Scilab case study project on

Analyzing Robotic Arm Kinematics of PUMA 560

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Abstract

This case study delves into the computational analysis of forward and inverse kinematics for robotic systems, leveraging Scilab, a powerful open-source platform for numerical computation and simulation. The study focuses on the PUMA 560 robotic arm, a widely recognized industrial manipulator, to demonstrate the practical application of kinematic principles in robotics. Utilizing the Robotics Toolbox for Scilab, the kinematic modeling is conducted in separate script files for clarity and precision. This case study aims to showcase how Scilab can be effectively used for simulating and solving complex kinematic problems, offering a reliable and efficient tool for the accurate computation of robotic movements. The results underline the potential of Scilab as a valuable resource for robotics research and development, particularly in areas requiring high accuracy and speed in numerical simulations.

1. Introduction

In the realm of robotics, kinematics plays a crucial role in determining the movement and positioning of robotic arms, enabling precise control of their actions in both industrial and research settings. Kinematics is broadly categorized into forward and inverse kinematics. Forward kinematics involves calculating the position and orientation of a robot's end-effector based on known joint parameters, while inverse kinematics reverses this process, determining the required joint angles to achieve a desired end-effector position and orientation.

This case study focuses on the PUMA 560 robotic arm, an iconic industrial manipulator known for its versatility and precision. The PUMA 560 has been extensively used in various applications, from manufacturing to medical procedures, due to its robust design and advanced control capabilities.

Leveraging Scilab, an open-source numerical computational software, this study aims to model and simulate the kinematic behavior of the PUMA 560. The Robotics Toolbox for Scilab provides a suite of functions that facilitate the creation, visualization, and analysis of robotic models. By conducting both forward and inverse kinematics simulations, this study demonstrates the effectiveness of Scilab in solving complex robotic problems.

The purpose of this study is twofold: first, to validate the use of Scilab as a reliable tool for robotic simulations, and second, to provide a comprehensive analysis of the kinematic performance of the PUMA 560 robotic arm. Through detailed simulations and analyses, this study contributes valuable insights into the application of open-source tools in the field of robotics.

2. Problem Statement

The challenge of accurately determining the position and orientation of a robotic arm's end-effector (forward kinematics) and calculating the necessary joint angles for a desired position (inverse kinematics) is critical in robotics. This study focuses on applying Scilab to solve these kinematic problems for the PUMA 560 robotic arm. The goal is to validate Scilab's effectiveness in performing these computations, using the Denavit-Hartenberg parameters to model the robot's geometry and simulate its kinematic behavior.

3. Basic concepts related to the topic

Denavit-Hartenberg (DH) parameterization is a minimal parameterization method used to describe the relative placements of joints in a revolute-prismatic kinematic chain. The four transformation parameters, known as DH parameters, are:

1. d: Offset along the previous z-axis to the common normal.
2. θ: Angle about the previous z-axis, from the old x-axis to the new x-axis.
3. r (a): Length of the common normal.
4. α: Angle about the common normal, from the old z-axis to the new z-axis.

Joint	θ	d	a	α
1	q1	0.475	0	0
2	q2	0	0.15	1.571
3	q3	0	0.6	0
4	q4	0.72	0.12	1.571
5	q5	0	0	-1.571
6	q6	0.085	0	1.571

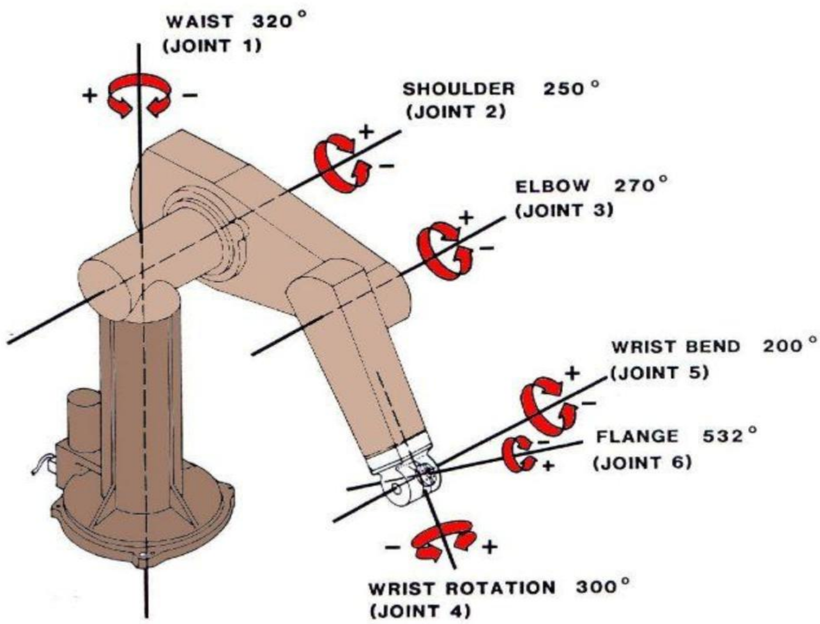
Robot model used and DH parameters is given in table

In this case study, the links of the robotic model are described using DH parameterization. The robot's kinematics refers to the motion of the robot's bodies relative to the movement of its joints. While kinematics is often associated with the robot's velocity, the same principles apply to higher-order motion derivatives, particularly acceleration, which is referred to as "second-order kinematics."

Forward kinematics involves using the robot's kinematic equations to determine the position and orientation of the end-effector based on specified joint parameters. This is a straightforward, closed-form function that is easy to calculate.

Inverse kinematics is the problem of finding the joint configurations that achieve a desired end-effector position and orientation. This is particularly important for tasks like trajectory planning. The inverse geometry problem can also be approached using Gauss-Newton descent, reformulated as a sequence of inverse kinematics resolutions.

In a real-world environment, the gravity vector has three components in 3D space (x, y, z), with the z-direction having a magnitude of 9.81 m/s^2. The base and tool positions are defined by 4x4 matrices. Joint angles, denoted by q1, q2, q3, q4, q5, and q6, are provided to the algorithm, which calculates the position of the end-effector. Functions like plot, robot, and teach in Scilab allow for the manipulation of the robot's direction and its roll, pitch, and yaw angles to achieve the desired output.



The PUMA (Programmable Universal Machine for Assembly) 560 is an industrial robotic system, also notable for being the first surgical robotic arm (1985). The PUMA 560 model is available in the Robotics Toolbox for Scilab, which is inspired by the ninth release of the Robotics Toolbox for MATLAB by Peter Corke.

This toolbox provides functions for:

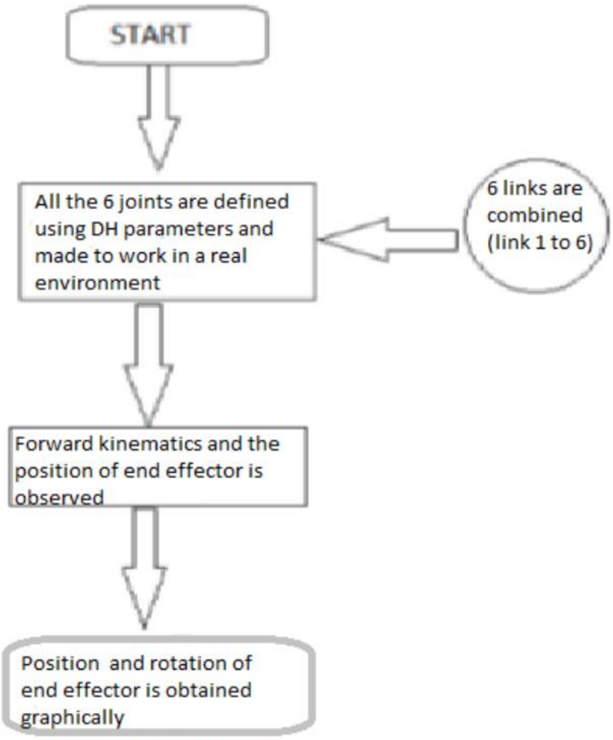
1. Creating a robotic model using the Denavit-Hartenberg notation.
2. Solving forward and inverse kinematics.
3. Managing forward and inverse dynamics.
4. Displaying and animating a graphical model of a manipulator.
5. Using Xcos blocks for simulating the control of a robotic model.
6. Performing geometric transformations.

The key functions from the Robotics Toolbox used in this case study include:

1. SerialLink
2. fkine
3. plot
4. teach
5. ikine6s
6. transl
7. mdl
8. rpy2tr

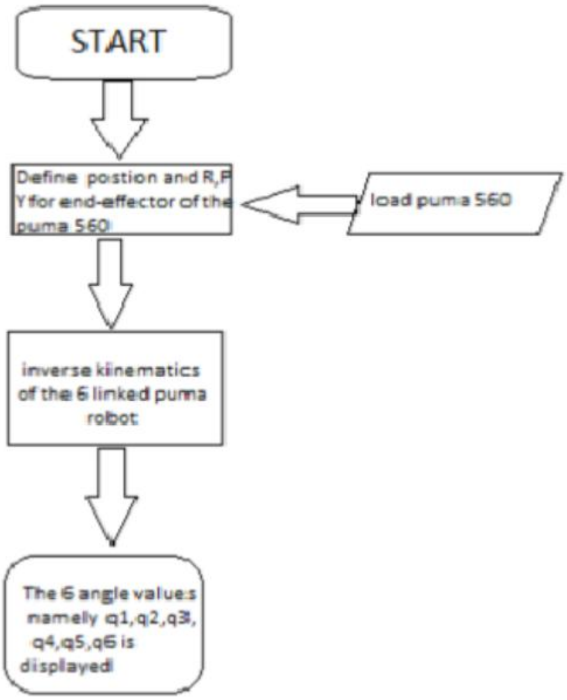
4. Flowchart

4.1 Forward kinematics



FORWARD KINEMATICS

4.2 Inverse kinematics



Inverse kinematics

5. Software/Hardware used

a. Windows 10 OS
b. Scilab 6.1.1
c. Robotics Toolbox 2.0.3

6. Procedure of execution

a. Go to the Applications menu and click on ATOMS.

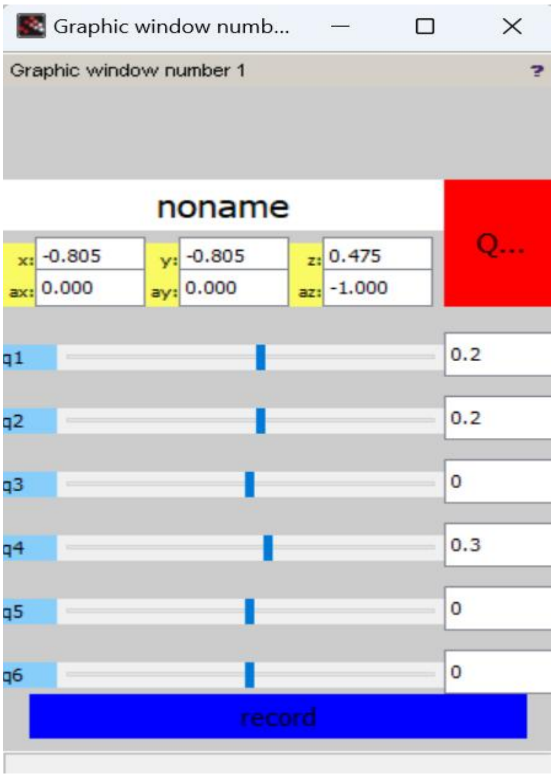
   In the ATOMS window:

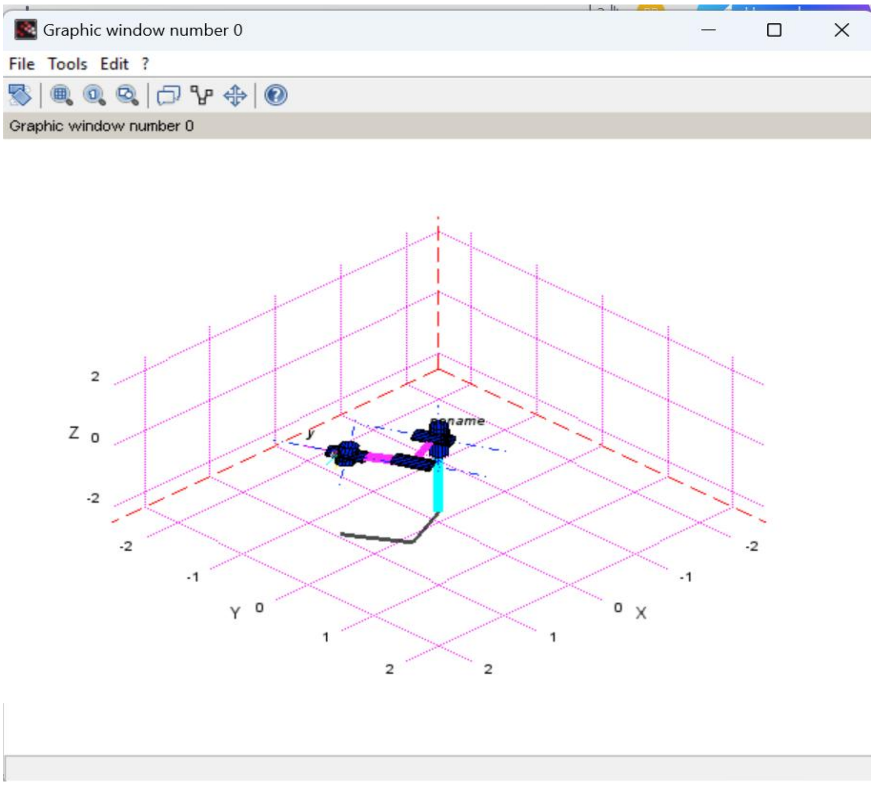
   - Select the **Modeling** module from the left-side panel.
   - Locate the toolbox named Robotics Toolbox.
   - Click on Install on the right side to install the toolbox.

b. After the installation is complete, restart Scilab to ensure the toolbox loads successfully.
c. Change the current working directory to the folder containing the code.
d. Execute forward kinematics:
e. Open the forward kinematics folder.
f. Load the `forward kinematics.sce` file into the Scilab console.
g. The graphic window will simulate the robot's movement based on the angles specified in the code.
h. Change the current working directory to the folder containing the code.
i. Execute inverse kinematics.
j. Open the inverse kinematics folder.
k. Load the `inverse kinematics.sce` file into the Scilab console.
l. The Scilab console will display the joint angles corresponding to the inverse kinematic equations.

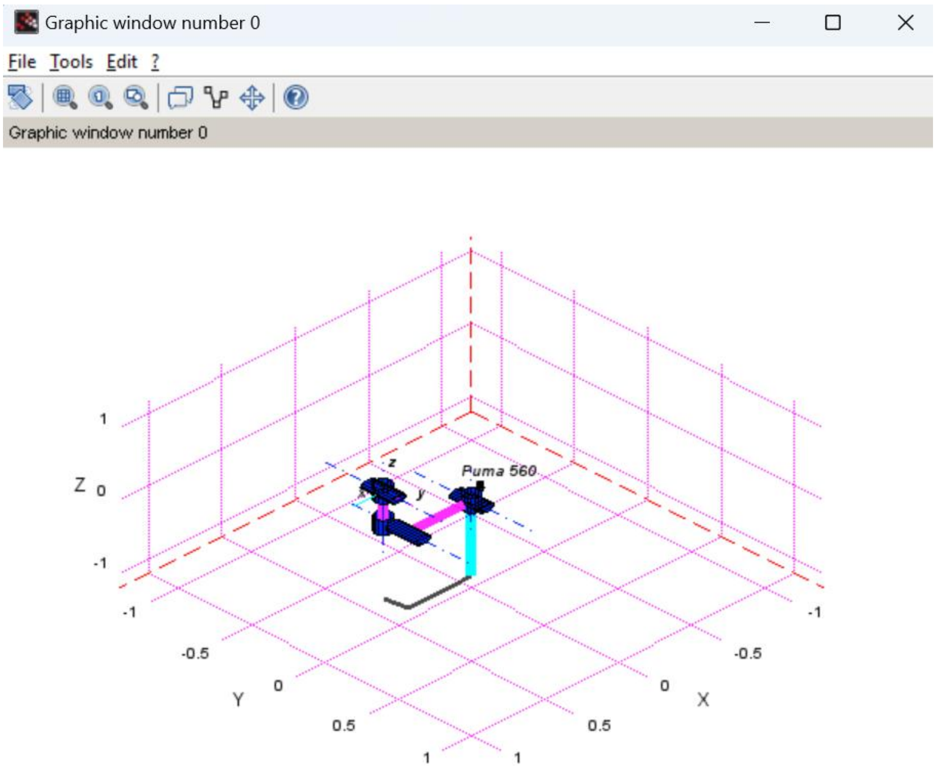
7. Result

Forward kinematics of a 6-joint industrial robot





Inverse kinematics



8. References

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