Mechatronic Systems Laboratory

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University of Siegen

Group 2

Submitted by:

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Content

Objective:

Our main Objective is to develop behaviours for picking, placing and homing from one station to another station as per desired task using inverse kinematic model (equations) for this manipulator with the geometric approach.

1. Develop the inverse kinematic model (equations) for this manipulator using the geometric approach and include the derivation in your report.
2. Program the manipulator to grasp and release the payload (ball). Include video proof for this.
3. Implement and tune PID controller variants (P, PI, PD or PID) for joint angle control. Include video proof for this and details in the report.
4. Develop behaviors for homing, and picking and placing from/to stations with different heights. Note, the home point is the topmost position at station B. Include video proof for these.
5. Use the behaviors in (3) to command the manipulator to home. Include video proof for this. Add a flow chart showing the process for achieving this in the report.
6. Use the behaviors in (3) to pick the ball from station B, place it at station C and then return to home without colliding into stations. Add a flow chart showing the process for achieving this in the report.
   - Use the depth sensor to measure the heights of the sections before any pick or place manoeuvre. Provide video proof for this.
7. Use the behaviors in (3) to command the manipulator to pick the ball from station C, place it at station A and then return to home without colliding with the station.
8. Use the behaviors in (3) to command the manipulator to pick the ball from station A, place it at station B and then return to home without colliding with the station.
9. Use the behaviors in (3) to command the manipulator to pick the ball from station B, place it at station A and then return to home without colliding into the station.
10. Use the behaviors in (3) to command the manipulator to pick the ball from station A, place it at station C and then return to home without colliding with the station.
11. Use the behaviors in (3) to command the manipulator to pick the ball from station C, place it at station B and then return to home without colliding with the station.

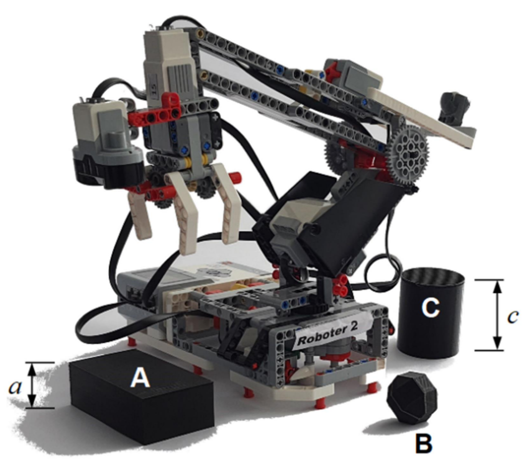


Figure 1: Manipulator Robot Specifying Station Height

Develop the inverse kinematic model (equations) for this manipulator using the geometric approach and include the derivation in your report.

As shown in the figure below, let θ_{max} is the maximum angle between Link2 and Link3. L_{max} (Measured value = 211mm) be the maximum Distance between Sonic senor and Ground. The measured distance between sonic sensor and Gripper is 45mm, it is already subtracted from L_4 while carrying out the calculations and in the code.

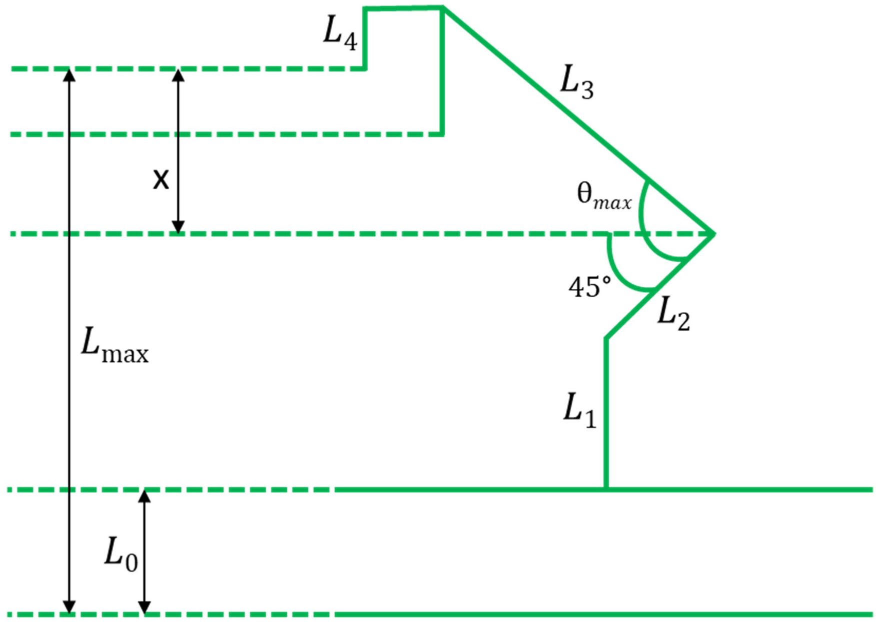


Figure 2: Line sketch of Robot with link 3 at highest position

The Value of the x is calculated using below equation:

$$X = L_{max} - L_0 - L_1 - L_2 \sin 45°$$

The maximum angle is calculated using the following equation:

$$\theta_{max} = 45° + sin^{-1}\left(\frac{L4 + Lmax - L0 - L1 - L2\, sin\, 45°}{L3}\right)$$

All the values are known and hence maximum angle can be calculated. By using θ_{max}, we can calculate the angle θ. θ is the angle that link 3 should move from its maximum position to pick or place the ball when sonic sensor is measuring a height L from sensor to Station height/Ground. It is calculated using below Inverse Kinematic Equation.

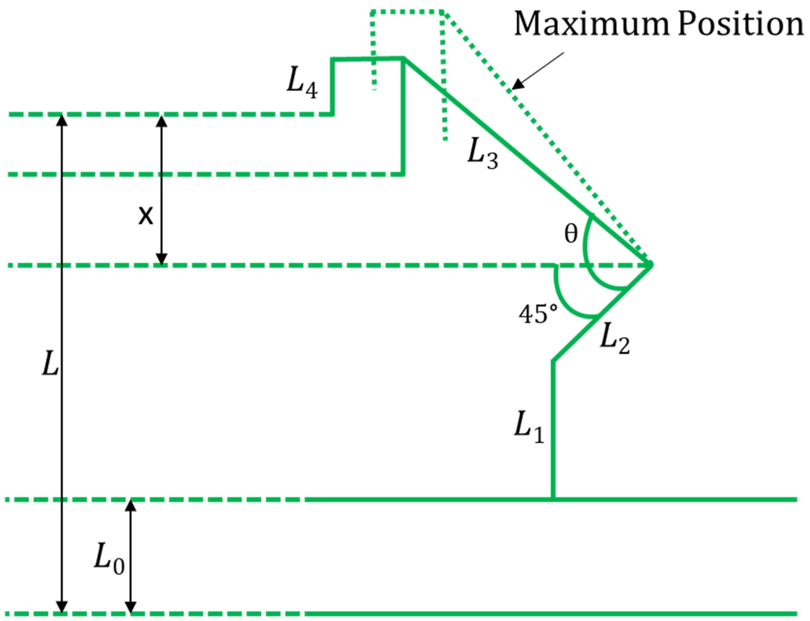


Figure 3: Line sketch of Robot with link 3 at random position

The Value of the x is calculated using below equation:

$$X = L - L_0 - L_1 - L_2 \sin 45°$$

By using X, we can calculate the value of the angle θ at any random position using below equation:

$$\theta = 45° + \sin^{-1}\left(\frac{L4 + L - L0 - L1 - L2 \sin 45°}{L3}\right)$$

The Gear Ratio for Motor B is given as 5 (40/8). For motor to move 1 degree, the correction factor is found to be 1.15. It is already included in the Gear Ratio (5*1.15).

Therefore, Arm Angle = Gear Ratio * 1.15 * θ.

Develop behaviours for homing, and picking and placing from/to stations with different heights. Note, the home point is the topmost position at station B. Include video proof for these.

- **Homing Behaviour**:
    - A function named home() is defined to get the robot from any working pose to its defined home pose. When the defined home function is called LEGO-EV3 robot moves to the centre position named as platform B. Based on the angle calculated by the encoder and the angle calculated by Invers-kinematics, the PID controller is used to control the speed for motor-C calculates the error and adjusts it to minimum error. of motor C. Then the arm link moves to its highest position until the mytouchsensor3 reads 1(True) after that gripper will be closed based on the speed given to Motor A.

- **Picking Behaviour**:
    - To pick the payload from the stations, a series of functions are performed. Once the robot reaches any particular station based on the movement () function given. At first, the claw_open() function is called. Later, Based on the station_height() functions the sonic-sensor reads the height of three stations(A, B, C). Moving forward, The invkin() function is invoked to perform inverse kinematics, which calculates the amount of angle the arm must be lowered to perform picking of the payload. Then the claw_close() function is performed to grasp the payload. Finally, The arm moves back to the highest position till the mytouchsensor3 reads 1(True).

- **Placing Behaviour**:
    - To perform the payload placing operation at a respective station, the place() function is implemented, which internally calls a series of functions to perform operations starting with arm_down() followed by claw_open(), arm_up() and ends with claw_close() functions.

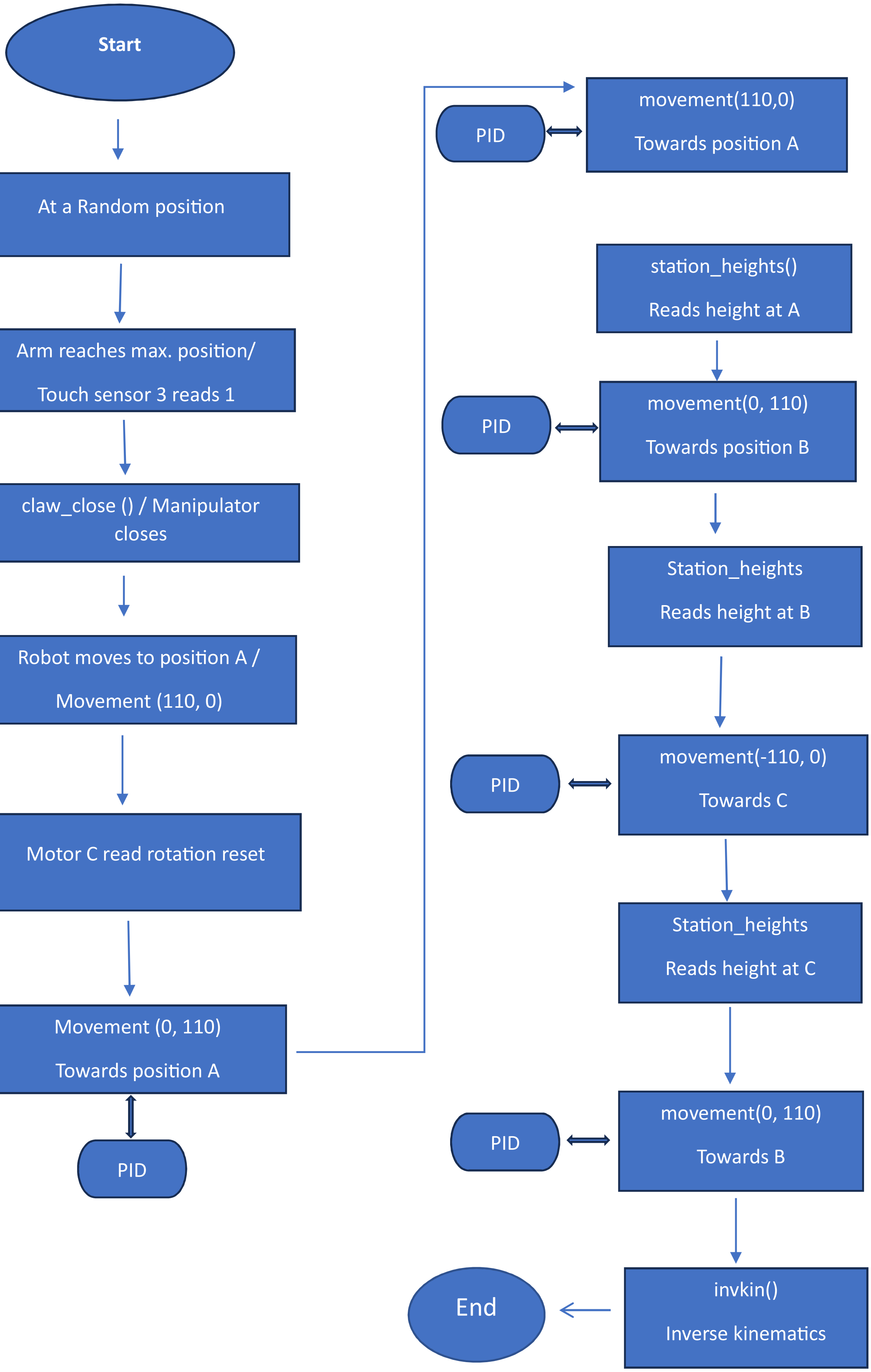
PID Tuning parameters for Motor_C:

K_P (Proportional)	K_I (Integral)	K_D (Derivative)	Remarks
0.25	0.5	0.03	Speed of the motor is drastically increased. Irregular operation.
0.25	0.1	0.03	Speed has been controlled but observed intermittent operation between picking and placing.
0.1	0.1	0.05	Slow performing of operations
0.1	0.1	0.01	Works as intended

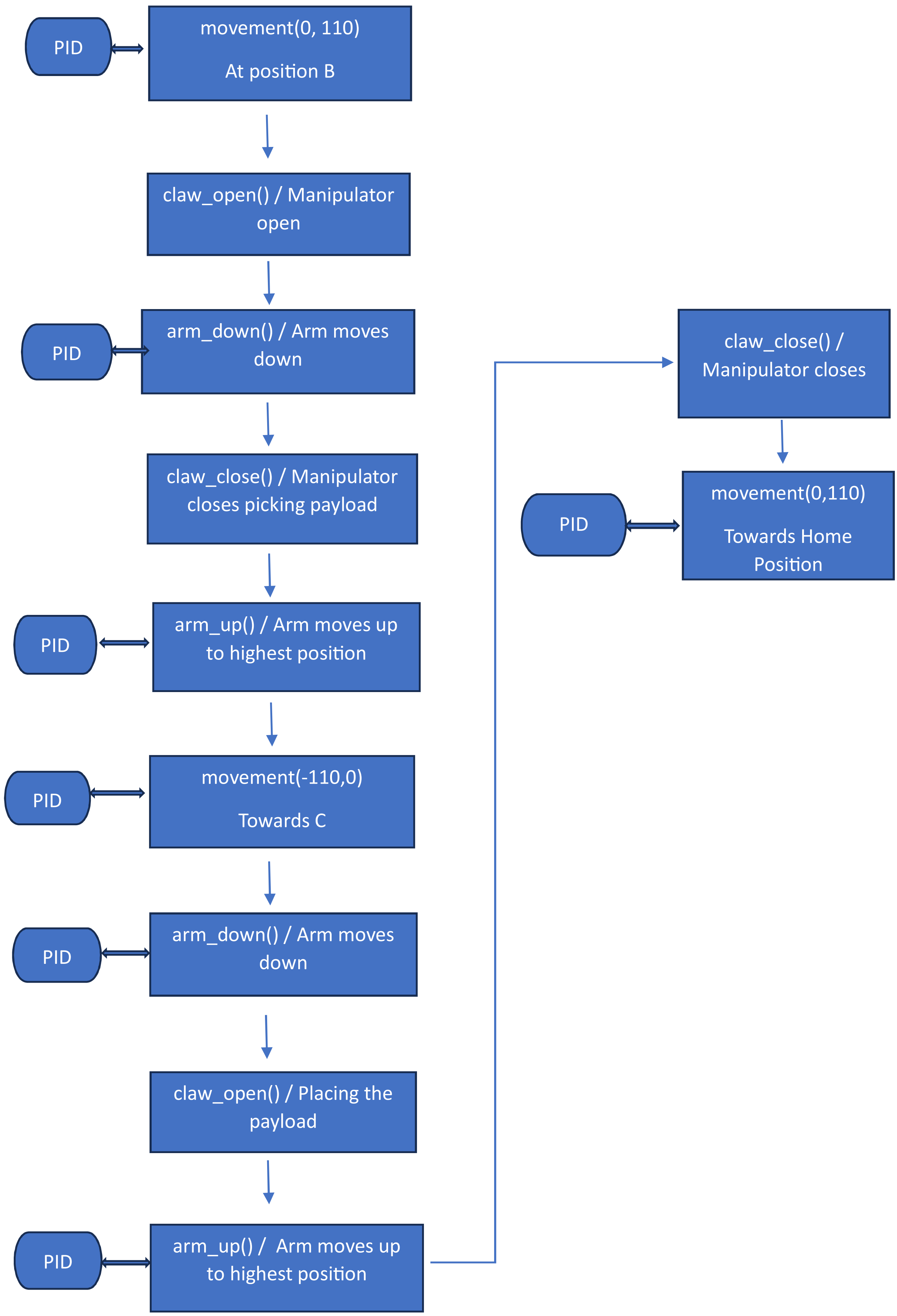
PID Tuning parameters for Motor_B:

K_P (Proportional)	K_I (Integral)	K_D (Derivative)	Remarks
0.3	0.3	0.5	Arm is giving irregular movement
0.5	0.5	0.5	Speed is drastically more and performs unevenly
0.5	0.15	0.45	Works as intended

Flow Chart showing the process of Homing:



Flow Chart showing the process of picking and placing of payload from B to C:



In the same way as explained above with flow chart, all the tasks (Station C to Station A, Station A to Station B, Station B to Station A, Station A to Station C, Station C to Station B) will follow the same steps. All the tasks will be performed in the sequential order as stated above.

Conclusion:

We have developed the behaviours for picking, placing and homing operations from one station to another station as per desired task using inverse kinematic model (equations) for this manipulator with the geometric approach. In the recorded video, all the tasks will be performed sequentially by measuring the station heights. We have recorded two videos by changing the station heights.