CONTROL AND REAL TIME OPTIMIZATION OF OVERACTUATED COOPERATIVE MANIPULATORS

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Abstract. This paper examines an exact as well as a near optimum method for real time optimization of a dynamic cost function for an overactuated robot. A controller is proposed for this purpose, consisting of two parts; the first part deals with the tracking task while the second part carries out the optimization task. The methods are validated by applying to a four bar linkage as a benchmark problem. They are then used to obtain the optimal solution for a two degree overactuated cooperative robot. The simulation results are provided in order to compare the performance of the methods.

Key Words. Cooperative manipulators, Real time optimization, Overactuated robot control

1. INTRODUCTION

Robot cooperation finds many applications in carrying heavy or big objects with irregular geometries or when large forces are exerted and fine alignment is required. The many problems that have to be resolved in all such applications include kinematic and dynamic aspects, object grasping, and cooperative robots control. Many studies have recently been directed toward the control of robots cooperating in a single task.

Cooperative robots are normally associated with kinematic redundancy or overactuation or both and, consequently, a corollary of cooperative robots is the kinematic or dynamic cost function optimization. Optimal solutions based on the proposed cost functions have usually been obtained offline and the controller is designed in order to keep the system close to an optimal solution.

Orin and Oh (1981) presented a method for reducing energy consumption in a closed loop chain [1]. For the joint torque optimization, Hollerbach and Suh (1987) proposed local and global algorithms for reducing actuator requirements [2]. Optimal control laws minimizing joint torque loading were discussed by Hu and Goldenberg (1993) [3]. Ding and Chan (1996) used a linear programming approach for torque minimization of a redundant manipulator [4]. Bergerman, *et al.* (1998) developed a method for robust control of cooperative manipulators with passive joints using feedback linearization method [5]. Sun and Liu (2000) proposed a method for position and force control of a two-manipulator robot system carrying a flexible beam [6].

In most applications, the motion trajectory is not predetermined in advance of the motion and, thus, a real time optimization is required which has been neglected in previous studies. This paper first investigates the real time optimization of a dynamic cost function in overactuated systems. The methods presented here, which are common to any overactuated system, are implemented on a cooperative robot.

2. STATEMENT OF THE PROBLEM

Consider a manipulator with m degrees of freedom and n actuators where $n > m$.

As an example one can think of two robots with degrees of freedom n_1 and n_2 cooperating for an object manipulation (Fig. 1). Each robot has n_i kinematic DOF and n_i actuators prior to motion