Robotics Project

Structural description & functioning of a

4-DOF SCARA Robot - A detailed case study.

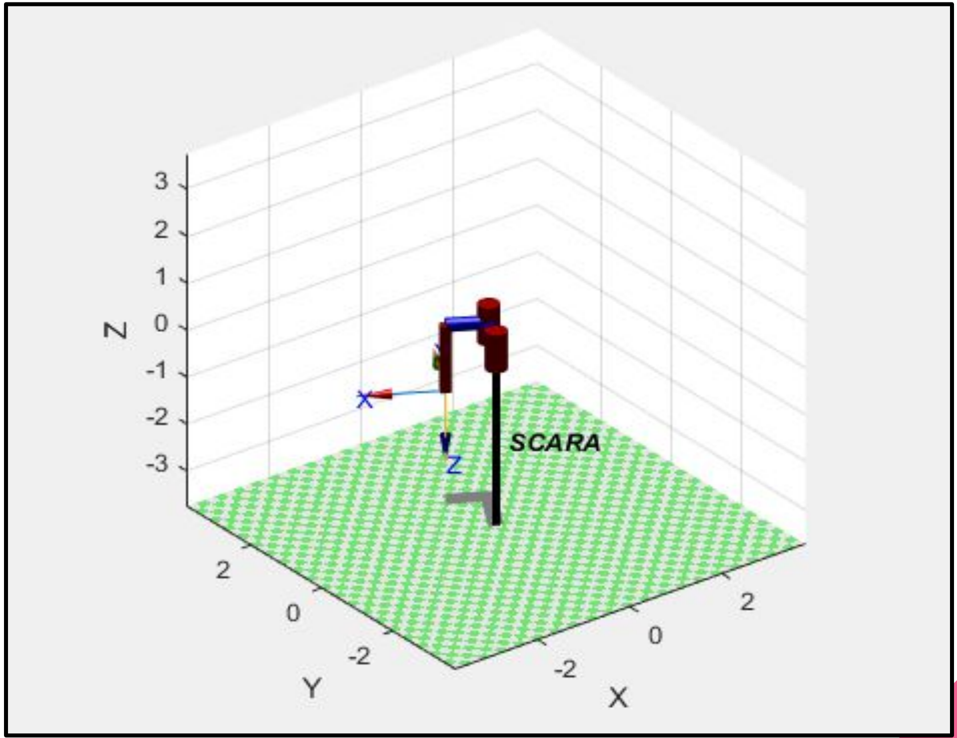
Introduction

- The SCARA is a type of industrial robot. SCARA stands for Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm.
- The SCARA robot is most commonly used for pick-and-place or assembly operations where high speed and high accuracy are required. Generally a SCARA robot can operate at higher speeds, even with optional cleanroom specifications.
- Industrial robots are defined as “multi-functional manipulators designed to move parts through various programmed motions”. As such, robots provide consistent reliable performance, repetitive accuracy, are able to handle heavy work loads, and perform in harsh environments.
- SCARA Robot Characteristics like high reliability, high accuracy, speed, minimum maintenance, ease of use, and extremely compact design.
- The SCARA robot is a manipulator with four degrees of freedom. This type of robot has been designed to improve the speed and repeatability ON PICK&PLACE TASKS from one location to another, or to speed up and improve the steps involved in assembly.

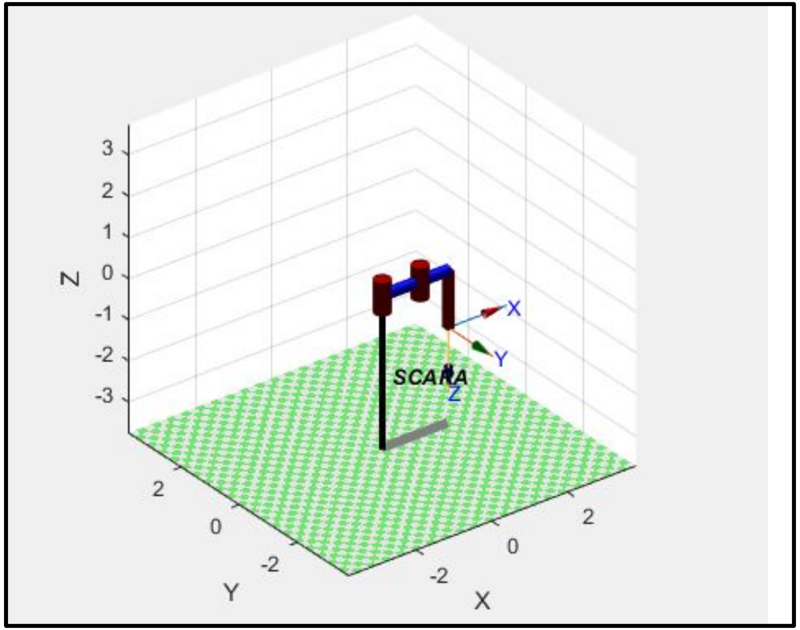
Overview

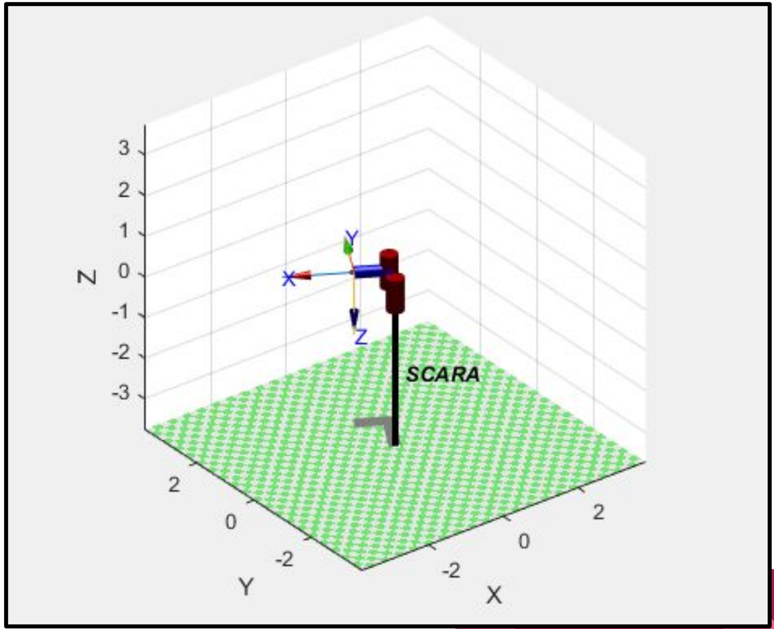
- SCARA is the name given to a certain type of industrial robot. In the early 1960s, robots were created and invented in Japan.
- Development of SCARA robots, an open-loop type manipulator that is used for assembly in production industries has been successful in speeding up assembly process.
- The SCARA robot is designed for applications that demand repetitive point-to-point arm operations, such as picking and placing objects or assembly techniques that require extreme speed and precision.
- SCARA is widely used in assembly processes. SCARA's unique end-effector movement makes it suited for activities that need circular motion and accelerations.
- A SCARA's ability to be remotely controlled also makes it a choice in work sites hazardous to humans, such as working with chemicals, or in environments with extreme conditions, such as in steel mill.
- A SCARA robot has high compliance in the x-y plane in the sense that the arm moves freely to accomplish the assembly task accurately.

Modelling



Motion Simulation





Kinematic Analysis

- The kinematic analysis is the relationships between the positions, velocities, and accelerations of the links of a manipulator.

- The Denavit-Hartenberg (D-H) model of representation or can be called Denavit Hartenberg convention was applied in forward kinematics method to determine modeling robot links and joints.

i	a_{i-1}	α_{i-1}	d_i	Θ_i
1	0	$\Pi/2$	d_1	0
2	0	$-\Pi/2$	l_i	Θ_2
3	l_2	0	0	Θ_3
4	l_3	Π	d_4	0
5	0	0	d_5	0

Forward Kinematics

- Forward kinematics is the mapping from joint coordinates, or robot configuration, to end-effector pose.
- The general form of transformations matrix that transforms vectors is given as:

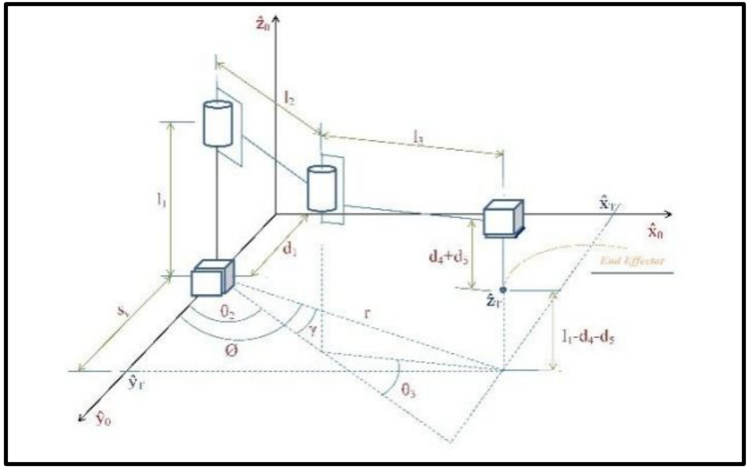
$$ {}^{i-1}_{i}T = \begin{bmatrix} \cos\theta_i & -\sin\theta_i & 0 & a_{i-1} \\ \sin\theta_i \cos\alpha_{i-1} & \cos\theta_i \cos\alpha_{i-1} & -\sin\alpha_{i-1} & -\sin\alpha_{i-1} d_i \\ \sin\theta_i \sin\alpha_{i-1} & \cos\theta_i \sin\alpha_{i-1} & \cos\alpha_{i-1} & \cos\alpha_{i-1} d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

- The end effector position is given by:

$$ \begin{bmatrix} x \\ y \\ z \\ \phi \end{bmatrix} = \begin{bmatrix} l_2 c_2 + l_3 c_{23} \\ l_2 s_2 + l_3 s_{23} - d_1 \\ l_1 - d_4 - d_5 \\ \theta_2 + \theta_3 \end{bmatrix} $$

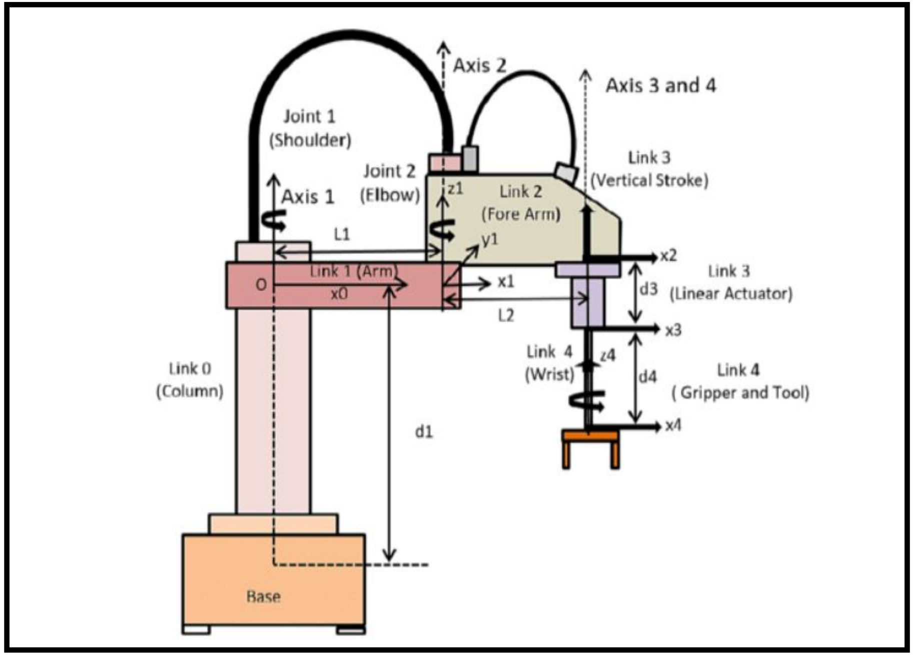
Inverse Kinematics

- The inverse kinematics the input is the Cartesian pose of an object and the output is the joint coordinates the robot needs in order to reach it.
- Based on the given figure, the inverse kinematic equations can be derived. Inverse kinematics of robot derived by solving for values of two joints parameters (θ2, θ3) and values of two links parameters (d1, d4).



Qualitative/Quantitative Discussion

- The Robotics Toolbox of MATLAB is widely used in robot development and gives a range of kinematic and path planning functions to robot research.
- In the meanwhile, the toolkit can do picture simulations using robots.
- SCARA robot kinematics simulation consists of two parts:i) forward kinematics ii) inverse kinematics simulation.
- In modeling, both Function Link and SerialLink can be employed.



Summary

- The SCARA robot kinematic model is created using the denavit-hartenberg (D-H) approach, and the forward and inverse kinematics are studied using MATLAB.
- After studying prior work on the SCARA robot and its application, the initial stage of the project is to build a manipulator for this project.
- The 4-DOF SCARA robot prototype with 3R1P. The rotating joints are Axis 1, 2, and 4, while the prismatic joint is Axis 3.
- Concept 1 employs a belt system to revolve the second link, which is located towards the base.
- To revolve both connections, Concept 2 employs a belt system.
- Gears are used in Concept 3 to revolute linkages 1 and 2.
- Concept 4 is similar to concept 2, with the exception that the motors are located in the center of link 1.
- The robot's improvement also involves the creation of a graphical user interface that can operate simulations and monitor the SCARA robot.