Ain Shams University

Faculty of Engineering

Mechatronics Engineering Department

Industrial Robotics (MCT344s)

2-DOF robotic arm project

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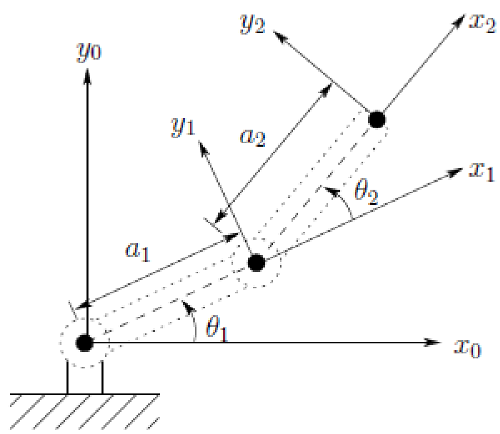
1. Project description



- A 2-Degree-of-Freedom (DoF) Robot Arm simulation is developed to give us more freedom to determine the robot movement so that the trial and error cycle can be avoided . Furthermore, the results of the simulation can be applied to SCARA robot for practical implementation.

- For a servo plotter to work, each motor must resist the torque from the opposite motor.

- An ideal servo should hold its position if it experiences an external torque ... in practice there is a slight movement or “dead-band” until the servo resists.

- Inverse kinematics requires complex mathematical analysis, especially in the higher degree of freedom (DoF). Taking an example of 2-DoF forward kinematics analysis depicted with a kinematic trigonometric diagram on figure 1. The equation to calculate the end effector point are given in equation 1 through equation 4

$$x_1 = L_1 \cos\theta_1 \tag{1}$$

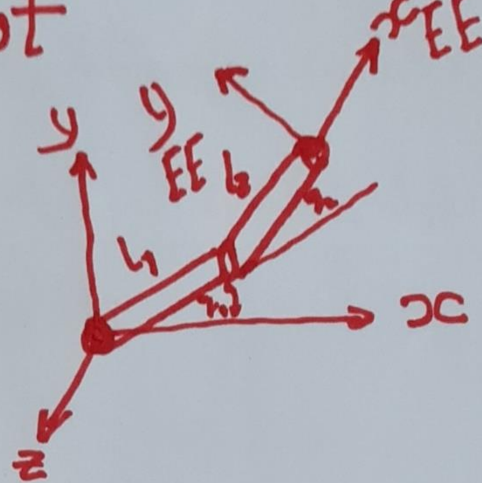
$$y_1 = L_1 \sin\theta_1 \tag{2}$$

$$x_2 = x_1 + L_2 \cos(\theta_1 + \theta_2) \tag{3}$$

$$y_2 = y_1 + L_2 \sin(\theta_1 + \theta_2) \tag{4}$$

2. Control analysis for equations

RR Robot



Fwd Pos.

$$x_{EE} = L_1 \cos q_1 + L_2 \cos(q_2+q_1)$$

$$y_{EE} = L_1 \sin q_1 + L_2 \sin(q_2+q_1)$$

Fwd velocity $\quad q_1 = \theta_1 \quad q_2 = \theta_2$

$$\dot{x}_{EE} = \frac{\partial x}{\partial q_1} * \frac{\partial q_1}{\partial t} + \frac{\partial x}{\partial q_2} * \frac{\partial q_2}{\partial t}$$

$$= [-L_1 \sin q_1 - L_2 \sin(q_1+q_2)]\, \dot{\theta}_1$$

$$[-L_2 \cos(q_1+q_2)] * \dot{\theta}_2$$

$$\dot{y}_{EE} = \frac{\partial y}{\partial q_1} * \frac{\partial q_1}{\partial t} + \frac{\partial y}{\partial q_2} * \frac{\partial q_2}{\partial t}$$

$$= [L_1 \cos q_1 + L_2 \cos(q_1+q_2)]\, \dot{q}_1 + \{L_2 \cos(q_1+q_2)\, \dot{q}_2$$

$$\begin{bmatrix} \dot{x}_{EE} \\ \dot{y}_{EE} \end{bmatrix} = \begin{bmatrix} -l_1 Sq_1 - l_2 S(q_1+q_2) & -l_2 C(q_1+q_2) \\ l_1 Cq_1 + l_2 C(q_1+q_2) & l_2 C(q_1+q_2) \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$$

Inv Velocity

$$\begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix} = J^{-1} \begin{bmatrix} \dot{x}_{EE} \\ \dot{y}_{EE} \end{bmatrix}$$

$$\begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix} = \frac{1}{|J|} * \begin{bmatrix} l_2 C(\theta_1+\theta_2) & l_2 C(\theta_1+\theta_2) \\ -l_1 C\theta_1 - l_2 C(\theta_1+\theta_2) & l_1 S\theta_1 + l_2 S(\theta_1+\theta_2) \end{bmatrix} \begin{bmatrix} \dot{x}_{EE} \\ \dot{y}_{EE} \end{bmatrix}$$

Fwd Acc

$$\dot{x}_{EE} = J\ddot{q} + \dot{J}\dot{q}$$

$$\begin{bmatrix} \dot{x}_{EE} \\ \dot{y}_{EE} \end{bmatrix} = J \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix} + \begin{bmatrix} -l_2 S(\theta_1+\theta_2)\dot{\theta}_1 - l_2 S(\theta_1+\theta_2)\dot{\theta}_2 \; \cdots \; l_2 S(\theta_1+\theta_2)[\dot{\theta}_1 + \dot{\theta}_2] \\ [-l_1 S\theta_1 + \tfrac{1}{2} S(\theta_1+\theta_2)]\dot{\theta}_1 + l_2 S(\theta_1+\theta_2)\dot{\theta}_2 \; \cdots \; l_1 C\theta_1 + l_2 C(\theta_1+\theta_2)\dot{\theta}_1 + l_2 C(\theta_1+\theta_2)\dot{\theta}_2 \end{bmatrix} * \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$$

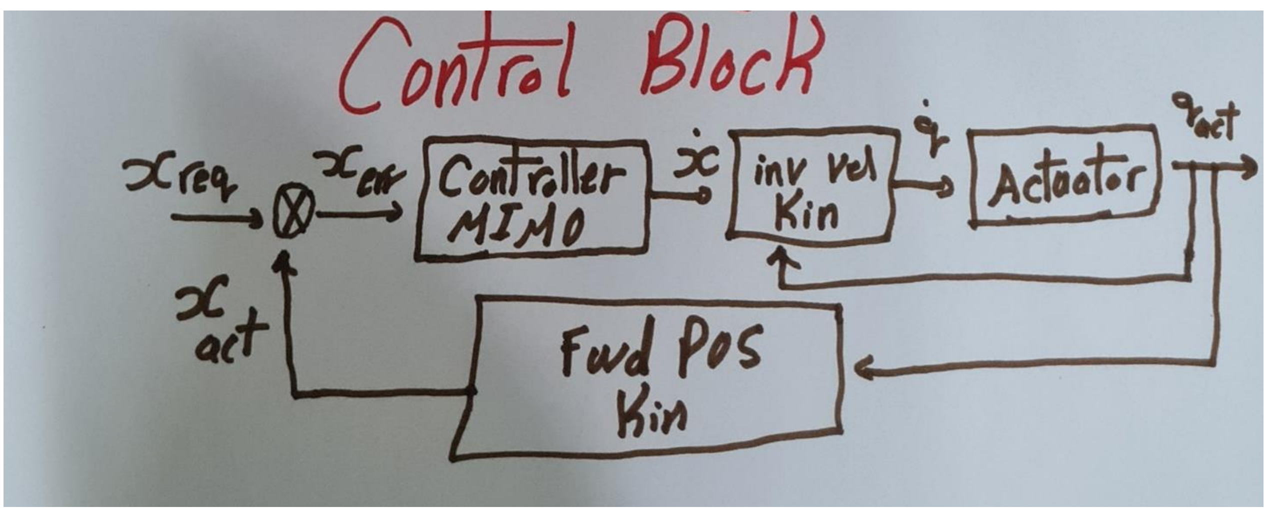
Inv Acc

$$\ddot{x}_{EE} = J\ddot{q} + \dot{J}\dot{q}$$

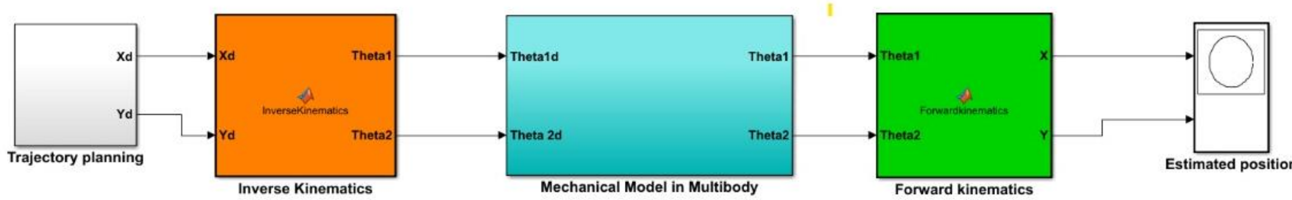
$$\Longrightarrow \ddot{q} = J^{-1}\left[\ddot{x}_{EE} - \dot{J}\dot{q}\right]$$

$$\begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix} = \frac{1}{|J|} \begin{bmatrix} L_2 C(\theta_1+\theta_2) & L_2 C(\theta_1+\theta_2) \\ -L_1 C\theta_1 - L_2 C(\theta_1+\theta_2) & L_1 S\theta_1 + L_2 S(\theta_1+\theta_2) \end{bmatrix} * \left(\begin{bmatrix} \ddot{x}_{EE} \\ \ddot{y}_{EE} \end{bmatrix} - \dot{J} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix} \right)$$

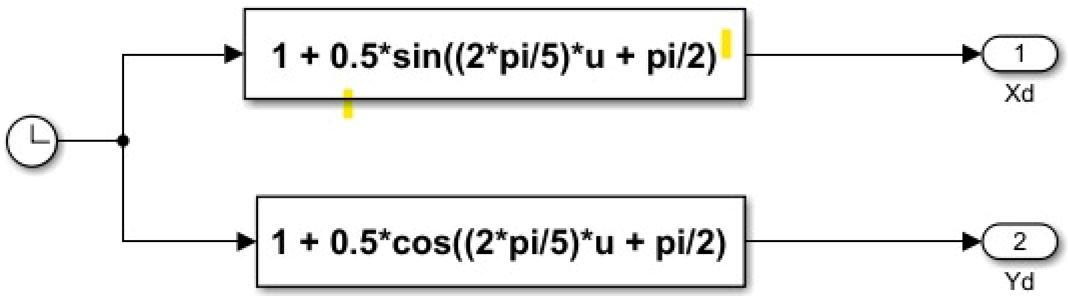
3. The Control Block Diagram :



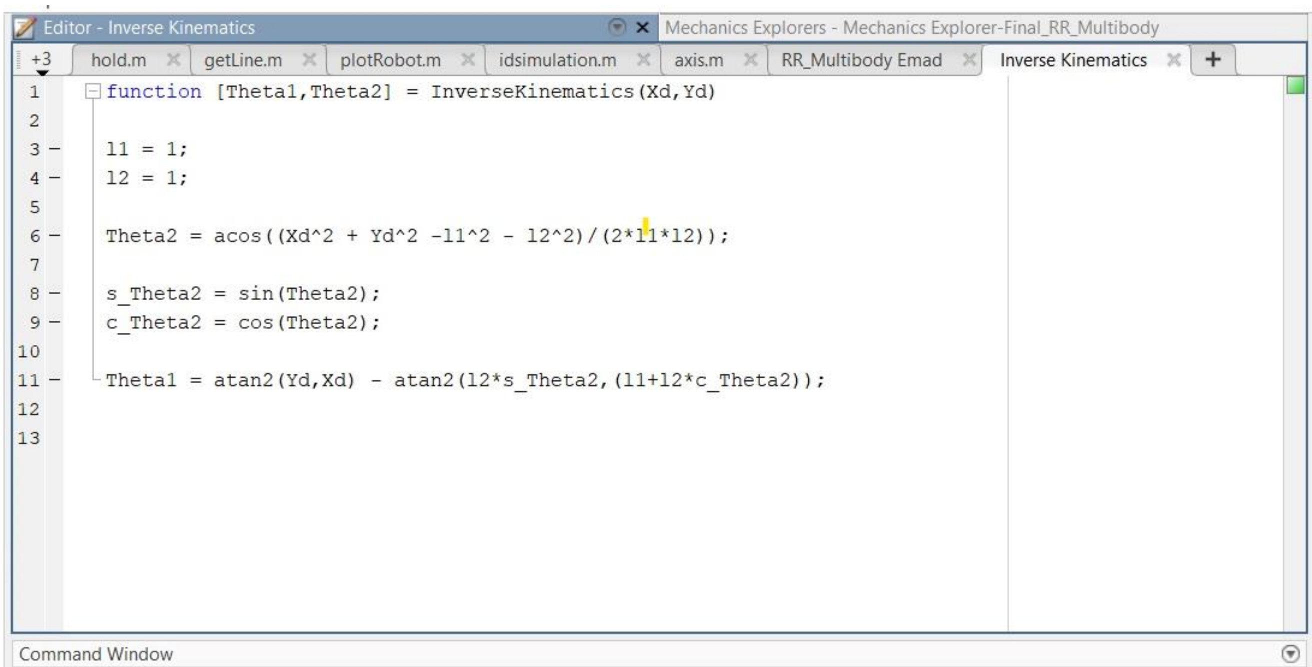
4. MATLAB Simulation



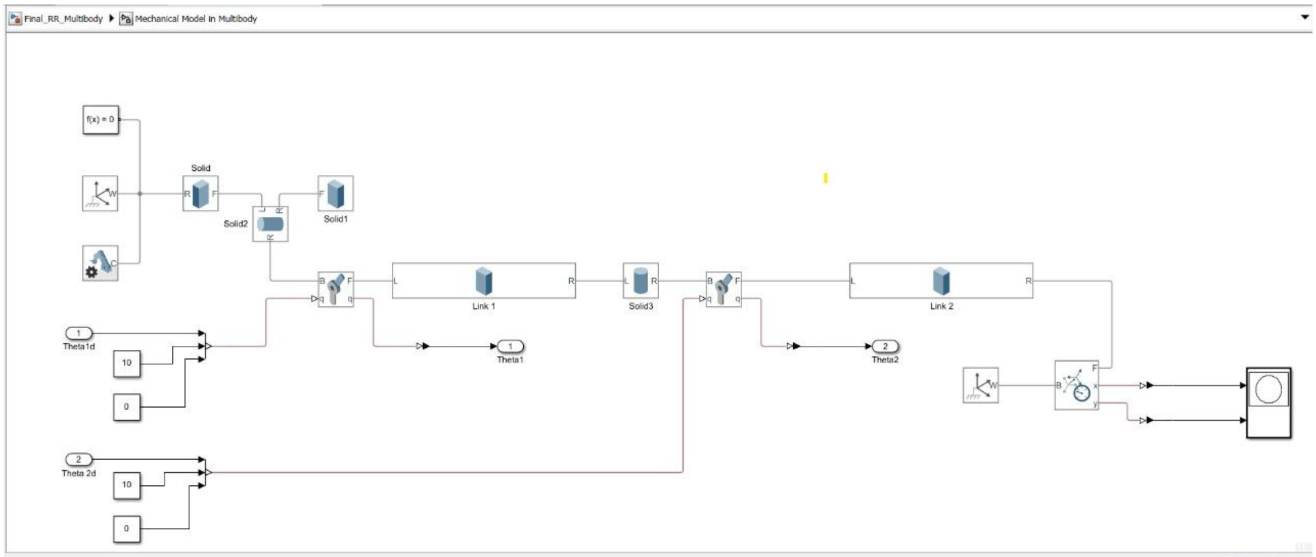
4.1 Trajectory planning



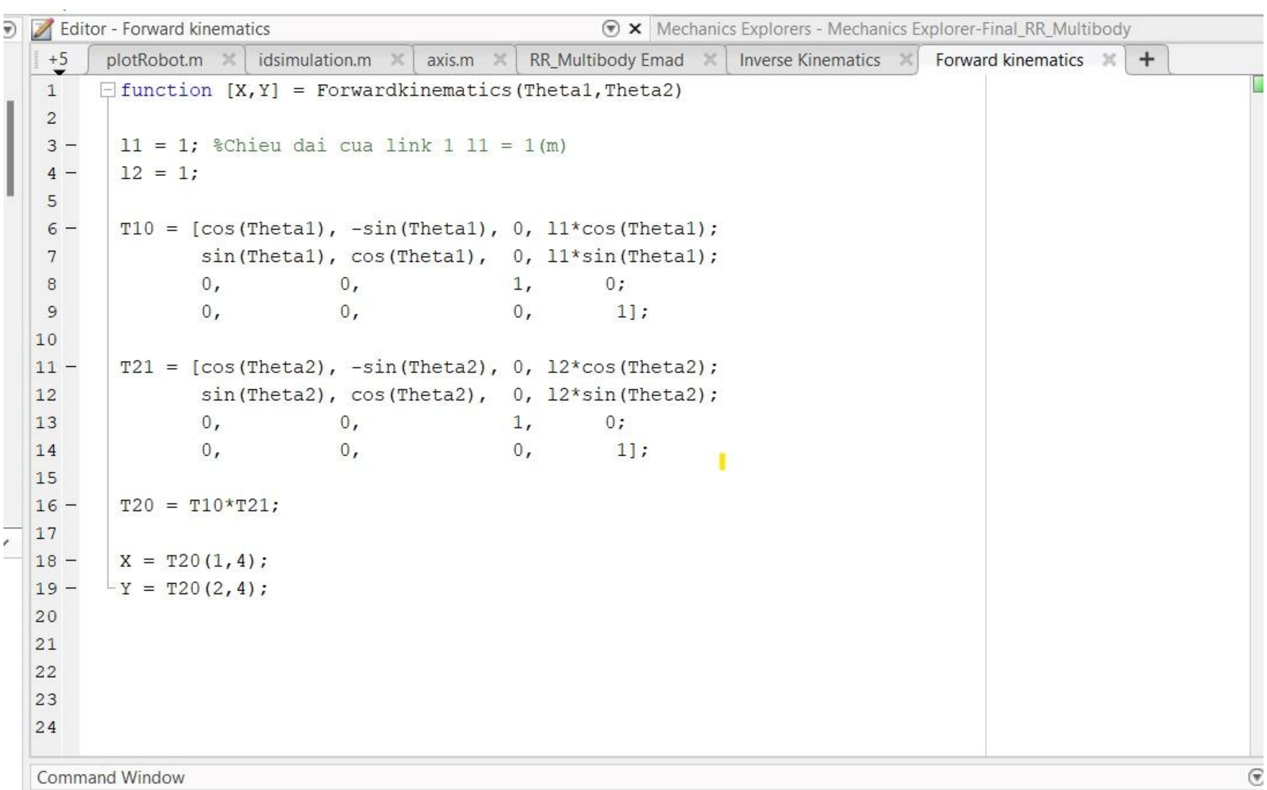
4.2 Inverse Kinematics



4.3 Mechanical model in multibody

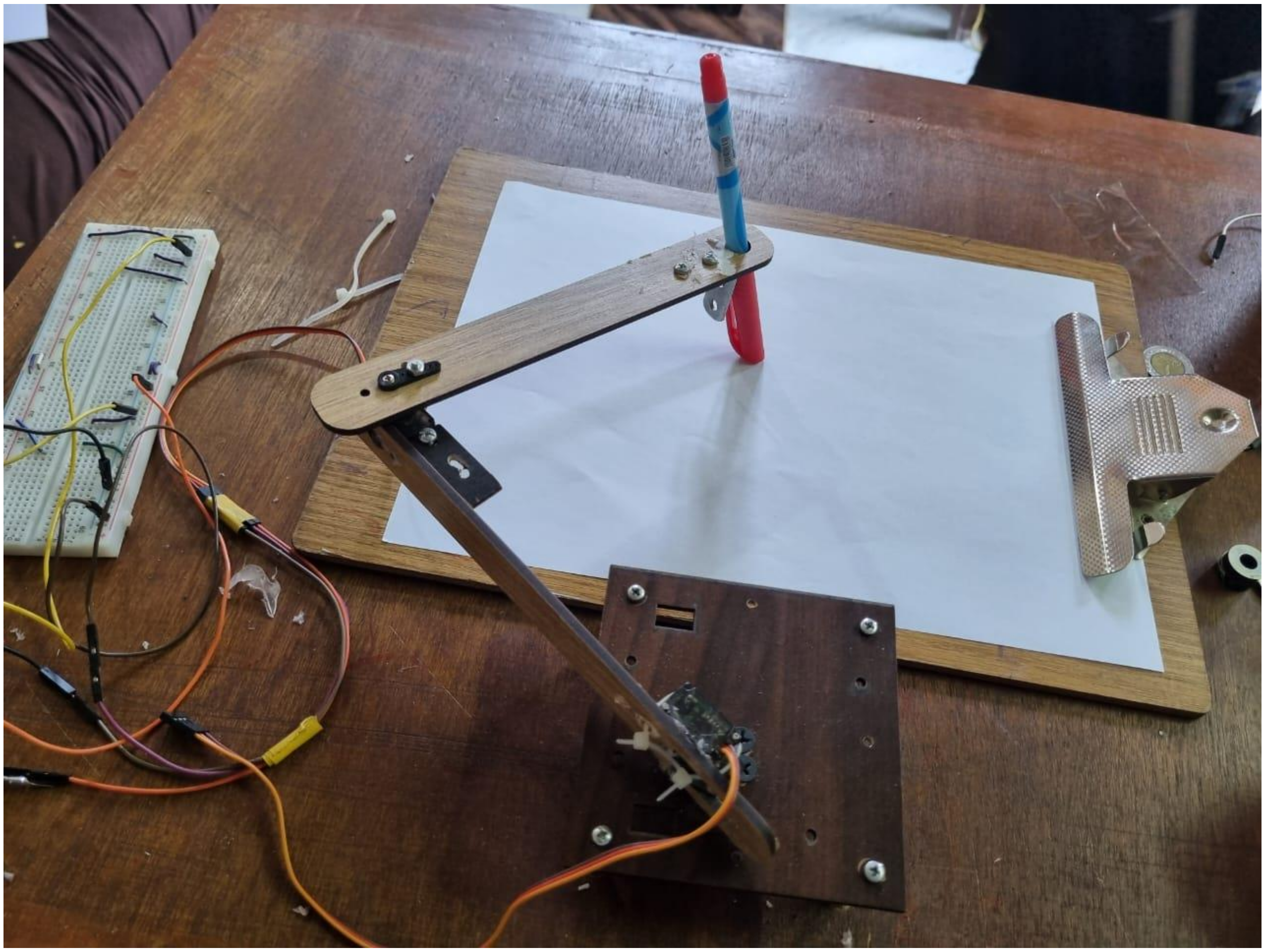


4.4 Forward Kinematics

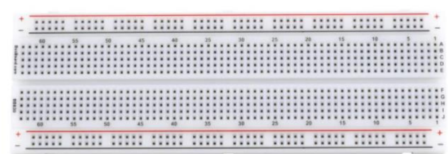
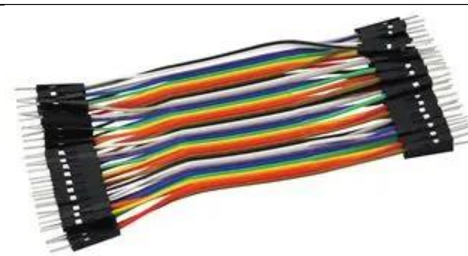



```
function [X,Y] = Forwardkinematics(Theta1,Theta2)

l1 = 1; %Chieu dai cua link 1 l1 = 1(m)
l2 = 1;

T10 = [cos(Theta1), -sin(Theta1), 0, l1*cos(Theta1);
       sin(Theta1), cos(Theta1),  0, l1*sin(Theta1);
       0,           0,            1,      0;
       0,           0,            0,       1];

T21 = [cos(Theta2), -sin(Theta2), 0, l2*cos(Theta2);
       sin(Theta2), cos(Theta2),  0, l2*sin(Theta2);
       0,           0,            1,      0;
       0,           0,            0,       1];

T20 = T10*T21;

X = T20(1,4);
Y = T20(2,4);
```

5. Overall real hardware system picture



6. Components

Name & Its Function	Picture
1 .Arduino uno : is able to read inputs and turn it into an output	
2. Servo motors : it transmits the rotation movement by angle	
3. Breadboard : allows for easy and quick creation of temporary electronic circuits or to carry out experiments with circuit design.	
4. Links : Two 100-mm links used to transmit the rotation movement of motors into writing commands by connecting between them	
5. Wires : used to create the circuit of the system and connect the components with each other	

7. Reference

https://www.instructables.com/Servo-Plotter/