Objective:

The objective of the project is to find out the forward and inverse kinematics of an industrial robot using MATLAB

Robot Selection:

The industrial robot chosen for this purpose was the ***"Schunk Powerball Light Weight Arm 4-P"***. This robot has 6 degree of freedom with all joints being revolute. The research paper used to gather the relevant data is "***Robotic Arm Calibration and Control 6-DOF Powerball LWA 4P***" by Curtis Bradley.

The DH parameters of the robotic arm are as follows:

Joint Axis	θ_{offset}	d	a	α
1	0	$0.205m$	0	$-\frac{\pi}{2}$
2	$-\frac{\pi}{2}$	0	$0.350m$	π
3	$-\frac{\pi}{2}$	0	0	$-\frac{\pi}{2}$
4	0	$0.305m$	0	$\frac{\pi}{2}$
5	0	0	0	$-\frac{\pi}{2}$
6	0	$0.075m$	0	0

Forward Kinematics:

The forward kinematics of the robotic arm can be evaluated using the DH parameters and using the homogeneous transformation matrix shown below:

$$
{}^{i-1}T_i = \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & \sin\theta_i\sin\alpha_i & a_i\cos\theta_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & -\cos\theta_i\sin\alpha_i & a_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

Using this method, the transformation matrix of each link is calculated. The final transformation matrix obtained after multiplication of these matrixes results in the forward kinematics matrix.

$$
{}^{0}T_6 = {}^{0}T_1\,{}^{1}T_2\,{}^{2}T_3\,{}^{3}T_4\,{}^{4}T_5\,{}^{5}T_6
$$

Inverse Kinematics:

The inverse kinematics were calculated using the transformation matrix obtained above. The algebraic approach was used for this purpose. Some of the formulae obtained are shown below:

$$
d_{elbow} = {}^{0}T_6(1:3,4) - dx - \begin{bmatrix} 0 \\ 0 \\ d_1 \end{bmatrix}
$$

$$
\theta_3 = \pm\left(\pi - \arccos\frac{a_2^2 + d_4^2 - |d_{elbow}|^2}{2 * a_2 * d_4}\right)
$$

$$
\text{axis } k_1 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \quad \text{axis } k_2 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \quad \vec{p} = \begin{bmatrix} 0 \\ 0 \\ a_2 \end{bmatrix} + \begin{bmatrix} -d_4\sin\theta_3 \\ 0 \\ d_4\cos\theta_3 \end{bmatrix}, \quad \vec{q} = \overrightarrow{d_{elbow}}.
$$

MATLAB OUTPUT:

- The transformation matrix output for various joint angles

```
Command Window
creating new robot
Current plot held
Warning: Stretch-to-fill scaling not supported;
use DASPECT or PBASPECT before calling ARROW3.
> In arrow3 at 377
  In trplot at 232
  In SerialLink.plot>create_robot at 443
  In SerialLink.plot at 247
  In forwardkinematics at 39

ans =

    1.0000         0         0    0.3500
         0    1.0000         0         0
         0         0    1.0000    0.5850
         0         0         0    1.0000


ans =

    0.8083   -0.4416    0.3894    0.4704
    0.4794    0.8776    0.0000    0.0000
   -0.3417    0.1867    0.9211    0.4187
         0         0         0    1.0000

>>
```

- Inverse kinematics numerical method iterations

0.0031	-0.0026	0.0011	0.0000	0.0025	1.7876
-0.0031	-0.0025	0.0011	-0.0000	0.0027	1.7624
-0.0031	-0.0024	0.0011	-0.0000	0.0028	1.7373
-0.0031	0.0019	0.0021	-0.5246	0.0002	0.9927
-0.0031	0.0020	0.0021	-0.4995	0.0001	0.9676
0.0031	0.0021	0.0022	-0.4744	0.0000	0.9425
-0.0031	0.0022	0.0022	-0.4492	-0.0000	0.9173
0.0031	0.0023	0.0023	-0.4241	-0.0001	0.8922
0.0031	0.0024	0.0023	-0.3990	-0.0001	0.8671
0.0031	0.0025	0.0024	-0.3738	-0.0001	0.8419
-0.0031	0.0025	0.0024	-0.3487	-0.0001	0.8168
-0.0031	0.0026	0.0025	-0.3236	-0.0001	0.7917
-0.0031	0.0027	0.0026	-0.3047	-0.0001	0.7728
-0.0031	0.0027	0.0026	-0.2859	-0.0001	0.7540
-0.0031	0.0028	0.0027	-0.2670	-0.0001	0.7351
-0.0031	0.0028	0.0028	-0.2482	-0.0001	0.7163
-0.0031	0.0029	0.0028	-0.2293	-0.0000	0.6974
-0.0031	0.0029	0.0029	-0.2105	-0.0000	0.6786
0.0031	0.0030	0.0030	-0.1916	0.0000	0.6597
-0.0031	0.0030	0.0030	-0.1728	0.0000	0.6409
-0.0031	0.0030	0.0031	-0.1539	0.0000	0.6220
-0.0031	-0.0018	0.0000	-0.0031	0.0018	-0.0000
-0.0031	-0.0018	-0.0000	-0.0031	0.0018	-0.0000
-0.0031	-0.0018	-0.0001	-0.0031	0.0017	-0.0000
-0.0031	-0.0018	-0.0001	-0.0031	0.0017	-0.0000
-0.0031	-0.0018	-0.0001	-0.0031	0.0017	-0.0000
-0.0031	-0.0018	-0.0002	-0.0031	0.0017	-0.0000
0.0031	-0.0018	-0.0002	0.0031	0.0016	0.0000
0.0031	-0.0018	-0.0002	0.0031	0.0016	0.0000
-0.0031	-0.0031	-0.0029	-2.1834	0.0002	-2.1174
-0.0031	-0.0031	-0.0029	-2.1708	0.0002	-2.1049

PLOT OF ROBOTIC ARM: