UNIT II-ROBOT KINEMATICS

SYLLABUS:

Forward kinematics, inverse kinematics and the difference: forward kinematics and inverse Kinematics of Manipulators with two, three degrees of freedom (in 2 dimensional), four degrees of freedom (in 3 dimensional) – derivations and problems. Homogeneous transformation matrices, translation and rotation matrices.

KINEMATICS:

Kinematics in robotics is the study of motion in robotic system without considering the forces that cause it. It focuses on the geometric relationship between a robot's joints, links and end-effectors (the tool or gripper at the end of a robotic arm). kinematics is critical because it enables precise control of robotic movement. Without accurate kinematic models, robots couldn't perform task like assembly, painting or surgery.

Two types of kinematics:

1. Forward Kinematics
2. Reverse Kinematics
3.

1. FORWARD KINEMATICS:

Forward Kinematics (FK) is the process of calculating the position and orientation of a robot's end effector (tool or gripper) in space, given the joint parameters (angles for revolute joints, displacements for prismatic joints) and the link dimensions. Here the link parameters are given we have to find out the motion and orientation of the end-effectors.

Uses of Forward Kinematics:

1. Position and Orientation Calculation – To determine the exact coordinates (x, y, z) and orientation (roll, pitch, yaw) of the robot's end effector.
2. Path Planning – Helps in generating the movement path of a robot's end effector in space.

3. Simulation and Visualization – Used in robotics software to simulate robot motion before actual implementation.
4. Calibration – Assists in aligning robot models with real-world robots.
5. Control Systems – Provides the necessary reference values for feedback and control loops.

Applications of Forward Kinematics:

1. Industrial Robots – For tasks like welding, painting, pick-and-place, and assembly.
2. Medical Robotics – In surgical robots to precisely position instruments.
3. Animation and Computer Graphics – To animate characters' limbs and body movements.
4. Humanoid Robots – To calculate the movement of arms, legs, and head for natural motion.
5. Space Robotics – In robotic arms used in satellites and space stations.
6. Virtual Reality (VR) and Gaming – To map user joint movements to virtual avatars.

2. INVERSE KINEMATICS:

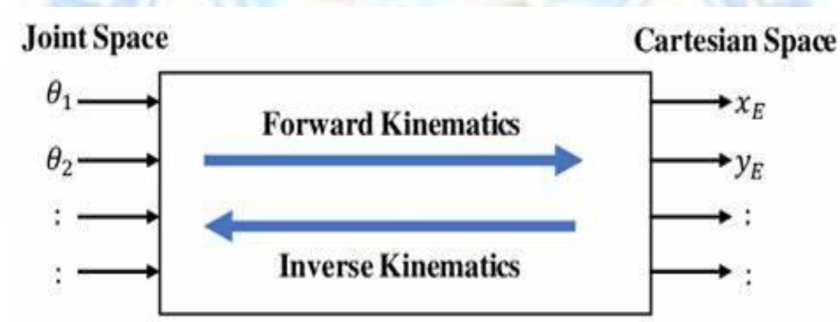
Inverse Kinematics (IK) is the process of calculating the joint parameters (angles or displacements) required to place a robot's end effector at a desired position and orientation in space. Which means it involves determining the necessary joint parameters to achieve a desired position and orientation of the robot's end effector.

Uses of Inverse Kinematics:

1. Trajectory Planning – To move a robot's end effector along a defined path.
2. Precise Positioning – Helps to reach a target point in space accurately.
3. Control of Complex Robots – Essential for multi-joint robots and humanoids.
4. Animation and Graphics – Used for realistic movement of characters (arms, legs, body).
5. Simulation – To test whether a robot can reach a point before actual operation.
6. Teleoperation – Operators set target positions, and IK determines joint movements.

Applications of Inverse Kinematics:

1. Industrial Robots – Welding, painting, CNC machining, pick-and-place operations.
2. Medical Robotics – Robotic-assisted surgery for accurate movement of tools.
3. Animation and Gaming – To animate human-like movements of characters and avatars.
4. Humanoid Robots – Making robots walk, bend, or grasp objects naturally.
5. Space Robotics – Controlling robotic arms on satellites or space stations to grasp and repair objects.
6. Virtual Reality (VR) / Motion Capture – Mapping human body movements to avatars by calculating joint angles.



DIFFERENCE BETWEEN FORWARD AND INVERSE KINEMATICS:

FEATURE	FORWARD KINEMATICS	INVERSE KINEMATICS
Definition	Calculation of end-effector position & orientation from given joint angles	Calculation of joint angles from a given end-effector position & orientation.
Input	Joint parameters (angles, displacements)	Desired end-effector position & orientation.
Output	Position & orientation of end-effector	Joint parameters (angles, displacements).

Direction of calculation	From joints to end-effector	From end-effector to joints
Uniqueness of solution	Unique solution for a given set of joint values	May have multiple or no solution depending on robot geometry.
Use Case	Used in simulation, animation and when control inputs are known.	Used in robot path planning and motion control when target positions are known
Example	Given a robotic arms joint angle, find where the gripper is.	Given a desired gripper location, find how the joints should move.