Posture Control and Stability of a Standing 2-Link Mechanism

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***Abstract*—This project focuses on the nonlinear control of a standing three-link mechanism, essentially simulating the dynamics of a single leg. The objective is to develop a robust control strategy that enables precise posture regulation, ensuring stability and adaptability in various conditions. By leveraging advanced control techniques such as feedback linearization and nonlinear state feedback, or other control methods such as backstepping, the project aims to address the complexities associated with the leg's dynamics, including its inherent nonlinearities and potential disturbances.**

***Index Terms*—Nonlinear Control, Feedback Linearization, Posture Control, Stability Analysis, Two-Link Mechanism**

I. Introduction

This project focuses on the nonlinear control of a standing three-link mechanism, simulating the dynamics of a single leg. The objective is to develop a control strategy that enables precise posture regulation and stability in various conditions. The study explores control techniques such as feedback linearization, nonlinear state feedback, and backstepping, with a goal of improving legged locomotion and robotic systems.

II. Literature Review

The concern of stabilizing and controlling legged link mechanisms has been extensively studied. Several analyses have focused on modeling methods, control strategies, and stability analysis. Various modeling approaches, such as Newtonian, Newton-Euler, and Lagrange Euler methods, have been employed to design controllers for link mechanisms. Forward kinematics using the Denavit-Hartenberg convention and Zero Moment Point (ZMP) models have been used for stability analysis.

III. Modeling

The modeling of a link mechanism can follow different approaches. The Newtonian approach, based on torque and inertia, is one option. Alternatively, the Newton-Euler equations or the Lagrange Euler equations can be used to model the dynamics, accounting for factors like the center of mass, external forces, and reaction torques. This project applies the Lagrangian approach to model the mechanism during its fully actuated phase, including the swing and impact forces.

IV. Stability Analysis

To analyze the stability of a single-legged link mechanism, methods such as Center of Pressure (CoP) and Zero Moment Point (ZMP) are used. ZMP analysis is the most accurate method for stabilizing a standing mechanism. Dynamic simulations and reinforcement learning can also evaluate the system's response to perturbations.

V. Controller Design

Controlling the posture of single-legged mechanisms can involve both linear and nonlinear methods. Linear control methods like PID and LQR controllers are useful for stabilizing systems in predictable environments. Nonlinear techniques, such as feedback linearization and sliding mode control, are more effective in handling disturbances and complex dynamics. Advanced techniques like reinforcement learning enhance adaptability.

VI. Conclusion

The Zero Moment Point (ZMP) analysis is a key tool in ensuring stability of legged link mechanisms. Nonlinear control methods, particularly feedback linearization and Lagrangian mechanics, offer precise posture control and adaptability in complex environments.

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