ADAPTIVE CONTROL FOR ROBOTIC MANIPULATORS EXECUTING MULTILATERAL CONSTRAINED TASK

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ABSTRACT

This paper presents a model-based adaptive control in task coordinates for robotic manipulators executing multilateral constrained tasks. The controller works based on the concept of orthogonality between force and motion in the subspaces derived from the constraints. The control gains are independently adjustable in each subspace. The friction force, depending on the contact force, is compensated adaptively. Asymptotic convergence for both force and motion tracking errors is guaranteed by the Lyapunov-Like Lemma. Experimental results obtained using a 3 D.O.F. robot are given.

KeyWords: Robot, manipulator, adaptive control, position and force control, friction.

I. INTRODUCTION

Robot applications, such as polishing, debarring, or assembly, require robots to be mechanically coupled to the environment. Generally, it is demanded that both motion and interaction force be simultaneously controlled during the execution of contact tasks. To this end, the position and force hybrid control [1-2] and the impedance control [3] were developed. McClamroch et al. [4] formulated the constrained robot dynamics in a reduced dynamic model that allows for separate motion and force control strategies. Using the reduced dynamic model approach, researchers have also studied impedance control [5] and adaptive control [6-7]. Generally, the independent freedoms of a robot vary with the constraints, which depend on the task, and it is difficult to investigate the reduced dynamic model in real time.

An adaptive controller is desirable because identification of the robot dynamics is difficult, and the payload often varies among robot tasks. Several adaptive constrained motion control methods that do not use the reduced dynamic model [8-12] have been developed; adaptive control in joint space by Arimoto et al. [8], Liu et al. [9], and J. Yuan [10], and adaptive control in task space by Lozano et al. [11], Siciliano et al. [12], and Kawasaki et al. [13]. These methods guarantee the convergence of motion and force tracking errors though most of them assume that the constraint is unilateral, and the transition between contact and non-contact states is not taken into account. Moreover, the force error and its integral gains are given as scalar gains, which makes gain adjustment difficult, and the friction depending on the contact force is not compensated.

This paper presents a model-based adaptive control method in task space that takes the multilateral constraints between the end-effector of the robot and the environment into account. A control law is constructed for each subspace derived from the constraints, and the control law switches to the following control laws according to the constrained state of the end-effector; adaptive position-force control at the contact state in the constrained subspace, adaptive velocity control at the non-contact state in the constrained subspace, and adaptive position control in the nonconstrained subspace. This scheme guarantees transitions from unconstrained motion to partially constrained motion or constrained motion, and from partially constrained motion to constrained motion based on supposition that there is no bouncing caused by contact motion. Control gains are adjustable in each subspace, which enables simple gain adjustment. The proposed controller also adaptively compensates for friction, depending not only on the position and velocity of the end-effector, but also on the contact force. The asymptotic stability of the controller is proved by the Lyapunov-Like Lemma [14]. Simulational and experimental results obtained using a 3 D.O.F. robot are given to show the effectiveness of the proposed method.