# Introduction to Robotics

## Lab 4a

Shaaf Farooque 08405, Mysha Zulfiqar 08443

**Task 4.1** Configurations Exploration (10 points)

Play around with the different modes of motion in the software and explore the capabilities and limitations of this arm.

(a) Move one joint at a time in Backhoe mode to get a sense of the motion of each joint.

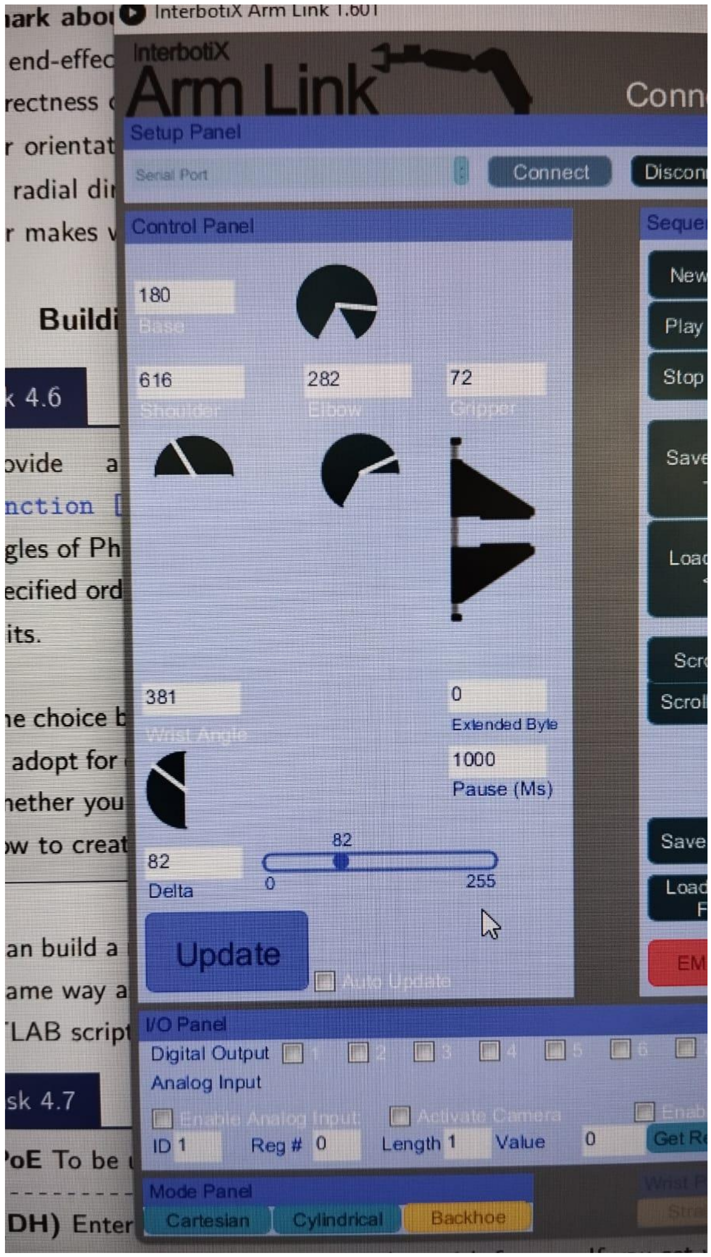
(b) In Cartesian mode, move the robot to an arbitrary $(x, y, z)$ location. Change the wrist angle from the panel and observe what happens to the other joints of the arm. Document your observations and comment on the reasons behind what you observe.

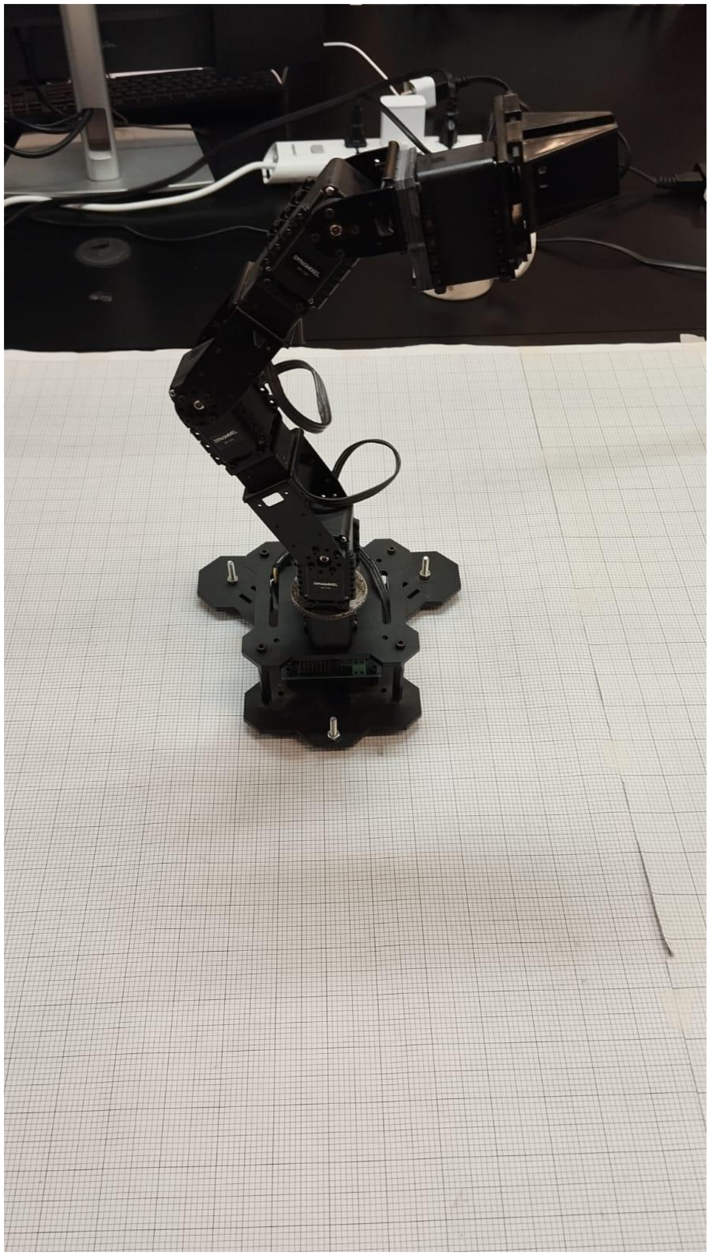
(c) From the Dynamixel reference manual (https://emanual.robotis.com/docs/en/dxl/ax/ax-12a/), find the angle rotation limits, resolution (see the definition below), speed limit, and torque limit[a] of AX-12A servo.

(d) [*] Will this motor resolution limit the possible Cartesian resolution of the end-effector? If yes, why?

[a] Note that the specifications provide the stall torque and is maximum torque the motor is capable of generating. This is the torque required to hold the load/weight connected to the motor shaft in position. For the same mass, you need torque greater than stall torque to move that mass, depending on required acceleration.

(a)


InterbotiX Arm Link 1.601
InterbotiX
Arm Link
Setup Panel
Serial Port
Connect
Control Panel
180
Base
616
Shoulder
282
Elbow
72
Gripper
381
Wrist Angle
0
Extended Byte
1000
Pause (Ms)
82
82
Delta
0
255
Update
Auto Update
I/O Panel
Digital Output
Analog Input
Enable Analog Input
Activate Camera
ID 1
Reg # 0
Length 1
Value
0
Mode Panel
Cartesian
Cylindrical
Backhoe
New
Play
Stop



(b) The x, y, and z coordinates define where the origin of the end effector will be. Changing the wrist angle requires all other joints to adjust their angles in such a way that the end effector frame's origin remains where it was but the wrist angle matches what is needed.

(c) Angle rotation limit: 0-300 degrees

Resolution: 0.29 degrees

Speed limit at no load: 59 [rev/min] (at 12V)

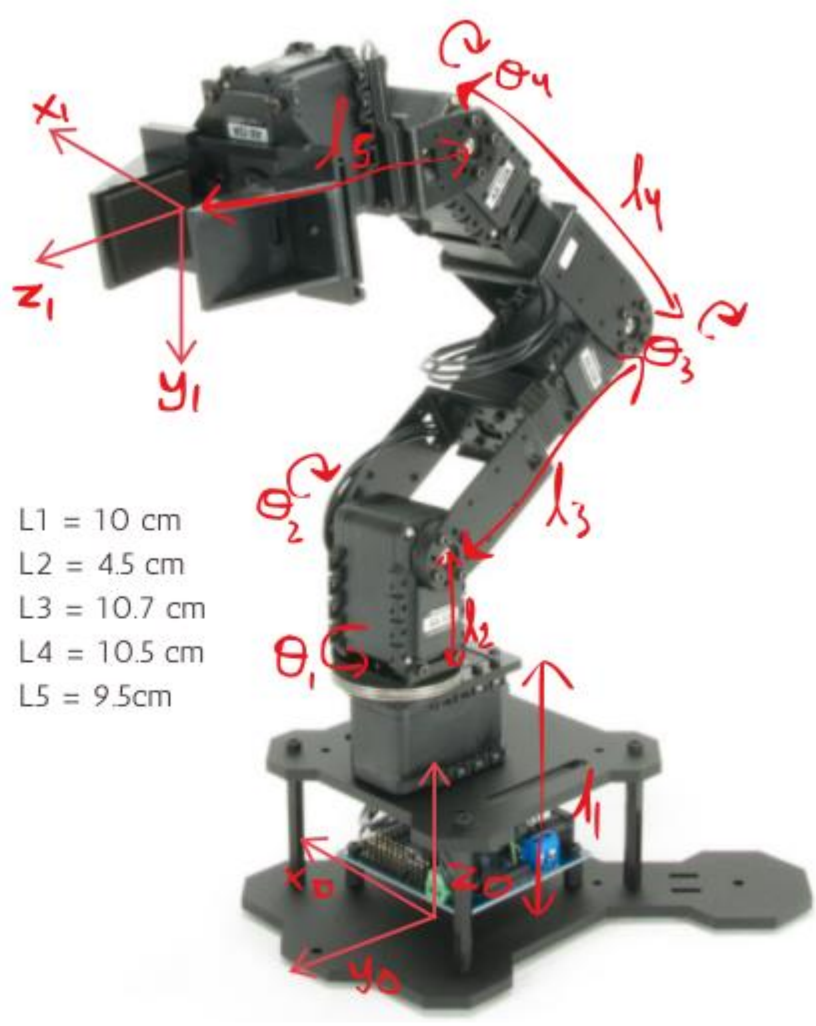
Torque limit: 1.5 Nm

(d) Since the AX-12A motor has a finite resolution (0.29° per step), it means that the joint angles cannot be adjusted continuously but only in discrete steps. This leads to discretization in Cartesian space.

Task 4.2 **Frame Assignment (10 points)**

*Common Instructions:* The base frame is to be assigned as follows: set the origin of the $x$ and $y$ axes at the center of the shaft of the first motor, and the origin of the $z$ axis at the level of the wooden baseboard. Place the origin of the end-effector frame at the center of gripper motor horn, for convenience of measurements in upcoming tasks.

**(PoE)** Assign fixed and end-effector frames to the robot arm in Figure 4.2, according to the instructions above. Draw and paste each frame's to the robot body at an appropriate location. This will help your visualization in later tasks.



## Task 4.3 Zero Configuration (15 points)

**(PoE)** Using MATLAB's connection to the arm determine the zero configuration of the arm and represent it as a homogeneous transformation, $M$. You'll have to physically measure the lengths. Also determine the positive direction of the axes of rotations and mark them on Figure 4.2.

M =

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & l_1 + l_2 + l_3 + l_4 + l_5 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Values of l1, l2, l3, l4, and l5 are shown in the frame assignment picture above.

## Task 4.4 Parameters (15 points)

**(PoE)** Determine the screw axes, $\mathcal{S}_i$, corresponding to each of the joints, $i$, of the robot arm, expressed in the base frame.

```
w1 = [0;0;1]
q1 = [0;0;l_1];
S1 = [w1;cross(-w1,q1)]
w2 = [1;0;0];
q2 = [0;0;l_2];
S2 = [w2;cross(-w2,q2)]
w3 = [1;0;0];
q3 = [0;0;l_3];
S3 = [w3;cross(-w3,q3)]
w4 = [1;0;0];
q4 = [0;0;l_4];
S4 = [w4;cross(-w4,q4)]
```

S1 = $\begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ S2 = $\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ l_2 \\ 0 \end{pmatrix}$ S3 = $\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ l_3 \\ 0 \end{pmatrix}$ S4 = $\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ l_4 \\ 0 \end{pmatrix}$