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Compliant motion control for handling a single object by two similar industrial robots

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Abstract

In this paper, we propose a compliant motion control strategy for handling a single object by two similar industrial robots. The dynamics of the object carried by the two robots is assimilated to the dynamics of a mass-spring-damper system described by a piecewise linear model (PWA). The coordination of the two robots is accomplished using a master slave synchronization approach dedicated for PWA systems, based on the Lyapunov theory, and solved via Linear Matrix Inequalities (LMIs). The performances of the proposed approach are proved by simulation results and compared to a related approach with larger stability criteria.

Keywords: Robot coordination, Compliant motion, Master-slave synchronization, Lyapunov Theory, PWA systems.

1. Introduction

Several industrial tasks, demanding precision, require robot coordination. A specified operation consists of handling a single object [1]. Compliant motion tasks are manipulation tasks that involve contacts between the manipulated object and the robots in which the trajectory of the manipulators are modified depending on the contact forces [2]. Position/force control is usually used for solving such cooperation problems [3, 4, 5, 6, 7, 8]. In fact, the control in position can ensure a tracking of the desired trajectory of the constraint robot and the control in force ensures a specific desired behavior of the robot when it enters in contact with the handled object. Master slave synchronization can be considered as a promising solution for such problems [9, 10].

This paper proposes a master slave synchronization approach for solving a coordination problem of two similar robots handling a single object. The dynamics of the object carried by the two robots is assimilated to the dynamics of a mass-spring-damper system described by a piecewise linear model (PWA). The master slave synchronization controller is based on the Lyapunov theory and solved via Linear Matrix Inequalities (LMIs).

The paper will be organized as follows: The cooperation problem is presented in the second section. The third section presents the analogical spring-dumper-mass system. A master slave synchronization approach is then applied. The effectiveness of the proposed approach is shown by simulation results and compared to a related approach.

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2. Problem formulation

We consider in this paper the cooperation problem of two industrial robots handling a single object as shown by Fig. 1. The cooperation problem consists on handling a single object and displacing it through a compliance strategy. The control problem will be solved as a master slave synchronization problem of positions and velocities of the two robots as shown by Fig.2.

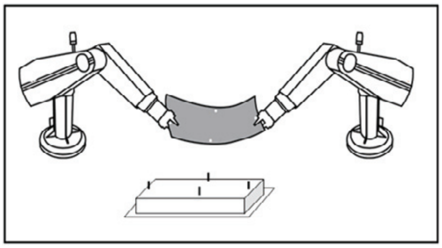

Fig. 1. Two similar robots handling a single object

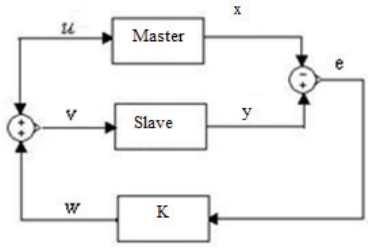

Fig. 2. Controlled master-slave system

3. System modeling

To develop the master slave synchronization approach, an analogical system is chosen [9]. The analogue model shown by Fig.3 is a mechanical system composed of two masses m1 and m2 joined by a spring-dumper combination with a stiffness parameter k and a dumping coefficient c. Masses, springs and dumpers ensure programmable compliances between the robots and the environment (case of the damper c_1), the robot and the object to be displaced (case of the dumper c and the spring k), or the object to be displaced and the second robot (case of the spring k_2). The result is an elastic virtual behaviour that we want to give to the whole moving system thanks to the control law in order to prevent robots and object damaging. We assume, here, that the master robot is actuated by a variable force $u(t) = A_d \sin(wt)$ and the slave's one by the control force $v(t)$ to be computed.

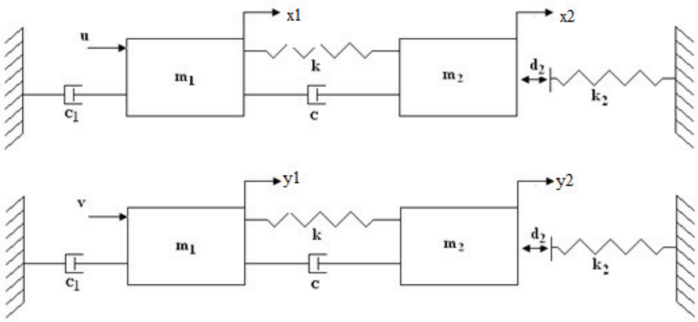

Fig. 3. Analogical spring-dumper-mass master and slave systems.

Using the Newton Euler formalism, the master dynamics are described by:

$$\begin{cases} \ddot{x}_1 = \dfrac{1}{m_1}[-k(x_1 - x_2) - c(\dot{x}_1 - \dot{x}_2) - c_1\dot{x}_1 + u] \\ \ddot{x}_2 = \dfrac{1}{m_2}[-k(x_1 - x_2) + c(\dot{x}_1 - \dot{x}_2) - k_2 g(x_2)] \end{cases} \quad (1)$$