KRaiRobotic SCILAB Toolbox

S. Udompuchphon, S. Yanyong and S. Kaitwanidvilai*

Abstract— **This paper presents a developed toolbox in SCILAB that is useful for teaching and training purposes in the field of robotics. The essential commands in kinematics have been developed to simulate a robotic arm, and the paper demonstrates the modeling of a specified robot arm, PUMA560, by comparing the results with those obtained using MATLAB software. The conclusion discusses the next steps for future work.**

*Index Terms—***Robotics Toolbox, SCILAB, Kinematics, Simulation**

I. INTRODUCTION

CURRENTLY, the manufacturing industry faces heightened competition due to the emergence of new markets and regional competitors, as well as the availability of lower wages in competing countries. This situation has had a significant impact on manufacturers in terms of cost, quality, and production capabilities, making it necessary for them to improve their production models to increase competitiveness in regional and global markets. Automated production lines have become increasingly prevalent in industrial production systems, and they are now more accessible to medium and small industries as well. While there are various solutions available, selecting automation, especially robot arms, is a crucial part of many automation systems.

This paper proposes a developed SCILAB toolbox that helps engineers design and simulates kinematic versions of robots. The toolbox provides a series of commands that can show the robot and its trajectories, among other features, which is beneficial for the community and avoids the high cost of simulation software. Additionally, this toolbox is available for free for educational purposes.

II. THEORY

A. Kinematics of Robot Arm

Kinematics is used to describe the motion of structural bodies in mechanical systems, which consist of

interconnected parts in the fields of mechanical engineering, robotics, and biomechanics. Geometric transformations, also known as rigid transformations, are employed to describe the movement of components within a mechanical system, thereby facilitating the determination of motion equations. Kinematics plays a vital role in dynamic analysis and enables the quantification of kinetics through calculation processes. A solid transformation ensures that the distance between any two sets of points remains unchanged.

Rotational or angular kinetics pertains to the rotation of an object and necessitates a method for expressing the object's orientation. Two common approaches for this purpose are Euler angles and algebraic products related to rotation kinematics. This paper will primarily concentrate on a straightforward rotation about the Z-axis with a fixed orientation, which has been chosen for convenience.
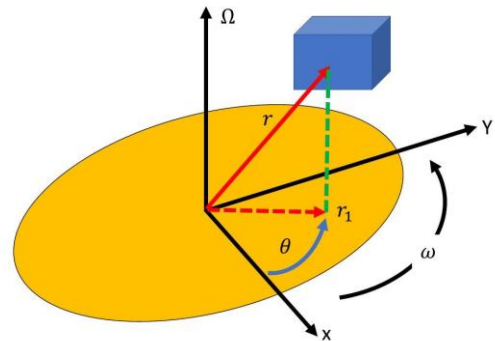

Fig. 1. Angular Velocity. Vector Ω. points up for counter clockwise rotation and downward clockwise rotation as indicated by the right-hand rule, the angular position $\theta(T)$ changes with time at a rate at which $\omega(T) = d\theta\, d/T$.

The Denavit-Hartenberg (D-H) matrix is a transformation matrix used to transform one coordinate frame into another. By performing a series of D-H matrix multiplications and referring to a D-H parameter table, the result is a transformation matrix that describes the motion of each joint in a robot's arm. The D-H matrix uses four parameter symbols, including $\alpha, a, d,$ and θ.

$$T(i) = \begin{bmatrix} \cos\theta_i & -\sin\theta_i & 0 & a_{(i-1)} \\ \sin\theta_i\cos a_{(i-1)} & \cos\theta_i\cos a_{(i-1)} & -\sin a_{(i-1)} & -\sin a_{(i-1)}d_i \\ \sin\theta_i\sin a_{(i-1)} & \cos\theta_i\sin a_{(i-1)} & \cos a_{(i-1)} & \cos a_{(i-1)}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Industrial robots are generally classified based on the shape of their working area, known as the geometric envelope. Before discussing robot types, it is important to understand the two basic joint types: Revolute (R), which involves rotation around an axis, and Prismatic (P), which involves

linear motion. Table I shows some examples of robot joints in terms of typical robot types and their respective joints. Table II presents the DH parameters for the PUMA560, which is a 6-degree-of-freedom articulated robot. These parameters are used to describe the robot's kinematics accurately. In addition, Table III provides examples of angle substitutions for a specific condition.

TABLE I
TYPES OF ROBOTS IN TOOLBOX

Kind of robot	Robot Axis		
	axis 1	axis 2	axis 3
Cartesian (gantry) Robot	P	P	P
Cylindrical Robot	R	P	P
Spherical (Polar) Robot	R	R	P
SCARA Robot	R	R	P
Articulated Robot	R	R	R

TABLE II
DH LINK PARAMETERS FOR PUMA560

i	PARAMETERS			
	$\alpha_{(i-1)}$	$a_{(i-1)}$	d_i	θ_i
1	0	a_1	0	θ_1
2	0	a_2	d_2	θ_2
3	0	a_3	d_3	θ_3
4	0	a_4	d_4	θ_4
5	0	a_5	d_5	θ_5
6	0	a_6	d_6	θ_6

TABLE III
EXAMPLE OF SUBSTITUTION OF D-H PARAMETERS FOR PUMA560

i	PARAMETERS			
	α	a	d	θ
1	0	0	0	0
2	0	1	1	90
3	0	1	1	-45
4	0	1	1	-30
5	0	1	1	-30
6	0	1	1	-30

To create a 2D model of a robot arm, the link parameters from Table II, i.e., the Denavit-Hartenberg parameters, can be inserted into a toolbox program. For example, Table III displays the values for an alternative PUMA 560, enabling the generation of a 2D model of the robot arm as shown in Fig. 2.
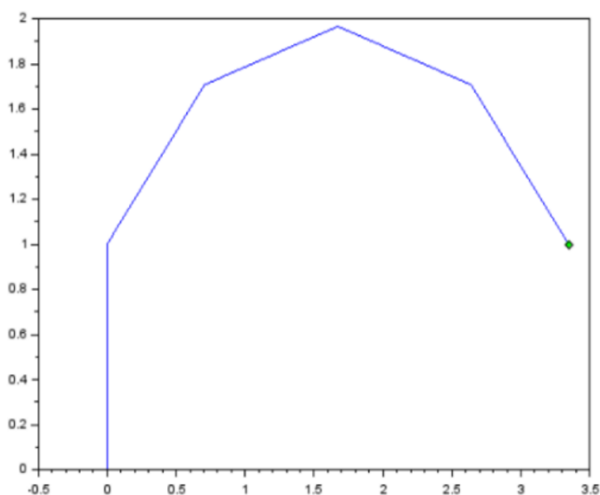

Fig. 2. The alternative 2D model of the PUMA 56 generated by inserting values from Table 3 into the toolbox program.

B. SCILAB Program

Many educational departments have implemented various tools, including computers and software, to support teaching and research across various fields such as engineering and science. However, due to the high licensing costs associated with popular software programs used for numerical calculations and generating complex graphics, many small companies in the industrial sector face limitations in accessing such resources. To address this issue, the SCILAB language program was developed by researchers from INRIA and ENPC in France. SCILAB is specifically designed for performing numerical calculations and displaying intricate graphics. The program offers comparable performance to many commercial software options while being freely available. As a result, SCILAB has emerged as a viable alternative, gaining popularity in universities as a teaching tool due to its efficiency and absence of software license fees. The advantages of the SCILAB program are expected to have a significant impact on future developments in the field.

C. Example of Functions in the proposed KRAIRoboticToolbox

This section presents several examples of functions available in the KRAIroboticsToolbox, which facilitate robot design and simulation. The following functions are provided as illustrative examples of the available commands:

<<Kinema>>
This function performs kinematic calculations for the robot, assisting in the modeling process.

<<KLink>>
This function creates a data structure that stores all data related to the robot's links, including kinematic and inertia parameters, motor parameters, and transmission information.

<<PlotRobo>>
This function enables the rapid creation of a 3D simulation model for the robot.

<<Robotdata>>
This function rapidly displays information related to the robot's calculated kinematic and inertial parameters, motor parameters, and transmission details.

<<SerialKLink>>
This function stores parameters in a robotic structure for later use in modeling and simulation.

<<StartKRaiRoboticToolbox>>
This function provides access to all functions within the KRaiRoboticToolbox, facilitating 3D modeling purposes.

III. IMPLEMENTATION

This section elaborates on the usage of a SCILAB-based Toolbox for modeling robotic arms. The Toolbox serves the purpose of simulating robotic arms and displaying the coordinate values acquired from the simulation. It allows for

the visualization of the obtained coordinate values and takes into account the number of coordinates present in the robotic arm model. In this section, a model for the PUMA robot is created by comparing Figure 3A, representing the PUMA560 from MATLAB software, with Fig. 3B, which illustrates the Puma 560 Robot model obtained from the KRaiRoboticToolbox.
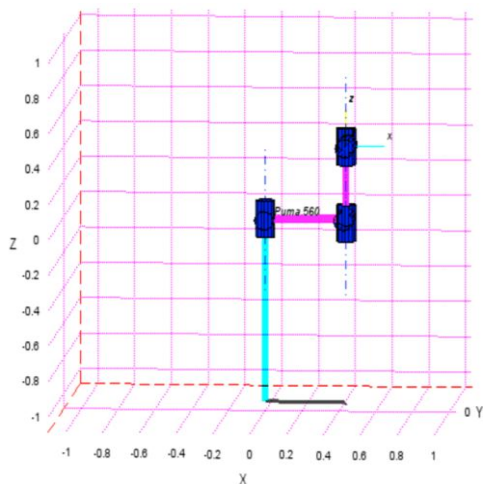
The forward kinematics of the robot were compared for five different sets of common angles. Each set of common angles was processed using a matrix to convert it into the transformation DH matrix. PUMA 560 robot was built, with its DH parameters shown in Table III. Fig. 4 presents a graphical representation of the PUMA 560 robot end effector moving from (x,y,z) [0, 0, 0] to [0.5, 2, 3] using synchronous point-to-point trajectory generation.

Fig. 3A. The Puma 560 Robot model from Robotics_Toolbox in MATLAB.

Fig. 3B. The Puma 560 Robot model obtained from KRaiRoboticToolbox

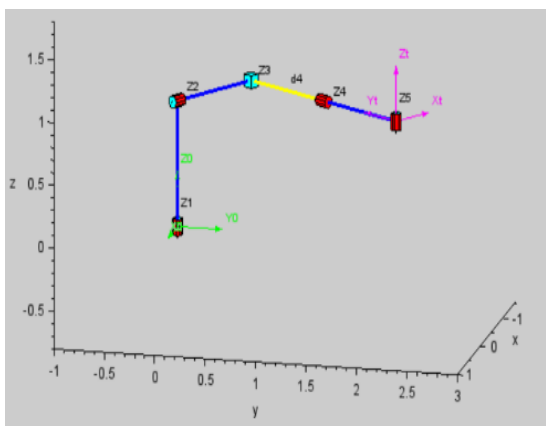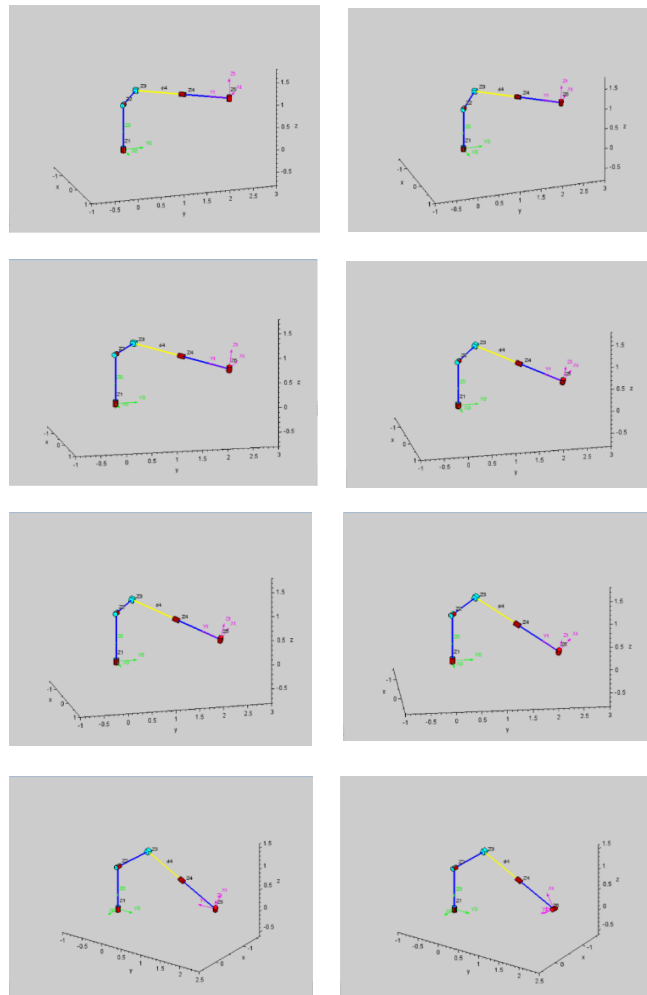Fig. 4. Graphical representation of the Puma 560 Robot from KRaiRoboticToolbox

To model a PUMA robot with a 6R mechanism, a series of commands is needed for each row of DH parameters, demonstrating the ability of our toolbox to work with both DH representations. Two PUMA robots are created to verify that they are the same.

```
L(1) = Link([0 0 0 0]);
L(2) = Link([0 1 0 -%pi/2]);
L(3) = Link([0 1 0 %pi/2]);
L(4) = Link([0 1 0 0],'p');
L(5) = Link([0 1 0 -%pi/2]);
L(6) = Link([0 0 0 0]);
q = [0 1 1.57 1 1.57 0];
```

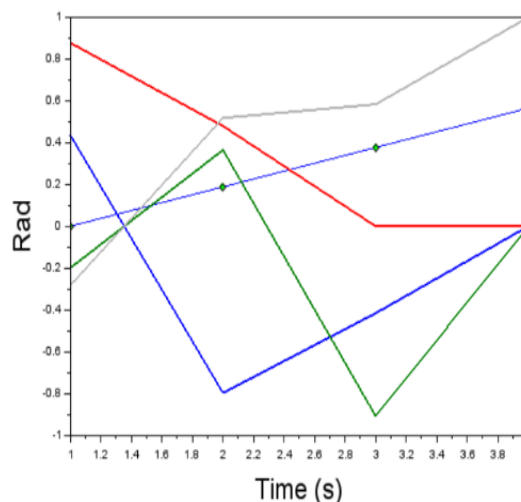| j	theta	d	a	alpha
1	q1	0.00	0.00	0.00
2	q2	1.00	0.00	-1.57
3	q3	1.00	0.00	1.57
4	0.00	q4	0.00	0.00
5	q5	1.00	0.00	-1.57
6	q6	0.00	0.00	0.00

Fig. 5. The relationship between angles and time for the specified robot model generated by the KRaiRoboticToolbox

IV. CONCLUSION

This paper introduces a toolbox developed for simulating industrial robots using SCILAB. SCILAB offers a wide range of computational capabilities for modeling industrial robots without any cost. While modeling industrial robots with certain commercial programs can be expensive, using SCILAB provides a cost-effective solution and has seen significant advancements recently. Furthermore, SCILAB serves as an accessible program for industrial robot modeling, catering to researchers and practitioners in the field. This allows for the expansion of SCILAB's capabilities, including the work presented in this paper, for various applications. The utilization of SCILAB in the development of industrial robot simulation models offers several advantages. As part of our future tasks, we aim to design the SCILAB kinetics toolbox for the next version of this program.

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