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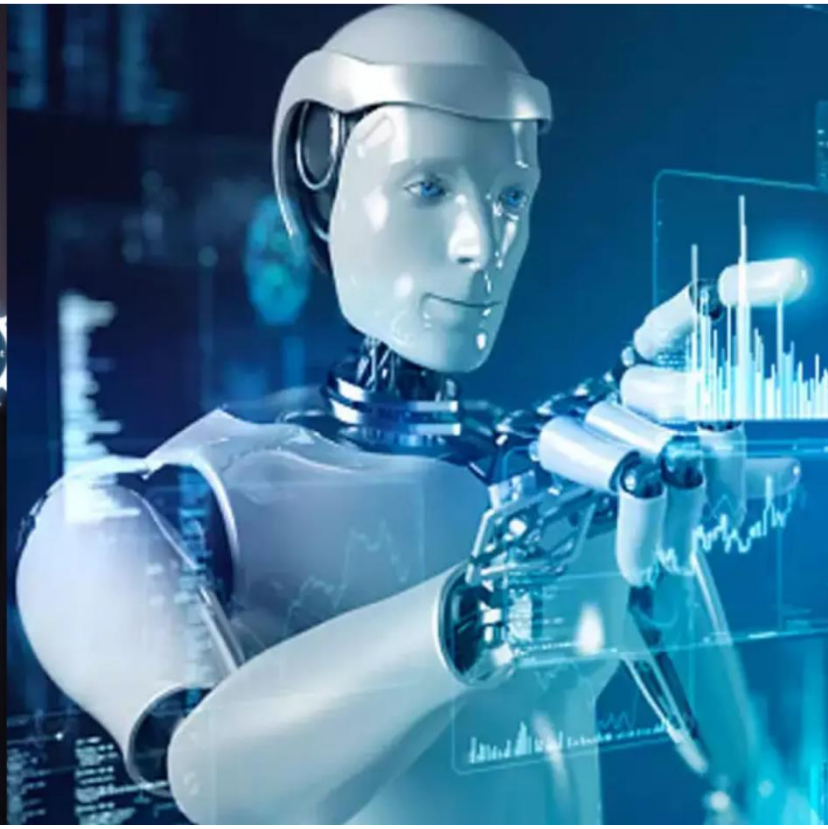

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Control of Robotic Arm Using Inverse Kinematics on Raspberry Pi Pico with Python

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ABSTRACT: This project focuses on controlling a 4-degree-of-freedom (DOF) robotic arm using inverse kinematics, with a Raspberry Pi Pico for hardware control and Python for computational modeling. The robotic arm consists of four joints: Base, Shoulder, Elbow, and Gripper. The PCA9685 PWM driver is used to control the servo motors, while inverse kinematics is utilized to calculate the joint angles (θ1, θ2, θ3, θ4) required to position the robotic arm's end effector at a desired 3D coordinate (x, y, z). Python solves these equations based on trigonometric principles and sends the resulting angles to the Raspberry Pi Pico via I2C communication. The Pico then sends PWM signals to the PCA9685, which adjusts the servo motors to move the arm accurately. This integration of inverse kinematics with hardware control enables precise object picking and dropping. The system is validated through real-time testing, confirming its ability to accurately follow input coordinates. This project demonstrates a practical application of inverse kinematics for robotic control, laying the groundwork for more advanced automation, precision tasks, and teleportation systems.

I. INTRODUCTION

Robotic arms are widely used in industries, research, and automation, performing tasks that require high precision and flexibility. To achieve such movements, the position and orientation of the arm's end effector must be accurately controlled. This is where inverse kinematics (IK) plays a crucial role. Inverse kinematics is the process of determining the joint angles of a robotic arm that will result in the end effector reaching a specific position and orientation in three-dimensional space. Unlike forward kinematics, where the joint angles are given, inverse kinematics involves solving for the unknown joint angles based on the desired end effector position.

This project aims to design a control system for a 4-degree-of-freedom (DOF) robotic arm using inverse kinematics. The control system is implemented using a Raspberry Pi Pico for hardware interfacing and Python for the computation of joint angles. The Python code calculates the required joint angles using trigonometric methods and sends them to the Raspberry Pi Pico via I2C communication. The Pico, in turn, controls the servo motors through the PCA9685 driver to move the robotic arm accordingly. This system not only demonstrates the principles of inverse kinematics but also integrates software and hardware for practical robotic control applications.

The key goal of this project is to achieve accurate and precise movement of the robotic arm in response to user inputs. It provides a foundation for more advanced applications in automation, robotics, and precision tasks.

Raspberry pi Pico:

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Acts as the microcontroller to control the motors.

- The Raspberry Pi Pico code listens for I2C input from the Python script. It reads the joint angles and uses the PCA9685 driver to control the servos at each joint:
    1. The servo motors are controlled by PWM signals generated by the PCA9685 based on the received joint angles.
    2. The Pico adjusts the motor positions accordingly, achieving the desired movement of the robotic arm.

Inverse Kinematics Algorithm:

- The core software component is the inverse kinematics (IK) algorithm, which calculates the joint angles based on the desired position of the end effector. For a 4 DOF robotic arm, the inverse kinematics equations are derived based on the geometric and trigonometric relationships between the joints and the end effector.
- The algorithm takes in the target (x, y, z) coordinates of the end effector as input and solves for the corresponding joint angles θ1, θ2, θ3, and θ4.
- The equations are solved using Python's NumPy and math libraries, which simplify matrix operations and trigonometric calculations.

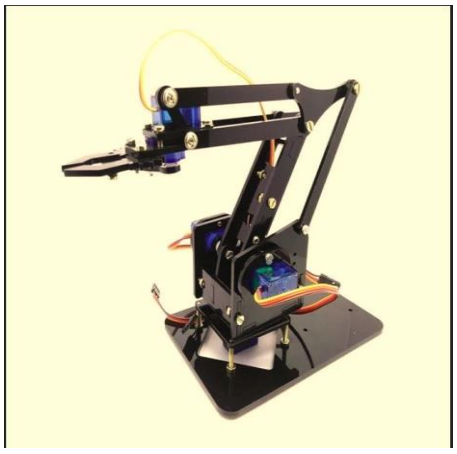
II.METHODOLOGY

The methodology for this project involves several key steps, including the Design and Setup of the Robotic Arm, Inverse Kinematics Calculation, Communication between Python and Arduino, User Interface (Optional), Testing and Evaluation. The given outlines the approach taken to accomplish the project's goals.

Python Implementation:

- The Python script calculates the inverse kinematics solution and sends the resulting joint angles to the Raspberry Pi Pico via I2C communication. This involves:
    1. Receiving user input for the desired position of the end effector.
    2. Solving the inverse kinematics equations to determine the required joint angles.
    3. Sending the joint angles (in the form of a data packet) to the Raspberry Pi Pico.
    4. Handling communication errors and ensuring that the joint angles are correctly transmitted.

Robotic Arm:



Design:

The design of the robotic arm control system consists of two primary components: the hardware design (including the robotic arm and its actuators) and the software design (including the inverse kinematics algorithm and communication system). The design follows a modular approach to ensure flexibility and scalability

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III. CONCLUSION

This project successfully implements inverse kinematics (IK) for robotic arm control using Raspberry pi pico and Python, enabling precise movement based on target coordinates. By calculating joint angles dynamically and transmitting them via serial communication, the system achieves accurate and stable positioning of the robotic arm. The use of PWM motor control ensures smooth motion without abrupt movements.

The system is highly scalable and adaptable, making it suitable for various applications such as industrial automation, medical robotics, agriculture, space exploration, and assistive technology. Future improvements include computer vision (OpenCV) for object detection, feedback sensors for accuracy, and AI-based motion planning for adaptive control.

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