

# Robotics Mini Project: Kinematic Analysis of a Robot Arm

## Objective

The objective of this mini project is to perform a kinematic analysis of a simple robot arm (3 DoF or more) constructed using servo motors. You can either build your custom robot arm or purchase a commercial hobby type robot arm. The analysis will involve creating a Denavit-Hartenberg (DH) table, calculating the forward kinematics, deriving the inverse kinematics, and finding the manipulator Jacobian for a pick and place task.

## Robot Description:

The robot arm consists of a series of connected servo motors to create a multi-link robot. It should not contain mechanisms such as 4-bar linkages. The robot should be capable of performing a pick and place task, where it picks up an object from one location and places it in another on the floor. You have the freedom to choose the two locations.

## Tasks:

### 1. Denavit-Hartenberg (DH) Table

Create a DH table for the robot arm. Define the following parameters for each joint:

- Link length ( $a$ )
- Link twist ( $\alpha$ )
- Link offset ( $d$ )
- Joint angle ( $\theta$ )

### 2. Forward Kinematics

- a) Using the DH parameters, compute the forward kinematics of the robot arm. This should involve finding the transformation matrix from the base frame to the end-effector frame.
- b) Test the forward kinematics with sample joint angles and verify that it correctly computes the end-effector's position and orientation.

### 3. Inverse Kinematics

- a) Derive the equations for the inverse kinematics of the robot arm. As you might not be able to achieve kinematic decoupling, focus only on determining the joint angles required to position the end-effector at a given location.
- b) Test the inverse kinematics with various end-effector positions to ensure that it accurately computes the required joint angles.

#### 4. Manipulator Jacobian

Find the Jacobian matrix of the manipulator.

#### 5. Pick and Place Task

- a) Design a simple pick and place task for the robot arm. Specify the initial and final positions of the object to be picked and placed.
- b) Use the inverse kinematics solver to plan and execute the pick and place task. Record the joint angles and end-effector positions for the initial and final configurations.
- c) Document the results and provide a video demonstration of the robot performing the pick and place task.

### **Deliverables**

1. DH Table for the robot arm.
2. Forward kinematics expressions.
3. Inverse kinematics equations.
4. Manipulator Jacobian
5. 3-page report summarizing the analysis, including calculations and explanations.
6. Video demonstration of the robot arm performing the pick and place task.

### **Grading Criteria**

Your project will be evaluated based on the completeness of the DH table, correctness of forward, and inverse kinematics calculations, successful execution of the pick and place task, and the clarity of your documentation and report.