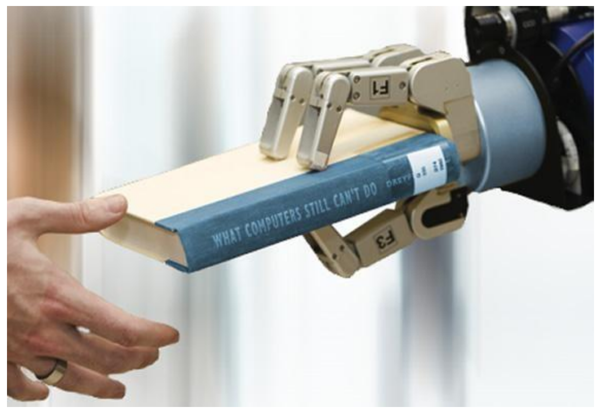
- **A human arm is considered to have seven DOFs**
- **A shoulder gives pitch, yaw and roll**
- **An elbow allows for pitch**
- **A wrist allows for pitch, yaw and roll**



Modeling the Human Arm



Example end-effector: Grippers



The Barrett Hand

Robot Manipulators

- **Workspace represents that portion of the environment the manipulator's end-effector can access**

- **Its shape and volume depend on the manipulator structure as well as on the presence of mechanical joint limits**

- **The task required of the arm is to position the wrist which then is required to orient the end-effector**

Robot Arm Structures

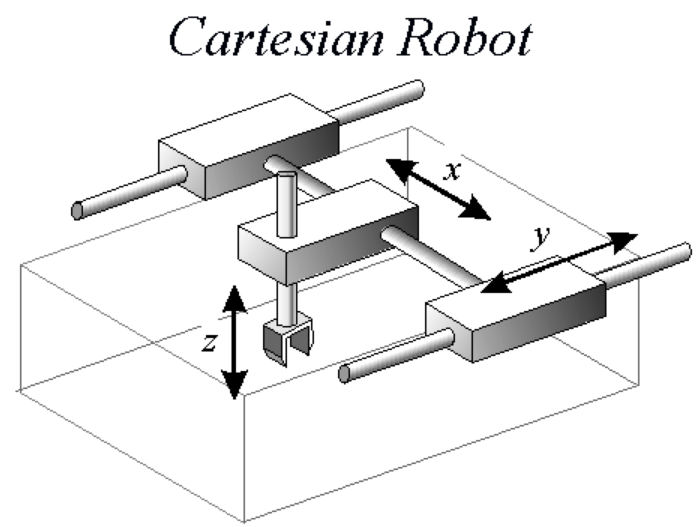
- **Figures on next slides show some common robot arm structures**

- **Robotic arms are meant to perform work similarly to the way human arms do**

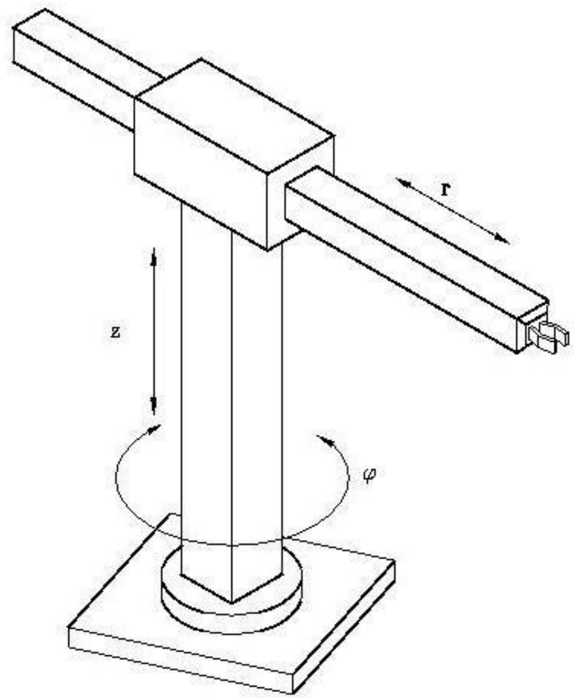
- **However, whereas as human arm has only rotational joints, robot can include prismatic and revolute joints and have greater ranges of motion strength in their joints**

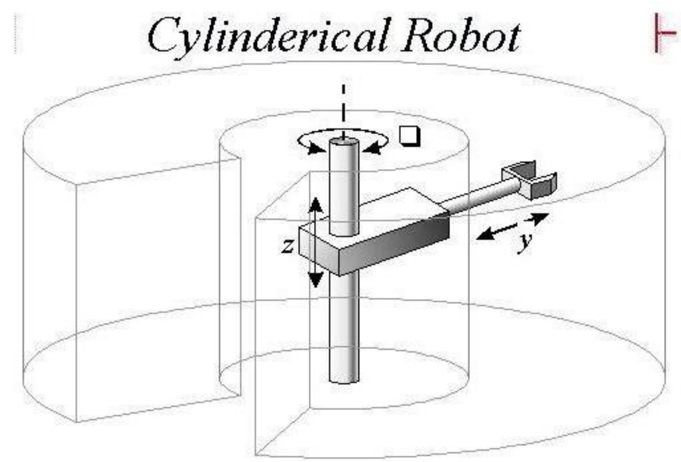
- **The robot structures shown in figures have three or four joints and can position their end effectors within their workspace**

Robot Arm Structures



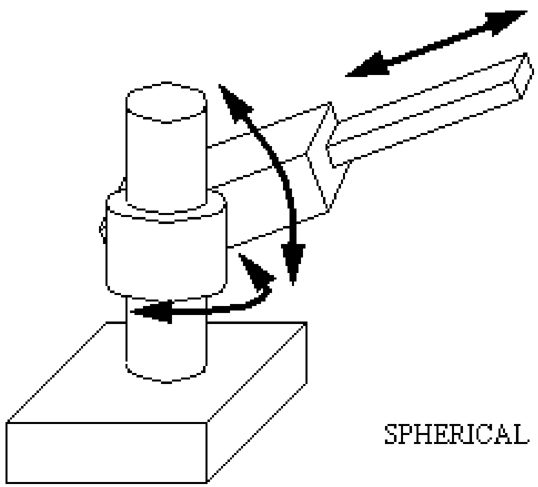
Robot Arm Structures

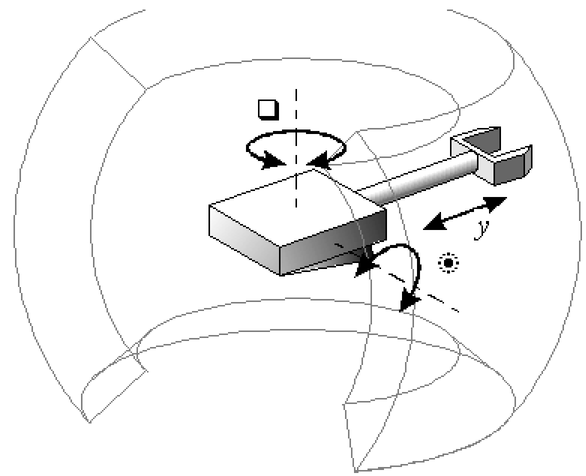




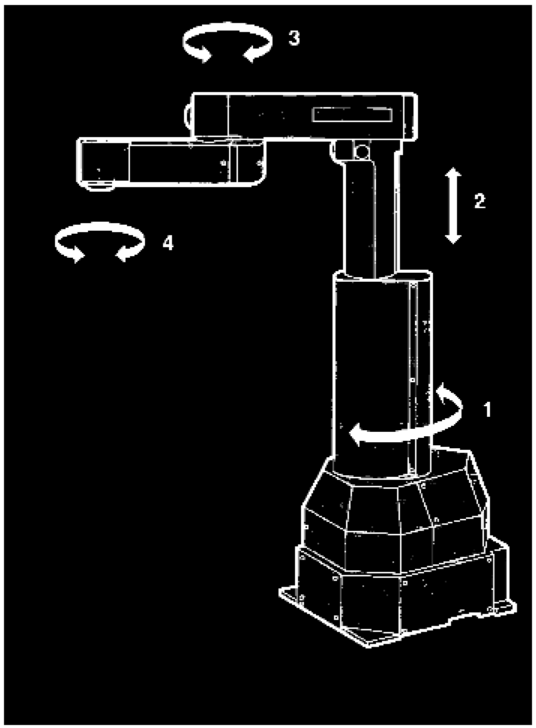
Cylindrical

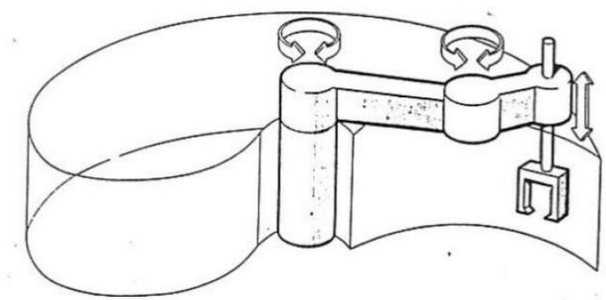
Robot Arm Structures





Robot Arm Structures





SCARA

Universe Coordinate System

- We adopt the philosophy that somewhere there is a universe coordinate system to which everything we discuss can be referenced.

- We will describe all positions and orientations with respect to the universe coordinate system or with respect to other Cartesian coordinate systems that are (or could be) defined relative to the universe system

Spatial Descriptions & Transformations

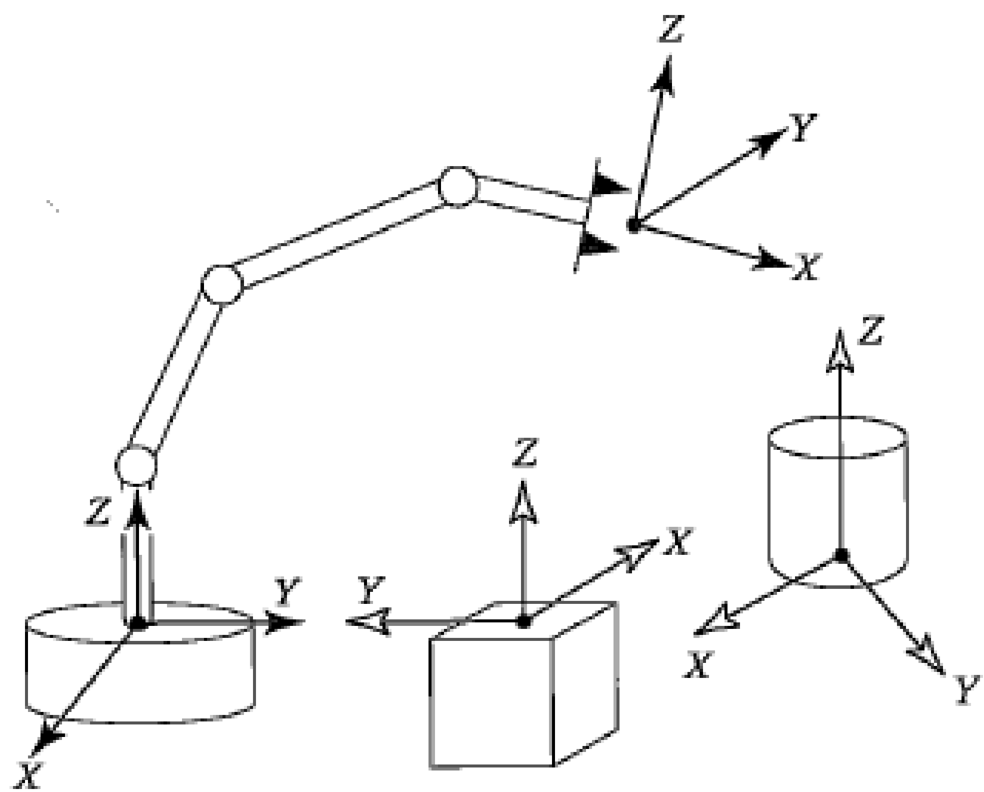
Spatial Descriptions and Transformations

- Robotic manipulation, by definition, implies that parts and tools will be moved around in space by some sort of mechanism.

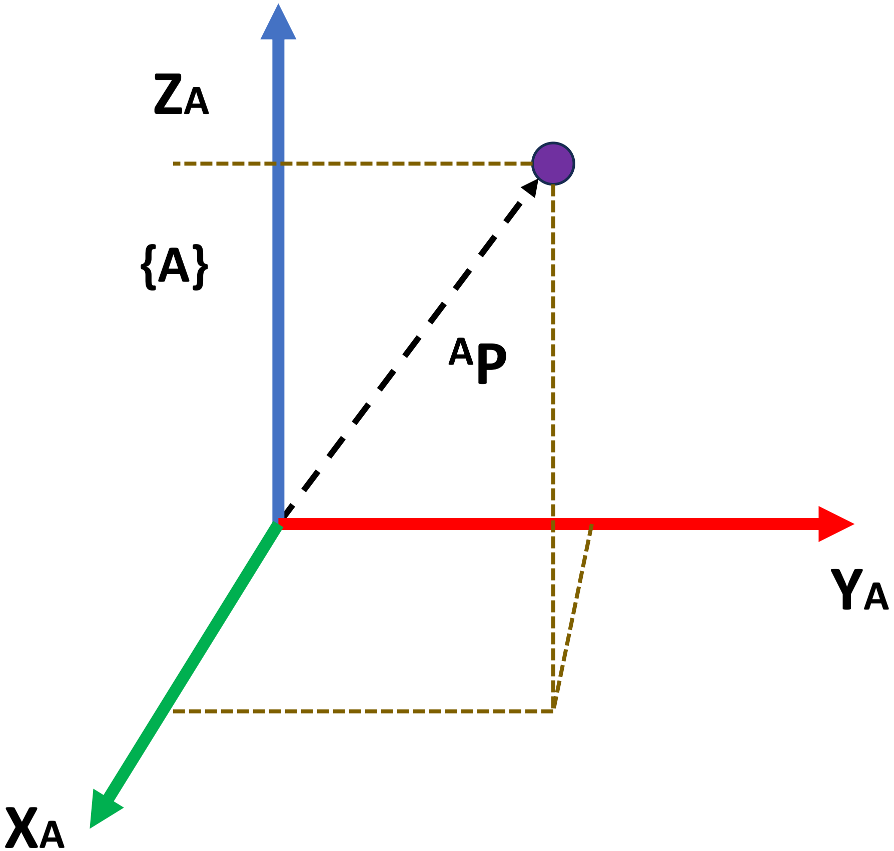
- This naturally leads to a need for representing positions and orientations of parts, of tools, and of the mechanism itself.

- To define and manipulate mathematical quantities that represent position and orientation, we must define coordinate systems and develop conventions for representation

Frames are used to describe position and orientation of a body in space

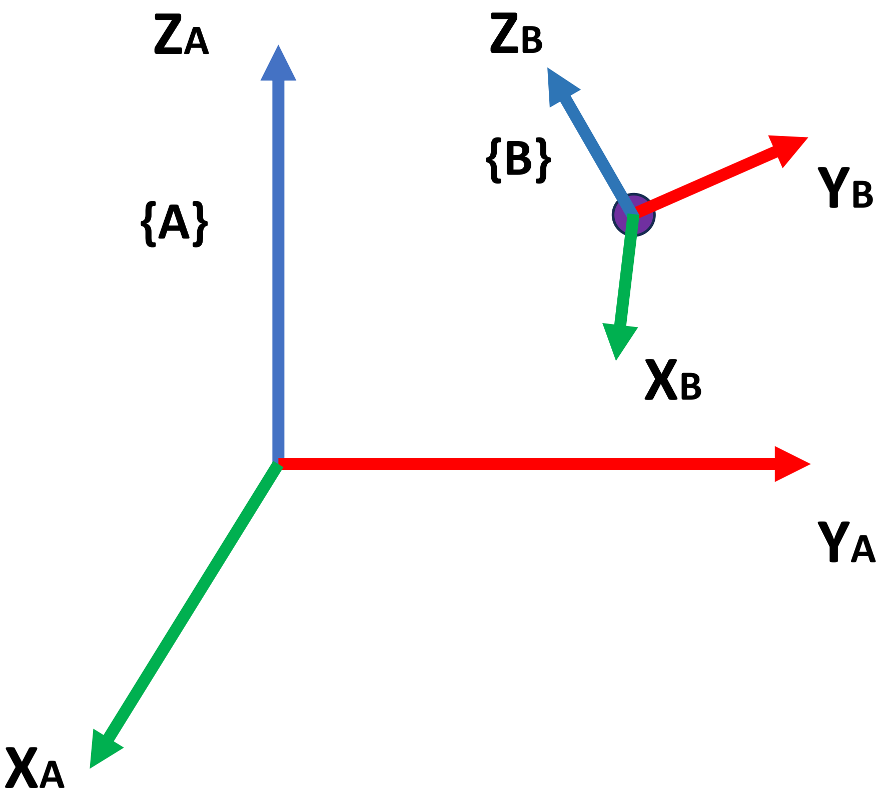


Description of a position



$$^{A}P = \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix}$$

Description of orientation



$$ {}^{A}_{B}R = \left[\, {}^{A}\hat{X}_{B} \quad {}^{A}\hat{Y}_{B} \quad {}^{A}\hat{Z}_{B} \,\right] : $$

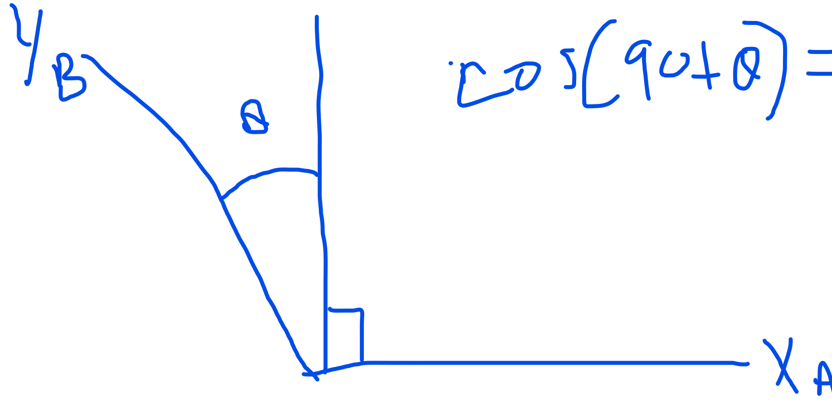
${}^{A}_{B}R$ refers to the orientation of {B} relative to {A}

Description of orientation

$$
{}^{A}_{B}R = \left[\, {}^{A}\hat{X}_B \;\; {}^{A}\hat{Y}_B \;\; {}^{A}\hat{Z}_B \, \right] = \begin{bmatrix} \hat{X}_B \cdot \hat{X}_A & \hat{Y}_B \cdot \hat{X}_A & \hat{Z}_B \cdot \hat{X}_A \\ \hat{X}_B \cdot \hat{Y}_A & \hat{Y}_B \cdot \hat{Y}_A & \hat{Z}_B \cdot \hat{Y}_A \\ \hat{X}_B \cdot \hat{Z}_A & \hat{Y}_B \cdot \hat{Z}_A & \hat{Z}_B \cdot \hat{Z}_A \end{bmatrix}
$$

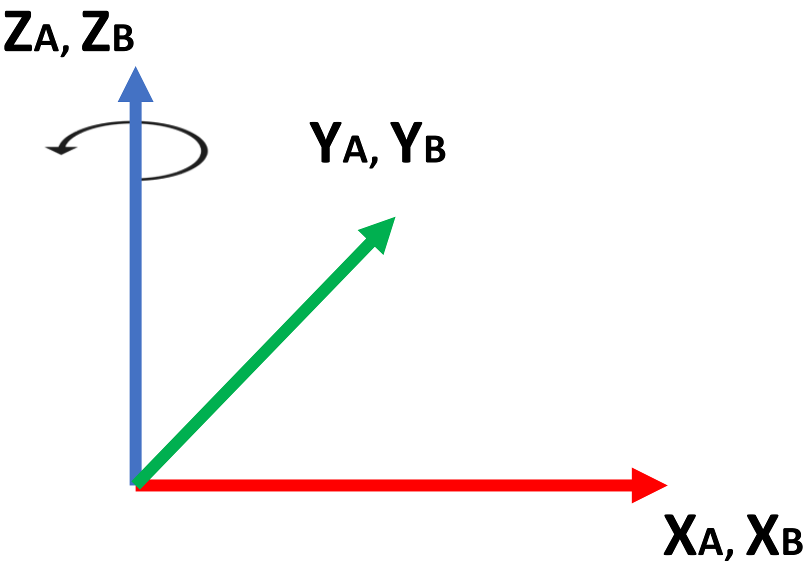
$$
{}^{A}_{B}R = \left[\, {}^{A}\hat{X}_B \;\; {}^{A}\hat{Y}_B \;\; {}^{A}\hat{Z}_B \, \right] = \begin{bmatrix} {}^{B}\hat{X}_A^T \\ {}^{B}\hat{Y}_A^T \\ {}^{B}\hat{Z}_A^T \end{bmatrix}.
$$

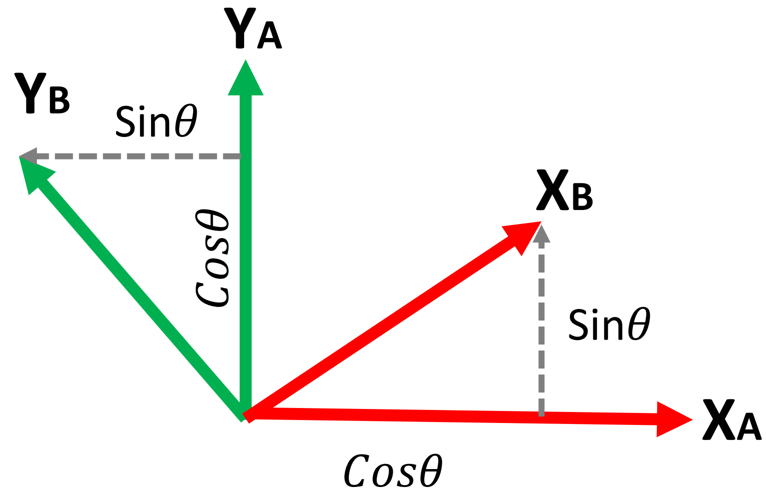
$$
{}^{B}_{A}R = {}^{A}_{B}R^T.
$$



$\cos(90+\theta) = -\sin\theta$

Rotation Matrix



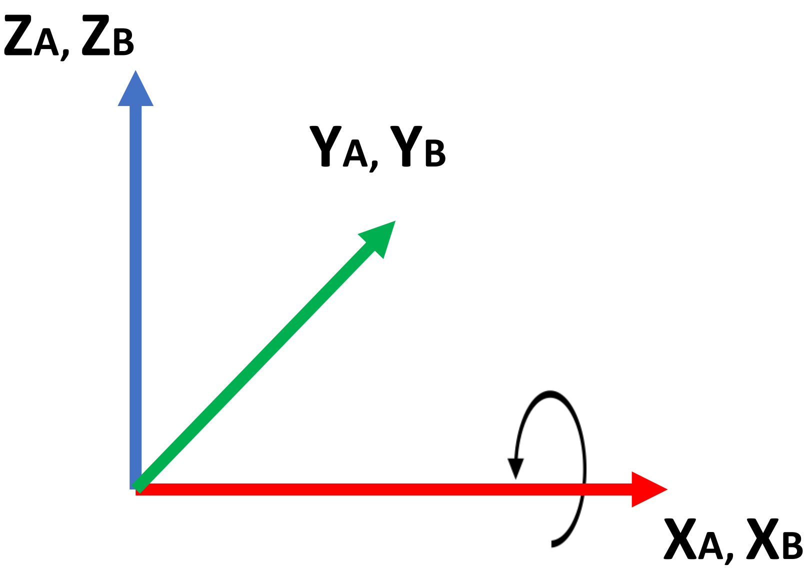


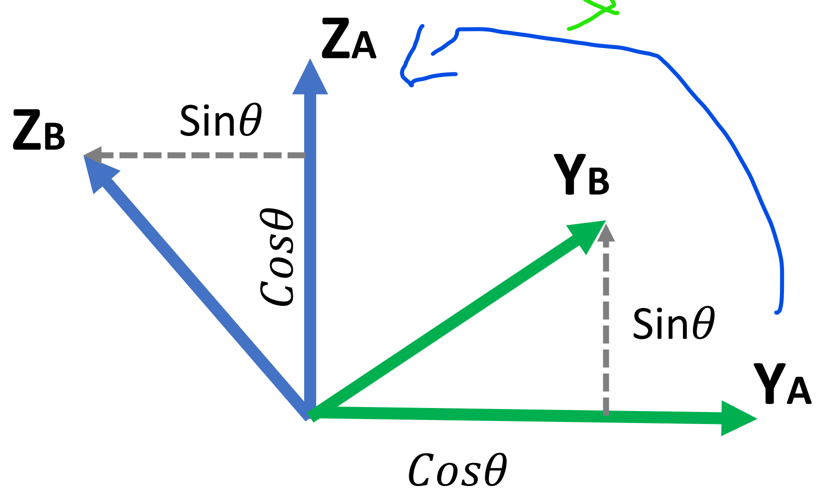
$R_{(Z)}$: Rotation about Z- axis

$$R_{(Z)} = \begin{bmatrix} Cos\theta & -Sin\theta & 0 \\ Sin\theta & Cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Rotation Matrix

Y will rotate towards Z

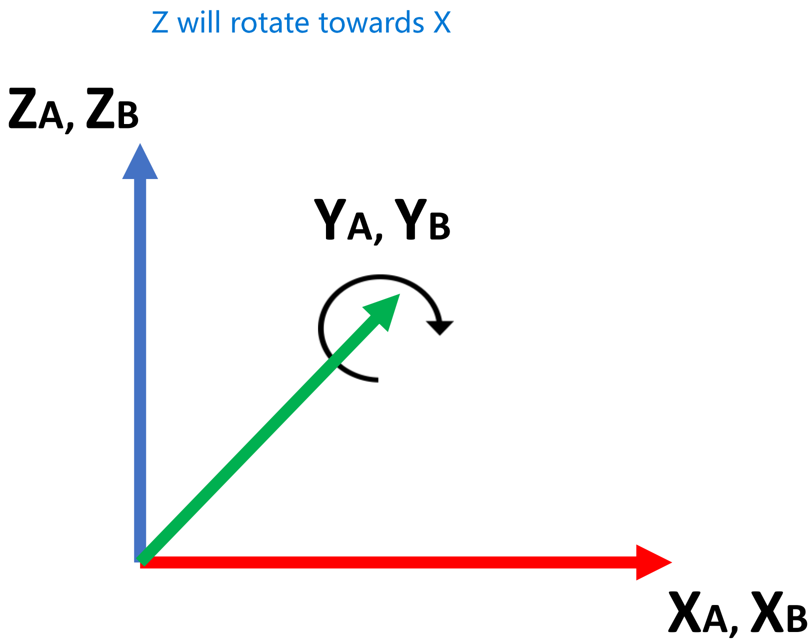


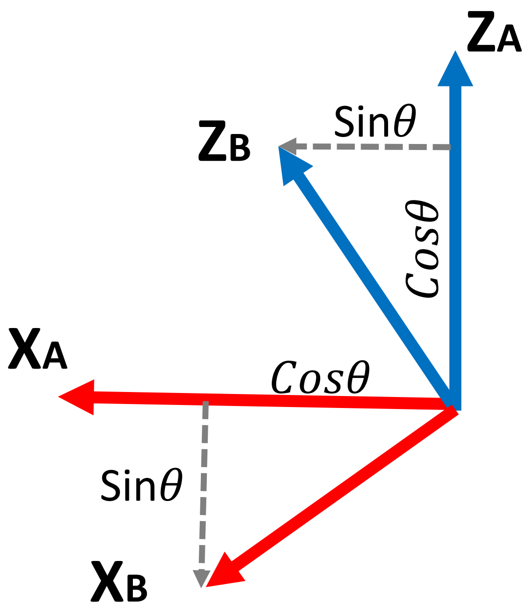


$R_{(X)}$: Rotation about X- axis

$$R_{(X)} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & Cos\theta & -sin\theta \\ 0 & Sin\theta & Cos\theta \end{bmatrix}$$

Rotation matrix





$R_{(Y)}$: Rotation about Y- axis

$$R_{(Y)} = \begin{bmatrix} Cos\theta & 0 & Sin\theta \\ 0 & 1 & 0 \\ -Sin\theta & 0 & Cos\theta \end{bmatrix}$$

Assignment 01

You are part of a team designing a space robot manipulator (a robotic arm) to capture and de-orbit a large piece of space junk. The robot will be attached to a satellite. Answer the following:

1. What sensors are required on the manipulator and why? Consider all phases of the mission: approach, inspection, capture, and post-capture. Justify the use of each sensor.
2. What type of end-effector will your robot use? Justify your choice based on the nature of the target.
3. What is the minimum number of Degrees of Freedom (DoF) the manipulator requires to perform this task in space? Explain your reasoning.
4. In the vacuum of space, there is no fixed ground. Where will you assign the world coordinate frame for your robotic manipulator system? Justify your choice.

Discussion allowed within the row.
Do not use mobile phones or laptops
Submission: 30 minutes from now