

# Assignment 01: Forward Kinematics and Visualization of a Planar Robotic Arm

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## Task 1: Position Calculations

The base of the robotic arm is fixed at the origin.

- **Base:**(0,0)

### Elbow Joint (x1,y1)

$$\begin{aligned}x_1 &= l_1 \cos(q_1) \\y_1 &= l_1 \sin(q_1)\end{aligned}$$

### End-Effector (x,y)(x, y)(x,y)

$$\begin{aligned}x &= l_1 \cos(q_1) + l_2 \cos(q_1 + q_2) \\y &= l_1 \sin(q_1) + l_2 \sin(q_1 + q_2)\end{aligned}$$

Configuration 1:  $q_1=0^\circ$ ,  $q_2=0$  (STRIAGHT ARM)

$$\begin{array}{ll}\text{Elbow Joint} & x_1 = 1 \cos(0^\circ) = 1 \\ & y_1 = 1 \sin(0^\circ) = 0 \\ \text{End-Effector} & x = 1 \cos(0^\circ) + 1 \cos(0^\circ) = 2 \\ & y = 1 \sin(0^\circ) + 1 \sin(0^\circ) = 0\end{array}$$

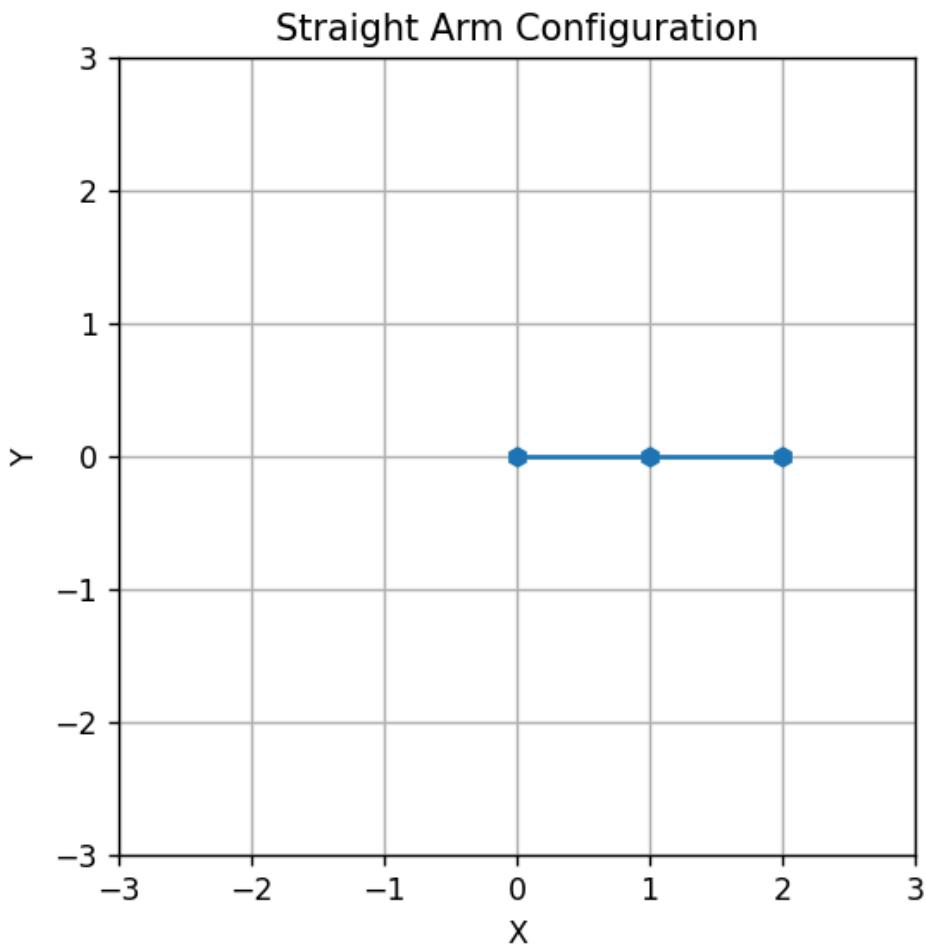
Configuration 2:  $q_1=45^\circ$ ,  $q_2=45$  (BENT ELBOW)

$$\begin{array}{ll}\text{Elbow Joint} & x_1 = 1 \cos(45^\circ) = 0.707 \\ & y_1 = 1 \sin(45^\circ) = 0.707 \\ \text{End-Effector} & x = 1 \cos(45^\circ) + 1 \cos(90^\circ) \quad \text{Here, } q_1+q_2=90 \\ & x = 0.707 + 0 = 0.707 \\ & y = 1 \sin(45^\circ) + 1 \sin(90^\circ) \\ & y = 0.707 + 1 = 1.707\end{array}$$

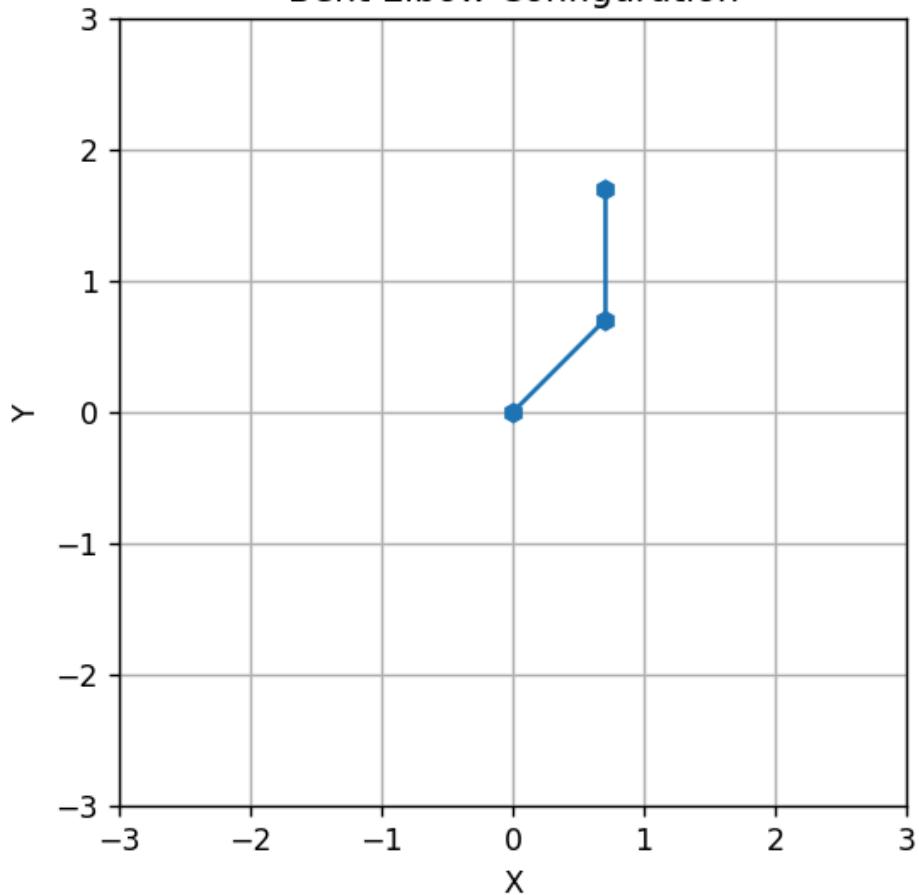
Configuration 3:  $q_1=45^\circ$ ,  $q_2=-90$  (FOLDED ARM)

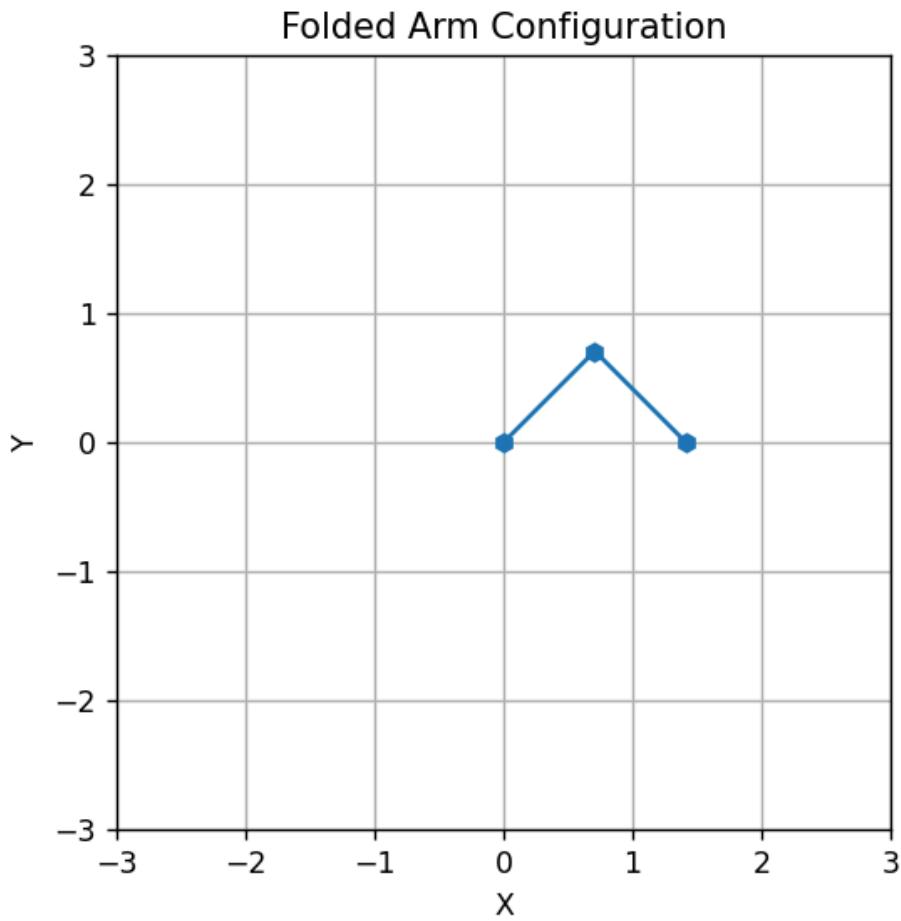
Elbow Joint	$x_1=1\cos(45^\circ)=0.707$	Here, $q_1+q_2=-45$
	$y_1=1\sin(45^\circ)=0.707$	
End-Effector	$x=1\cos(45^\circ)+1\cos(-45^\circ)$	
	$x=0.707+0.707=1.414$	
	$y=1\sin(45^\circ)+1\sin(-45^\circ)$	
	$y=0.707-0.707=0$	

## TASK 2:



Bent Elbow Configuration





## **Effect of Joint Angles on Arm Position and Workspace**

The joint angle  $q_{1q\_1q1}$  controls the orientation of the entire robotic arm with respect to the base. Changing  $q_{1q\_1q1}$  rotates both links together around the origin.

The joint angle  $q_{2q\_2q2}$  controls the relative angle between the two links. Changing  $q_{2q\_2q2}$  bends or folds the arm, directly affecting the distance and direction of the end-effector from the base.

By varying both  $q_{1q\_1q1}$  and  $q_{2q\_2q2}$ , the end-effector can reach a wide region in the plane. This reachable region is known as the workspace of the robotic arm.

## PYTHON SCRIPT:

```
import numpy as np
import matplotlib.pyplot as plt

l1 = 1
l2 = 1

def forward_kinematics(q1, q2):
    x_e = l1 * np.cos(q1)
    y_e = l1 * np.sin(q1)
    x_ee = x_e + l2 * np.cos(q1 + q2)
    y_ee = y_e + l2 * np.sin(q1 + q2)
    return (x_e, y_e), (x_ee, y_ee)

def plot_arm(q1, q2, title):
    elbow, ee = forward_kinematics(q1, q2)

    x_points = [0, elbow[0], ee[0]]
    y_points = [0, elbow[1], ee[1]]

    plt.figure()
    plt.plot(x_points, y_points, '-h')
    plt.xlim(-3, 3)
    plt.ylim(-3, 3)
    plt.xlabel("X")
    plt.ylabel("Y")
    plt.title(title)
    plt.grid(True)
    plt.gca().set_aspect('equal')
    plt.show()

q1 = 0
q2 = 0
plot_arm(q1, q2, "Straight Arm Configuration")

q1 = np.pi / 4
q2 = np.pi / 4
plot_arm(q1, q2, "Bent Elbow Configuration")

q1 = np.pi / 4
q2 = -np.pi / 2
plot_arm(q1, q2, "Folded Arm Configuration")
```

