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A REVIEW OF PERFORMANCE AND DYNAMIC ANALYSIS OF ROBOTIC ARM MANIPULATOR

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Abstract

This study reviews the modeling, simulation, optimization, kinematics, and dynamics of robotic arms, representing the first phase of a broader research initiative that will be expanded into the field of robot trajectory generation mechanisms. Following an introduction that highlights the significance of robots in industrial processes and the need to optimize their motion, recent approaches concerning kinematic and dynamic analysis, motion optimization, and trajectory generation modeling for robots are presented.

Keywords: *Dynamic Analysis; Robot Arm Manipulator; Simulation; Optimization.*

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1. Introduction

In the physical realm, robots are tangible entities that accomplish tasks through manipulation. Typically, robots are fitted with sensors to perceive their surroundings and interact with physical forces acting upon them. In the automation process, industrial robots are crucial for the grinding method. Most grinding robots operate in a controlled environment, where precise position and force management is essential. Given the growing pressure to cut costs and boost productivity, there has been a shift towards the widespread deployment of industrial robots in automated manufacturing processes.

The primary issue is the overall efficiency of the robotic system within the production process. A major factor affecting efficiency is how well the robot's entire motion sequence performs in industrial settings. Today, advanced software tools have made it easier to model and simulate complex systems, and many researchers are actively working in this area. This study presents a procedure for creating a numeric prototype to model and simulate robot manipulators via software, illustrated with an example.

2. Literature Review

Heim and Stryk [1] conducted research to derive optimal robot trajectories by applying constrained optimal control to comprehensive, nonlinear dynamic models of robots. Customized direct transcription techniques quickly calculate approximations of the optimal control and the corresponding optimal trajectory. Offline-optimized trajectories can now be implemented almost automatically via fly-by points, significantly cutting cycle time. Therefore, trajectory optimization is already well positioned as a new tool for computer-aided robotics.

Munasinghe et al. [2] provided the general solution to the contouring problem for industrial robot arms, while adhering to constraints on assigned Cartesian velocity and joint torque/acceleration. The proposed solution involves an offline trajectory generation algorithm, making it highly industrially relevant since it requires no modifications to existing hardware. The proposed method ensures that the joint torque/acceleration achieves maximum utility while remaining within the specified velocity constraint. The proposed method creates a feasible trajectory based on the target trajectory and adjusts for delay dynamics through a forward compensator. The proposed method was tested on Performer MK-3 industrial robot arms, achieving optimal contouring.

Ata [3] presents and examines a review, discussion, and analysis of optimization techniques aimed at identifying the optimal trajectorywhether in Cartesian space or joint space. Various trajectory selection methodsincorporating kinematics and dynamics under different constraintsare introduced and detailed. Although the kinematics approach is straightforward and simple, it will encounter certain issues during implementation due to the absence of inertia and torque constraints. The use of Genetic Algorithms to determine the best trajectory for manipulators, particularly for obstacle avoidance, is also emphasized. Combining Genetic Algorithms with other classical optimization methods demonstrates superior performance when used as a hybrid optimization technique.

Gea and Kirchner [4] confirmed the theoretical components within a simulated setting, and their findings support the approach's validity; further experiments are planned for a real-world platform. An experimental setup is currently being assembled, featuring a Mitsubishi PA-10, a seven-degree- of-freedom industrial robot arm, to evaluate impedance control in a real-world environment. The robot will use force sensors in its wrist to detect contact forces and adjust its grip according to the object it's handling.

Qassem et al. [The kinematics of the AL5B robot arm were analyzed, and a Graphical User Interface (GUI) was created to test and simulate its motion characteristics. A physical interface connecting the AL5B robot arm and the GUI will be created. The created system will be recognized as an educational experimental tool; it is applicable in both graduate and undergraduate robotics courses to demonstrate the connections between theoretical concepts and practical applications of robot manipulator movements in real time.

Banga and colleagues [6] demonstrated the ideal motion of a 4 DOF robotic arm through inverse kinematics. A method for optimization that utilizes genetic algorithms and fuzzy logic is assessed. In the advanced genetic algorithms, elitism has been maintained from one generation to the next to achieve the optimal angular displacements for the robotic arms across the entire workspace.

Reddy et al. [A robust technique was proposed and applied to predict the optimized value from the generated chromosomes. Generally, there is some discrepancy between experimentally measured values and numerically calculated values. To eliminate those conflicts, the parameter values are tuned to reduce the errors in the equations, yielding an optimized result that closely matches the experimentally derived value. The optimized value achieved should definitely enhance the flexibility of the robotic arm.

Ranjan et al. [8] developed and implemented the block and machine models of a robotic humanoid arm using MATLAB Simulink. The equations of kinematics are obtained using D-H notation. Using this equation and inverse kinematics, the parameters for the motion trajectory have been calculated. Kinematic parameters fall into two categories: link parameters and joint parameters. A geometric model and motion simulation of a robotic humanoid arm have been implemented, featuring a two-link structure with three degrees of freedom, along with a detailed hand and finger assembly possessing 18 degrees of freedom. Simulating the arm virtually is also the initial step toward controlling the actual mechanical structure.

Duicu and Popa [9] introduced a five-axis robotic arm model along with its simulated motion path. This robot is quick, precise, dependable, and simple to program. Equipped with sensors, the robot arm is built to manipulate objects without requiring human involvement. The robot presented has five degrees of freedom, and all of its movements involve rotation. To model the robot arm, we employed SolidWorks, and for trajectory simulation, we used Matlab and Simulink.

Patel and George [10] derived and presented the mathematical formulation covering the full kinematics and dynamics of a two-degree-of -freedom robotic arm. Kinematic and dynamic simulations are conducted using Pro/ Engineer software, and the outcomes are then compared against analytical results. The results are plotted to measure performance using the condition number and manipulability index. The condition number's value is not well-defined at the moment of actuation and also when the joint reaches its limit. The workspace boundary defines the limits of motion and the area available for positioning workpieces. In a robotic joint, friction is influenced by factors such as temperature, applied force or torque, position, velocity, acceleration, and the characteristics of the lubricant. In his work, the models incorporated nonlinearities, while frictions were ignored. It was noted that the average torque variation calculated using Newton-Euler methods at both joint axes remained around 3% across all possible positions, when compared to results from Lagrangian dynamics.

3. Conclusion & Future Scope

This study introduces a modeling, simulation, and optimization approach for various robotic arms, along with methods for selecting their trajectories. Kinematics-based methods yield intriguing outcomes, but in real-world applications, inertia and torque limitations complicate their implementation. Dynamic methods offer a more realistic approach by better accounting for torque limits and physical joint constraints. Sometimes, nonlinearities and unmodeled dynamics continue to pose challenges in achieving a complete dynamics model, particularly for flexible manipulators.

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