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Mechatronics Systems Laboratory

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Manipulator Robot

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Task1: Develop the inverse kinematic model (equations) for the manipulator robot

To develop the inverse kinematic model for a robot we generally follow the D-H (Denavit - Hartenberg) parameters approach or Graphical approach.

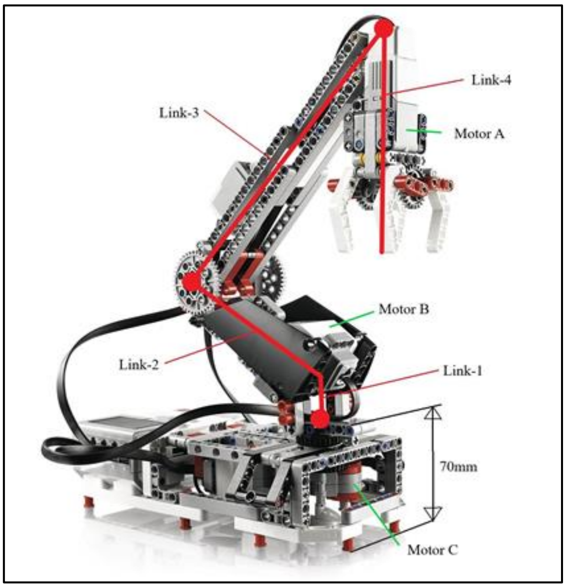

Fig 1: Manipulator Robot.

For our task to control the manipulator robot we have used the graphical method approach based on trigonometric relationships between links length and angles. In Trigonometry method we use the angular functions by considering x, y, z co-ordinates to determine the angles of links of the robot. These angles can be obtained by considering the different viewpoints of the robot.

The Coordinate system is chosen as shown in figure 1. The Z-axis points vertically downwards. The origin is on the table at the base of link-0.

Calculating the angles by considering the Top view and the Side view,

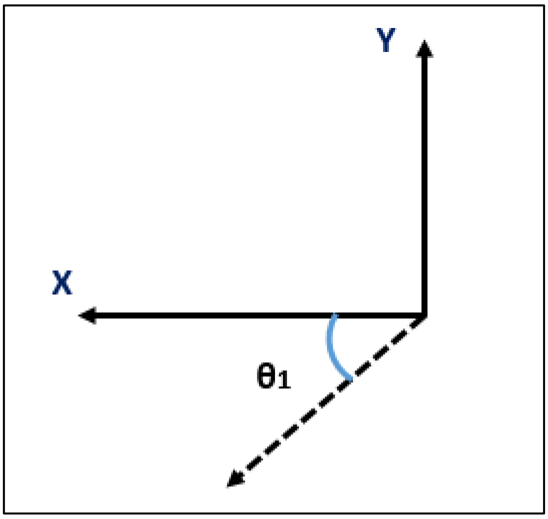

Fig 2: Top View

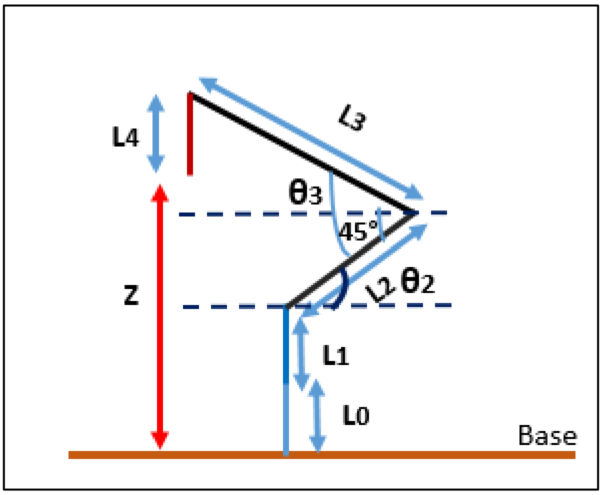

Fig 3: Side View

θ_1 is defined as the angle rotated by motor C from the X-axis as shown as in figure 2.

θ_3 is the angle between link-2 and link-3. θ_3 changes as motorB rotates.

θ2 is angle between link-2 and the horizontal plane. This is fixed and is equal to 45 degrees

Now, by considering the top view and side view, we can obtain relationship between angles θ_1 and θ_3 and the co-rodinated of the end-effector.

From the top view we have,

$$tan(\theta_1) = \frac{Y}{X}$$

$$\theta_1 = Tan^{-1}\left(\frac{Y}{X}\right) \qquad (1)$$

We obtain θ_3 and from the side view,

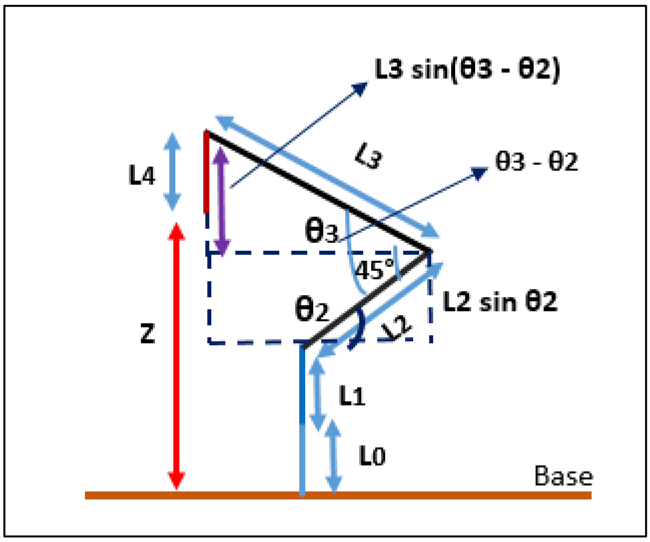

Fig 3: Side View with link angles

From the above figure we can obtain the z by,

$$-z = L0 + L1 + L2 * \sin\theta2 + L3\sin(\theta3 - \theta2) - L4$$

Which gives us θ3 as follows:

$$\theta3 = sin^{-1}\left(\frac{-z+l4-l0 - l1 - l2*sin(\theta2)}{l3}\right) + \theta2 \quad (2)$$

Task 2: Develop behaviours for picking, placing and homing.

We develop three set of behaviours for homing, picking and placing.

Homing

We start with operating motorA with constant speed for 1 seconds to reset the direction of opening and closing of the grip. Then we opertate the motorC and MotorB at contasnt speeds till we reach the limit switch.After which the encoder values are reset and both the motors are stopped.

Picking

This behaviour takes one paramter i.e the position from which the ball has to be picked up.

We start with operating motorA with constant speed for 0.2 seconds to open the grip of the robot.
The robot is then moved to the desired co-ordinates by using discrete PID controller to control the speed of MotorC and MotorB

motorC.Speed = (C1_A * errorA + C2_A * errorA_k1 + C3_A * errorA_k2);

Where k1 and k2 are the Previous errors, and the saturation speed is set between 10 to 15.

For motor B,
motorB.Speed = (C1_B * errorB + C2_B * errorB_k1 + C3_B * errorB_k2);

the saturation speed is set between 15 to 30.

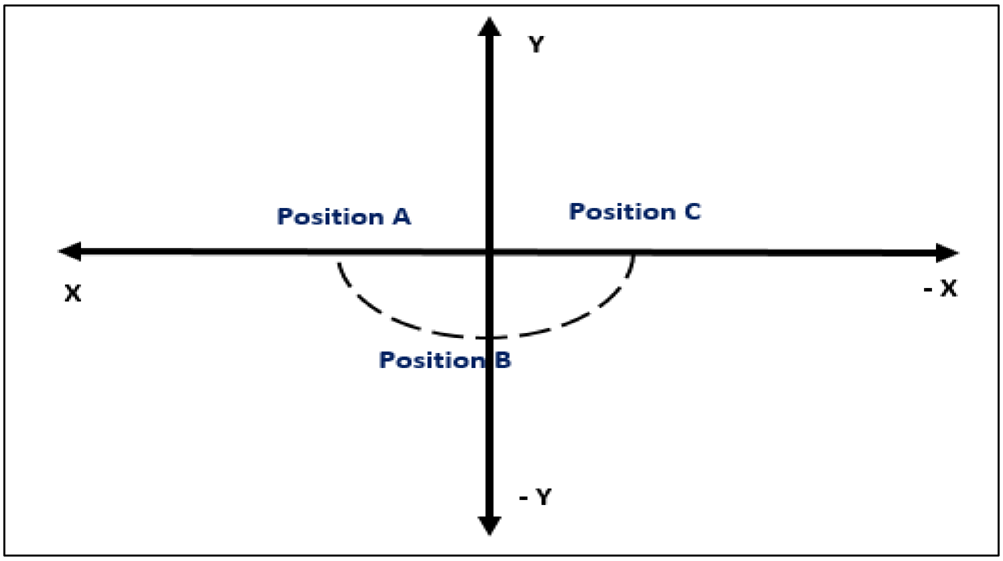

Fig 4: Positions of the ball coordinated

First, we operate motorC till we reach the desired θ_1 and thereafter motorB is operated to reach θ_3. θ_1 and θ_3 are calculated using equation (1) and (2) respectively.

Once the desired position is reached, we operate motorA with constant speed to close the grip and thus picking the ball.

After picking motion, we operate motorB to reach a height of 140mm above the table. This completes over picking behaviour

Placing
This behaviour takes one parameter i.e location to place the ball. We start with operating motorC followed by motorB to reach the desired co-ordinates. We use the same controller as used for picking behaviour.

Once the desired position is reached, we operate motorA with constant speed to open the grip which releases the ball.

We complete the behaviour by operating motorB to reach the height of 140mm above the table.

Range of Motion
At homing position, we reset the encoders for θ3 and θ1, θ1 varies from 0° at position A to -180° at position C and for θ3 from 20° at table to 110° at homing position.

Task 3: Use the behaviours in (2) to command the manipulator to pick the ball from station C and place it at station A.

Initially the ball is placed at position C, after homing the end effector has to reach to the ball position that has coordinates ‘z’ = 0, ‘y’ = 0 and ‘x’ = -115.

pick('c')
We call the picking behaviour with parameter 'c' which first operates motorC to reach desired θ_1 as calculated from inverse kinematics equation (1), then motorB is operated to reach the desired z-coordinate i.e zero. After which motorA operates to grip the ball.

place('a')
Co-ordinates of station A: 'z' = -70, 'y' = 0 and 'x' = 115.

We call the placing behaviour with parameter 'a' which first operates motorC to reach desired θ_1 as calculated from inverse kinematics equation (1), then motorB is operated to reach the desired z-coordinate. After which motorA operates to release the ball.

Task 4: Use the behaviour in (2) to command the manipulator to pick the ball from station A and place it at station B.

pick('a') and place('b')
Co-ordinates of station B: 'z' = 0, 'y' = -115 and 'x' = 0.

To place the ball in station B from station A only the 'y' position has to be varied, that is the y is given negative (-115) from figure 4 and the 'x' is made to zero and as the ball is to be placed on the ground so the 'z' is made to 0. As the 'y' position to be moved the motor C works accordingly with the given input data and the motor A works the same.

Task 5: Use the behaviour in (2) to command the manipulator to pick the ball from station B and place it at station C.

pick('b') and place('c')

To move the ball from station B to station C the 'x' position has to be feeded negative (-115) and the 'y' remains to be zero, as the ball is to be placed on the ground 'z' position in zero and the motor works with the same given values.