

Adaptive Robust Control Based on Moore-Penrose Generalized Inverse for Underactuated Mechanical Systems

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ABSTRACT To address the uncertainty existing in underactuated mechanical systems (UMSs) and their nonholonomic servo constraints, we propose a class of adaptive robust control based on the Moore-Penrose generalized inverse for UMSs in this paper. The uncertainty is considered as (possible fast) time-varying and bounded. However, the bound is unknown. To estimate the bound information, an adaptive law is designed, which combines leakage type and dead-zone type. This adaptive law can simultaneously regulate the control effort and computation speed. The proposed control can guarantee deterministic system performance, which is analyzed by using Lyapunov method. The effectiveness of proposed control is shown by an example of simplified two-wheeled self-balancing robot.

INDEX TERMS Underactuated mechanical systems, servo constraints, adaptive robust control, adaptive law, Moore-Penrose generalized inverse.

I. INTRODUCTION

Underactuated manipulators [1], [2], UAVs [3], surface vessels [4], spacecraft [5], [6], underwater vehicles [7] and so on have generally become active fields for the past few years, because they are all underactuated mechanical systems (UMSs) that have the advantages of low number of actuators, weight, cost and energy consumption. However, complex internal dynamics, lack of feedback linearization and nonholonomic behavior also accompany UMSs, which increase the difficulty of designing controller for such systems. Even so, many brilliant work for such systems have been achieved in control field, such as sliding-mode [8]–[10], LQR [11], partial feedback linearization [12], [13], LMI [14], [15], H_∞ [16] and so on. However, most of the control methods mentioned above are difficult to deal with nonholonomic servo constraints [17].

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In 1992, Udwadia and Kalaba proposed a novel Udwadia-Kalaba equation [18] based on the Moore-Penrose generalized inverse, and through which can easily establish the motion equation of a mechanical system and solve the constraint forces without considering Lagrange multiplier. The Udwadia and Kalaba's work is a significant breakthrough in the field of dynamics. Based on the breakthrough, Udwadia proposed a novel servo control [19], which can easily handle nonholonomic servo constraints without relying on additional sophisticated mathematical tools in the control design of fully actuated mechanical systems. Furthermore, based on Udwadia's and Kalaba's work, in [20], Chen systematically proposed the concept of servo control for constrained mechanical systems and the design method of constraint forces. In [21], Liu et al. proposed a new servo control based on pioneer's work, which makes the advantages of Udwadia's control apply in controlling UMSs. However, Liu's work does not consider the uncertainty existing in UMSs. In real life, the uncertainty should be nonnegligible.

Adaptive Control Of Underactuated Mechanical Systems

Ahmad Taher Azar, Quanmin Zhu



Adaptive Control Of Underactuated Mechanical Systems:

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