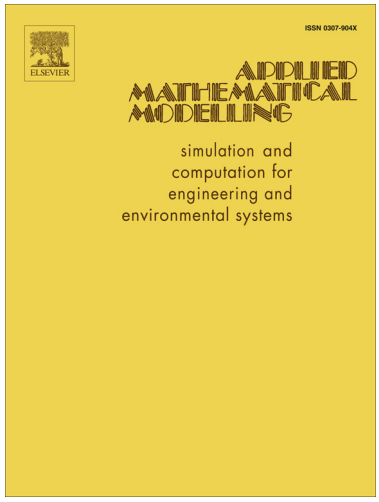

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Global stabilization of underactuated spring-coupled three-link horizontal manipulator using position measurements only

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Abstract

This paper concerns the global stabilization of an underactuated spring-coupled three-link horizontal manipulator (STHM), which is an underactuated mechanical system (UMS) with two actuators and three degrees of freedom (DOF). A new control method is developed that asymptotically stabilizes the STHM at the origin using the position measurements of the manipulator only. First, we introduce a homeomorphic coordinate transformation for the STHM system. This changes the stabilization of the STHM into that of the transformed system. Next, we analyze the characteristics of the transformed system. After that, we construct an equivalent-input-disturbance- (EID-) based control system to globally stabilize the transformed system at the origin. Finally, a numerical example demonstrates the validity of the presented method. Our method only uses the position measurements of the STHM to design stabilizing controller. It reduces the cost of the whole control system and avoids the influence on the system's control performance imposed by velocity noises. In addition, the analysis and control method of this paper is easy to extend to the global stabilization of other n-DOF ($n \geq 3$) UMSs.

Keywords: Underactuated mechanical system, Nonlinear dynamics, Horizontal manipulator, Equivalent input disturbance

1. Introduction

We call a mechanical system to be an underactuated mechanical system (UMS) if the numbers of actuators are less than system's degrees of freedom (DOF) to be controlled. There are many examples of UMSs in people's daily lives, e.g., a spacecraft, a helicopter, an underwater vehicle and an industrial manipulator. The reduction of actuator makes a UMS lighter, more flexible and more energy efficient than a fully actuated one. As a result, study on this kind of system is of great meaning. And many researchers have discussed the control problems presented by UMS in many fields ([1]-[4]).

In the past few years, 2-DOF underactuated pendulum-type systems have been intensively studied by researchers ([5]-[7]). Among them, a two-link underactuated vertical manipulator (UVM) especially attracts a great deal of attention. A two-link UVM is a planar manipulator moving in a vertical plane that has two DOFs and has only one actuator. Acrobot [8] and Pendubot [9] are two well-known examples of this class. For a two-link UVM, a commonly discussed control objective is to stabilize it at the unstable upright equilibrium point from a stable downward equilibrium point. But the complicated nonlinearities and nonholonomic constraint [10] make this objective difficult to achieve by a single controller. An effective method of solving this problem is a switching strategy, which designs two controllers for the two motion subspaces of the two-link UVM respectively and achieves the stabilization of the UVM by switching the controller from one to another. Many stabilizing control approaches have been presented based on

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