Mechatronic Systems Laboratory

Report on

Manipulator Robot

Pick and Place Task

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Group 14

1537943 Chaithanya Tenneti

1536199 Kaushik Goud Chandapet

1522044 Nishanth Iruthayaraj

1533846 Sai Radha Krishna Vangaveeti

1536988 Venkata Sai Tarak Padarthi

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Objective:

Implementation of the motion control of a manipulator robot to achieve a pick-and-place sequence of motion.

Inverse Kinematics:

The motion of this 2-DOF manipulator robot (θ_1 and θ_2) can be controlled using two motors Motor B and Motor C whereas the gripper action can be controlled using Motor A.

Assuming the Origin at the base of the robot (exactly below the Motor C) with X axis pointing outward, Y axis pointing to the right and Z-axis to the top when looked from the Front side of the robot.

Using Graphical method and performing Inverse Kinematics, we can deduce the formulae for the θ_1 and θ_2 from the given position of the gripper in rectangular co-ordinates X, Y, Z.

The inverse kinematics of manipulator robot is found by the following expressions

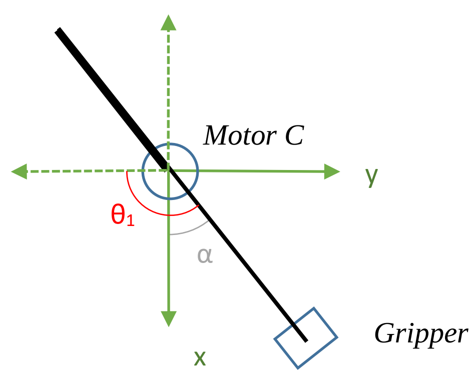

Fig 1: Top view of manipulator robot

$$\alpha = tan^{-1}\left(\frac{y}{x}\right)$$

$$\theta_1 = 90^{\,0} + \alpha$$

$$\theta_1 \;=\; 90 + \tan^{-1}\left(\frac{y}{x}\right)$$

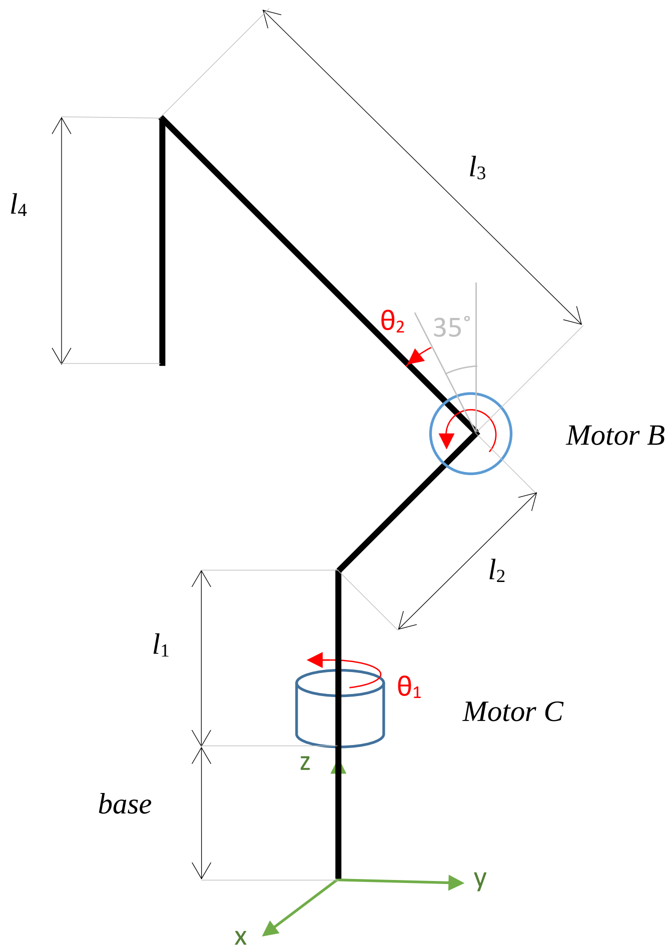

Fig 2: Front view of manipulator robot

$$z = base + l_1 + l_2 \sin 45 - l_4 + l_3 \sin(35 - \theta_2)$$

$$\theta_2 = 35 - \sin^{-1}\left(\frac{z + l_4 - base - l_1 - l_2 \sin 45}{l_3}\right)$$

Calculating station Co-ordinates:

$$Station\ A = (0, -118, 70)$$

$$Station\ B = (118, 0, 0)$$

$$Station\ C = (0, 118, 0)$$

Considering the angle θ_2 when the link l_3 is parallel to the ground, we get Y co-ordinate for station A with respect to Origin.

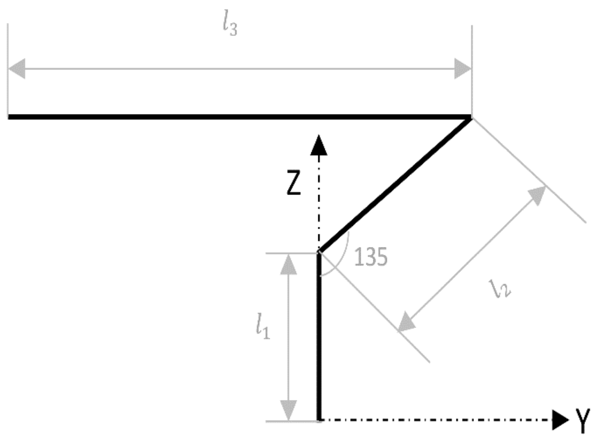

Fig 3: Cropped view of manipulator robot

$$y = l_3 - l_2 * \sin 45 \approx 118$$

The X co-ordinate is *zero* and the Z co-ordinate is ‘70’ (elevation of station A) for station A.

Similarly, we get the Station B and Station C co-ordinates as $(118, 0, 0)$ and $(0, 118, 0)$ respectively.

Program implementation:

The task can be divided into three behaviors – Homing, Picking and Placing

Homing – We take the robot arm to a position where both the touch sensors are active(touching) and reset the encoder values of the motor B and motor C making θ_1 and θ_2 to be equal to zero.

Function call: homing()

Picking – We take the robot arm to the given station, close the gripper to hold the object and then bring back elbow to the initial position (θ_2=0).

Function call: pick(stationA)

Placing – We take the robot arm to the given station, open the gripper to release the object and then bring back elbow to the initial position (θ_2=0).

Function call: place(stationA)

As motors are coupled through Gear Boxes, using Gear ratio formula between motor C (encoder values) θ_{mC} and the link 1 angle θ_1, we get,

$$N_1 * \theta_1 = N_{mC} * \theta_{mC}$$

$$\theta_{mC} = \theta_1 * \frac{N_1}{N_{mC}}$$

$$\theta_{mC} = \theta_1 * \frac{36}{12}$$

$$\theta_{mC} = 3\theta_1$$

Similarly for motor B (encoder values) θ_{mB} and the elbow angle θ_2,

$$\theta_{mB} = \theta_2 * \frac{N_2}{N_{mB}}$$

$$\theta_{mB} = \theta_2 * \frac{40}{8}$$

$$\theta_{mB} = 5\theta_2$$

Program Sequence:

```
homing();% Reset to position where touch sensors are active
         % and reset the encoder reading values to zero

% Sequence start
pick(stationC);  % Move to StationC and Close the gripper
place(stationA); % Move to StationA and Open the gripper
pick(stationA);
place(stationB);
pick(stationB);
place(stationC);
% Sequence end
```

References :

1. MATLAB Support Package for LEGO MINDSTORMS EV3 Hardware
   https://de.mathworks.com/help/supportpkg/legomindstormsev3io/

2. Building Instructions for LEGO MINDSTORMS EV3 Robot Arm