Cairo University
Faculty of Engineering

Computer Engineering
Frist Year

SCARA Robot 800

Dr. Mohamed El Gamil

1.Menna Allah Ahmed Ali

2. Radwa Ahmed Mohamed Kamel

3.Reem Emad Ramadan

4. Esraa Gamal Saad Ahmed

5. Basant Abd-Elazim Mohammed

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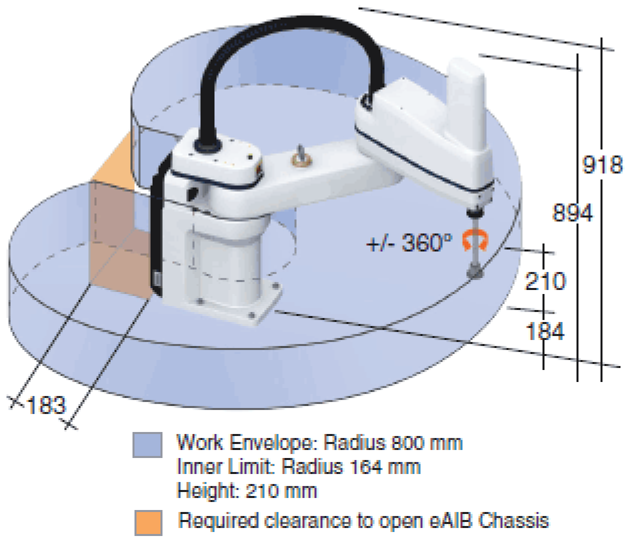
SCARA Robot (eCobra 800 Lite)

Specifications:

Product name		**eCobra**		
	Size	**800**		
	Type	**800 Lite**		
	Cleanroom/IP	**Standard**	**Cleanroom**	**IP65**
Part Number		17010-18000	17010-18010	17010-18030
Number of axes		4		
Mounting		table/floor		
Reach		800 mm		
Maximum Payload		5.5 kg		
Repeatability	**XY**	±0.017 mm		
	Z	±0.003 mm		
	Theta	±0.019°		
Joint Range	**Joint 1**	±105°		
	Joint 2	±157.5°		

	Joint 3	210 mm		
	Joint 4	±360°		
Inertia Moment (Max.)	**Joint 4**	450 kg-cm^2		
Joint Speeds	**Joint 1**	386°/s		
	Joint 2	720°/s		
	Joint 3	1100 mm/s		
	Joint 4	1200°/s		
Cycle times (Payload 2.0 kg)	**Burst**	0.73 s		
	Sustained	0.73 s		
Power Requirements		24 VDC: 6 A 200 to 240 VAC: 10 A, single-phase		
Protection		IP20	IP20	IP65
Clean Class		---	Class 10	---
Environment Requirements	**Ambient Temperature**	5 to 40°C		
	Humidity Range	5 to 90% (non-condensing)		
Weight		43 kg		
Basic configuration	**Controller**	eAIB		
	On-board I/O (Input/Output)	12/8, 4 Solenoid Output		
	Conveyor tracking input	No		
	RS-232C serial communications port	No		
	Programming environment	ACE		
	ACE Sight	No *2		
	ePLC Connect	No		
	ePLC I/O	No		
Connectable controller		No		

Dimensions:



Motion Type: RRPR

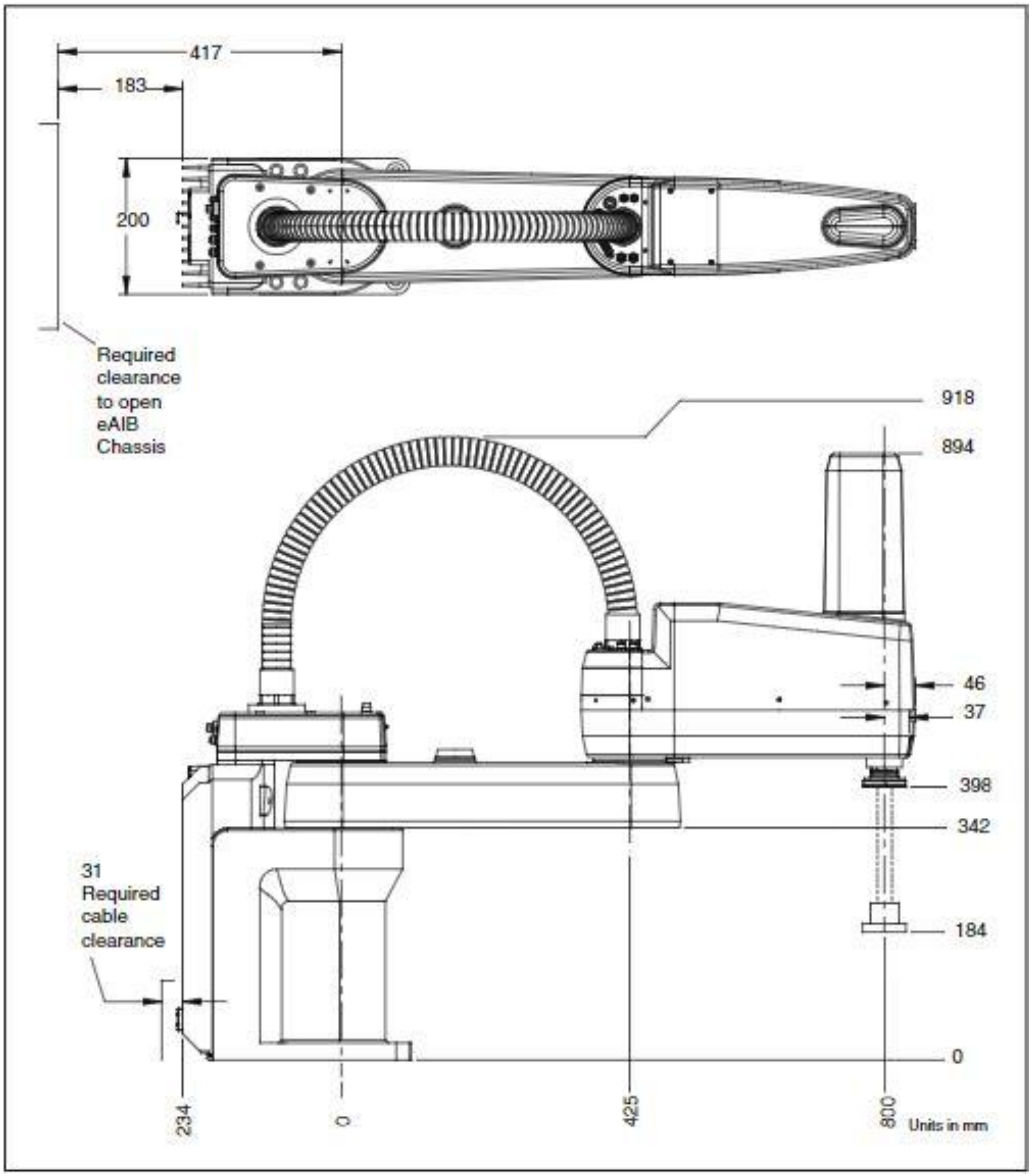
Links: 3 Links, 4 including the base

- Link1 (L1) The Base
- Link2 (L2) 450 mm
- Link3 (L3) 350 mm
- Link4 (L4)

Joints: 4 joints

- Joint1 (J1) motion type: R [ranges (±105^{O})]
- Joint2 (J2) motion type: R [ranges (±157.5^{O})]
- Joint3 (J3) motion type: P [ranges (210 mm)]
- Joint4 (EE) end-effector; Gripper [ranges (±360^{O})]

eCobra 800 Robot Top and Side Dimensions:



About the Program:

A MATLAB file is attached with the report, calculating the end effector position and orientation with DH convention, also provides animation of the robot Kinematic diagram movements, Robot arm simulation and animation of workspace.

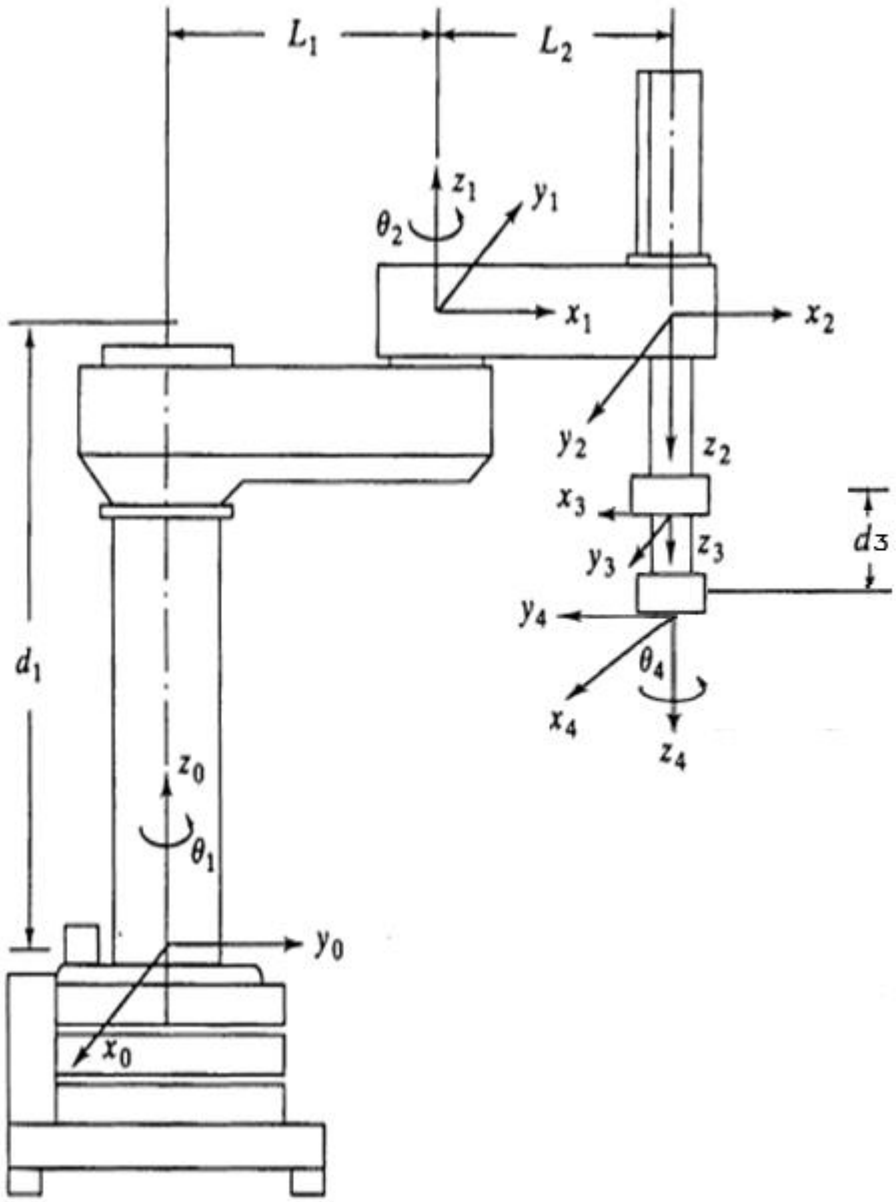
To know the position of the end effector at a certain moment you need to enter (theta1 which is the angular position of the joint1 (J1)), (theta2 which is the angular position of the joint2 (J2)), (theta4 which is the angular position of the end effector [the angle that the end effector is rotated with]) and (d3) which is the distance the end effector moved [joint3 is P type, it moves vertically, so d3 is the distance which joint3 makes the link3 move by and it should be positive value]

The function that makes this calculations is called [Calc_PosAndOren_Of_EE], its inputs are: theta1, theta2, theta4, d3, the output of the DH convention is a 4x4 matrix represents the position of the EE (end effector) [the fourth column], and a rotation matrix of EE [3x3 matrix starts with the first row and column]

$$T_4^0 = \begin{matrix} \cos(\theta_1+\theta_2-\theta_4) & -\sin(\theta_1+\theta_2-\theta_4) & 0 & a_1 cos\theta_1 + a_2\cos(\theta_1+\theta_2) \\ \sin(\theta_1+\theta_2-\theta_4) & \cos(\theta_1+\theta_2-\theta_4) & 0 & a_1\sin(\theta_1) + a_2\sin(\theta_1+\theta_2) \\ 0 & 0 & -1 & d-d_3 \\ 0 & 0 & 0 & 1 \end{matrix}$$

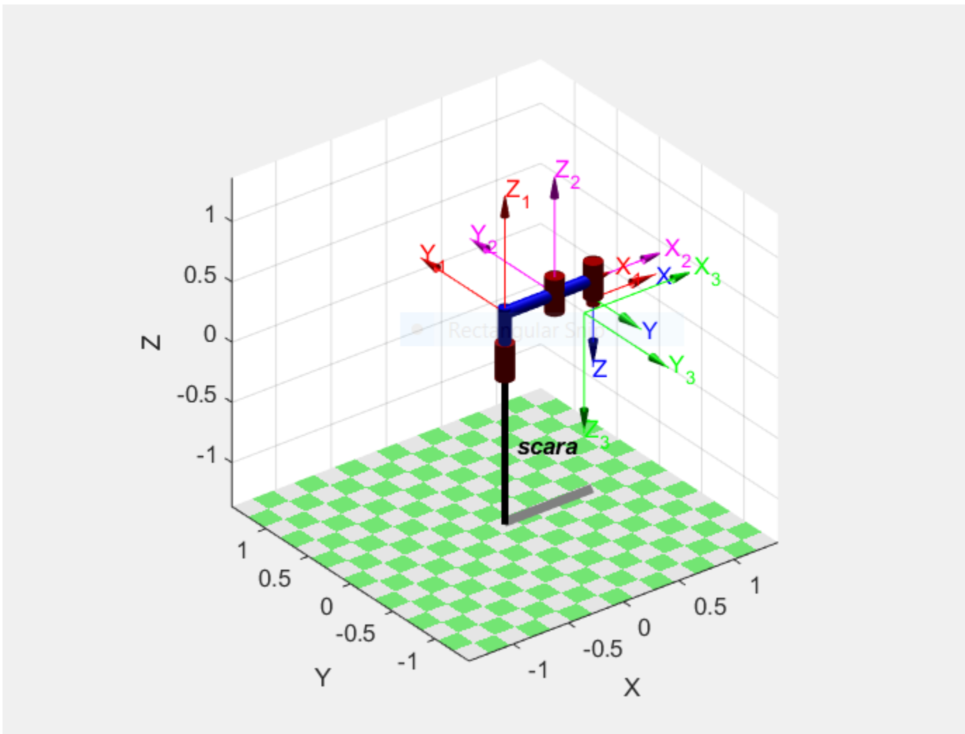
Where d is the height of the base, since we calculate the position of the EE relative to the base not to the first joint. And d3 as we mentioned before is the distance which Link3 moved vertically.

Kinematic diagram of the Robot

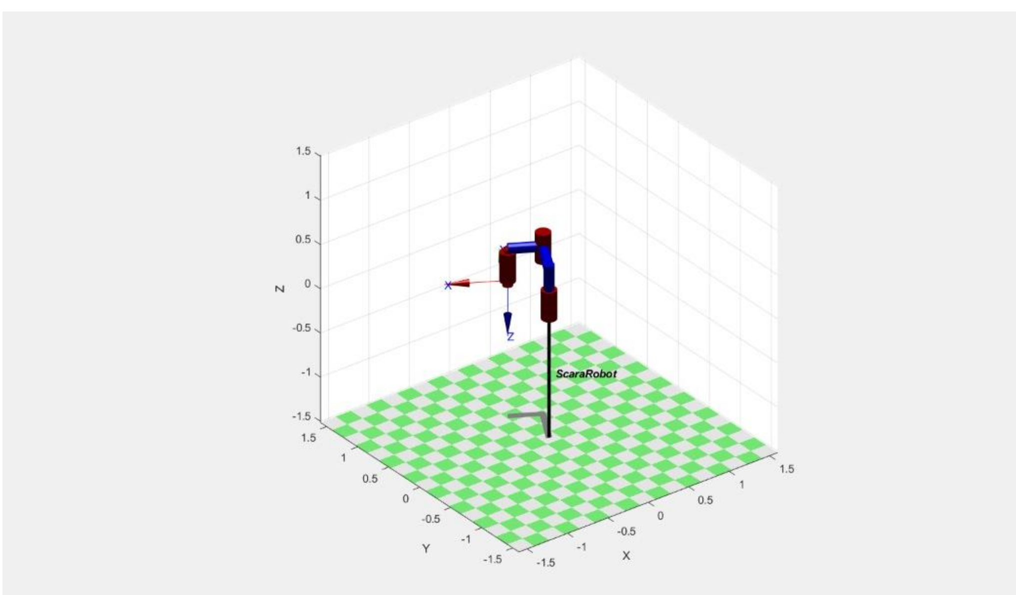


Animations and Simulations captured from the Program:

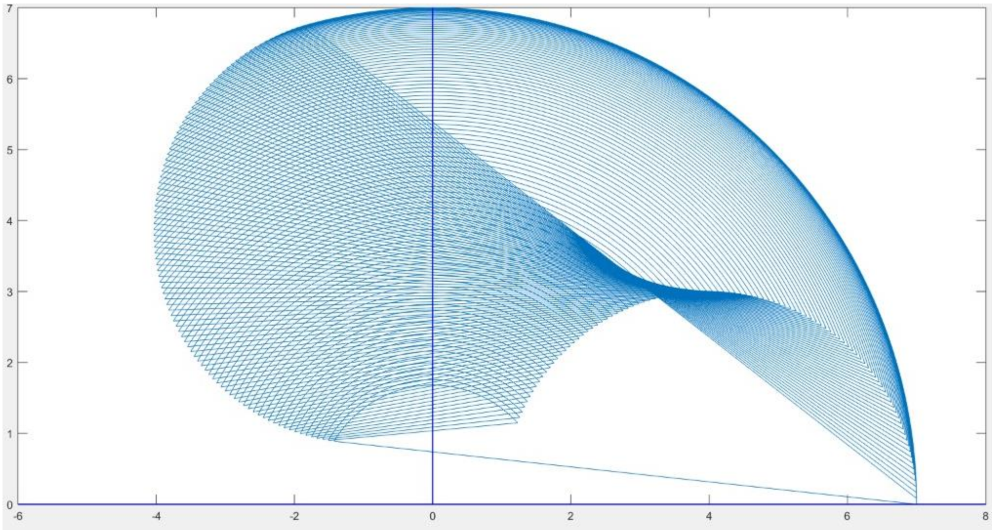
- Kinematic diagram:



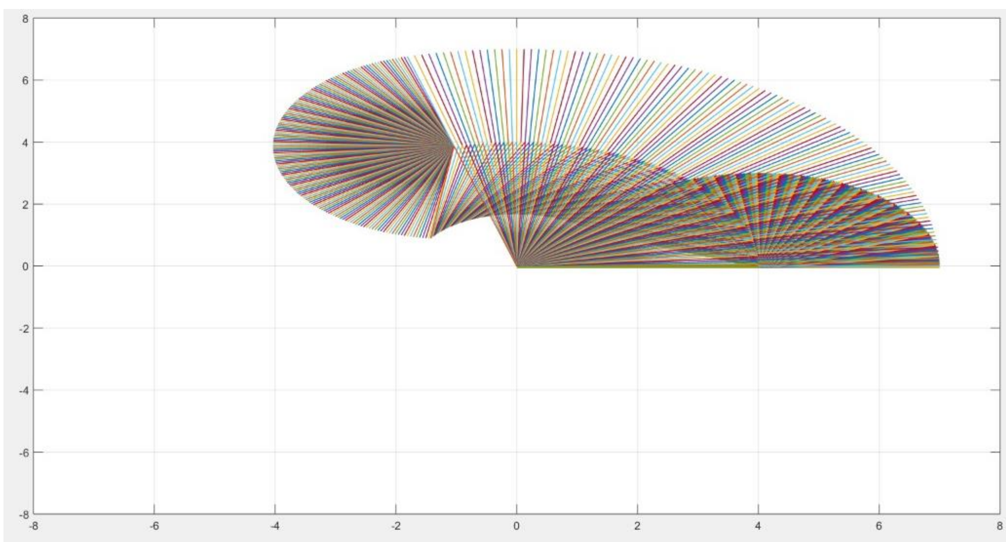
- SCARA Arm animation:



- Workspace:



- Workspace animation:



DH Convention for Robots:

The general format for the matrix for a single joint is:

$$T_i^{i-1} = \begin{matrix} cos\theta_i & -sin\theta_i * cos\alpha_i & sin\theta_i * sin\alpha_i & r_i * cos\theta_i \\ sin\theta_i & cos\theta_i * cos\alpha_i & -cos\theta_i * sin\alpha_i & r_i * sin\theta_i \\ 0 & sin\alpha_i & cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{matrix}$$

And for a SCARA 800 robot, the DH parameters are described in the following table:

joints	$d_i(mm)$	$a_{i-1}(mm)$	$\alpha_{i-1}(°)$	$\theta_i(°)$
1	d_1	L_1	0	θ_1
2	0	L_2	180	θ_2
3	-d_3	0	0	0
4	0	0	0	θ_4

So

$$T_1^0 = \begin{matrix} cos\theta_1 & -sin\theta_1 & 0 & L_1 * cos\theta_1 \\ sin\theta_1 & cos\theta_1 & 0 & L_1 * sin\theta_1 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{matrix}$$

$$T_2^1 = \begin{matrix} cos\theta_2 & -sin\theta_2 & 0 & L_2 * cos\theta_2 \\ sin\theta_2 & cos\theta_2 & 0 & L_2 * sin\theta_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

$$T_3^2 = \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & -d_3 \\ 0 & 0 & 0 & 1 \end{matrix} \quad , \quad T_4^3 = \begin{matrix} cos\theta_4 & -sin\theta_4 & 0 & 0 \\ sin\theta_4 & cos\theta_4 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

So the final matrix of the end-effector will be as mentioned before:

$$T_4^0 = T_1^0 * T_2^1 * T_3^2 * T_4^3 =$$

$$\begin{matrix} \cos(\theta_1 + \theta_2 - \theta_4) & -\sin(\theta_1 + \theta_2 - \theta_4) & 0 & L_1 cos\theta_1 + L_2 \cos(\theta_1 + \theta_2) \\ \sin(\theta_1 + \theta_2 - \theta_4) & \cos(\theta_1 + \theta_2 - \theta_4) & 0 & L_1 \sin(\theta_1) + L_2 \sin(\theta_1 + \theta_2) \\ 0 & 0 & -1 & d - d_3 \\ 0 & 0 & 0 & 1 \end{matrix}$$

$$= \begin{matrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{matrix}$$

where the robot end-effector position is (p_x, p_y, p_z)

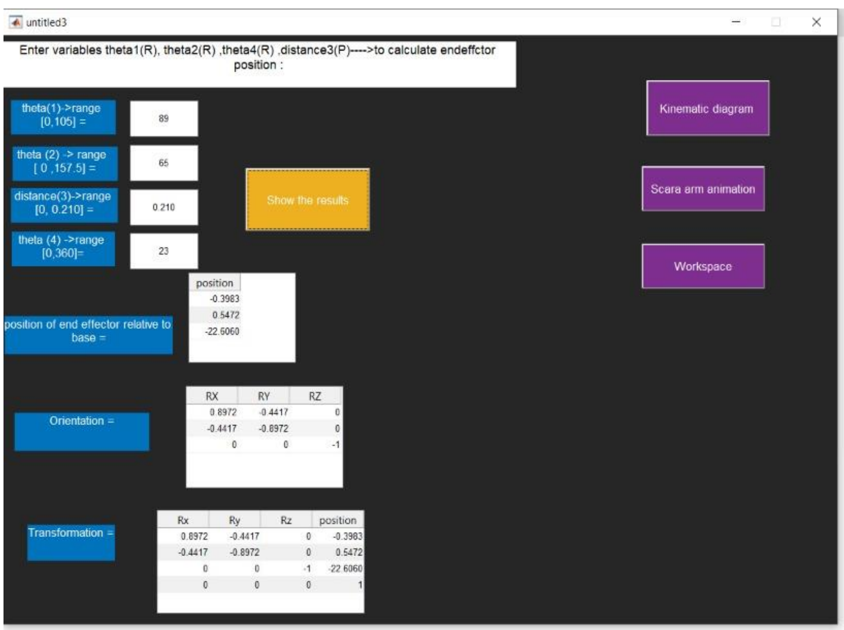
and the rotation matrix is: $\begin{matrix} n_x & o_x & a_x \\ n_y & o_y & a_y \\ n_z & o_z & a_z \end{matrix}$

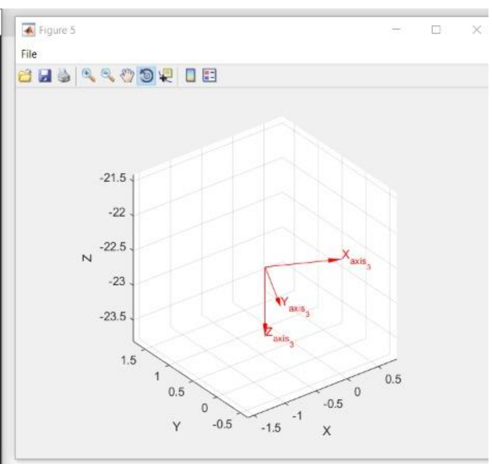
Test Cases Included In the Code:

Test 1:

joints	$d_i(mm)$	$a_{i-1}(mm)$	$\alpha_{i-1}(°)$	$\theta_i(°)$
1	398	450	0	89
2	0	350	0	65
3	210	0	180	0
4	0	0	0	23

And the results were as in the image:

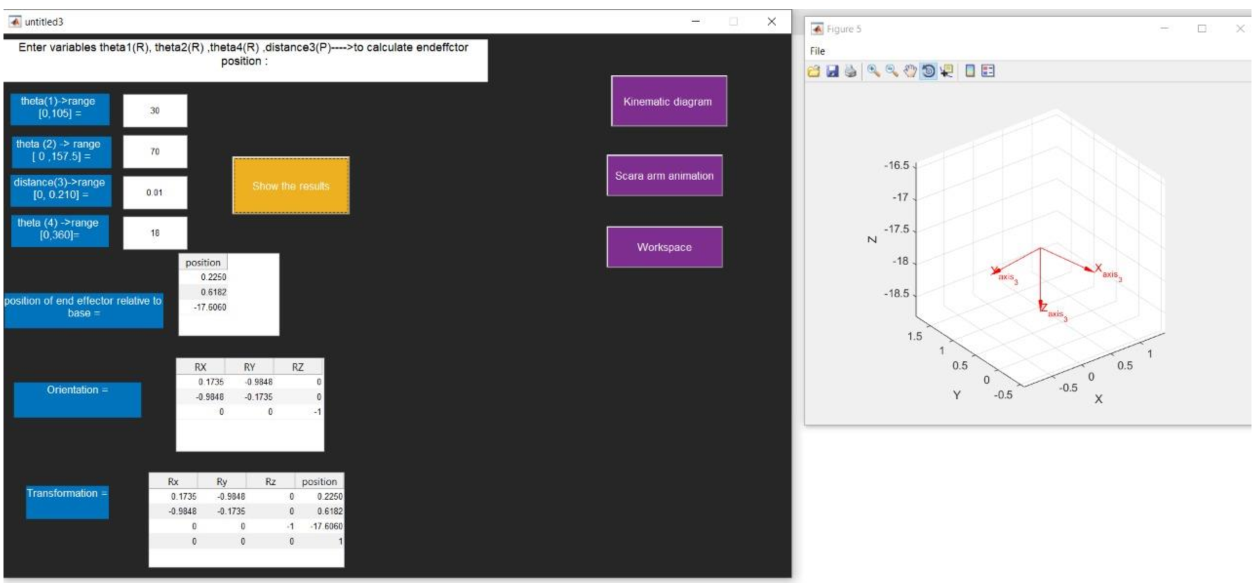




Test 2:

joints	$d_i(mm)$	$a_{i-1}(mm)$	$\alpha_{i-1}(°)$	$\theta_i(°)$
1	398	450	0	30
2	0	350	0	70
3	10	0	180	0
4	0	0	0	18

And the results were as in the image:



Test 3:

joints	$d_i(mm)$	$a_{i-1}(mm)$	$\alpha_{i-1}(°)$	$\theta_i(°)$
1	398	450	0	28
2	0	350	0	45
3	50	0	180	0
4	0	0	0	56

And the results were as in the image: