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ADAPTIVE CONTROL OF OBJECT PATH TRACKING AND FINGER TIP SLIPPAGE IN A MULTI-FINGERED ROBOTIC SYSTEM

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ABSTRACT

Considering slippage between finger tips and an object, adaptive control synthesis of grasping and manipulating an object by a multi-fingered system is addressed in this paper. Slippage can occur due to many reasons such as disturbances, uncertainties in parameters and dynamics. In this paper, using a novel representation of friction and slippage dynamics, a new approach is introduced to analyze the system dynamics. Then an adaptive controller with a simple update rule is proposed to ensure the bounded trajectory tracking and slippage control, and at the same time to compensate for parameter uncertainties including coefficients of friction. The performance of the proposed adaptive controller is shown analytically and studied numerically.

1 INTRODUCTION

During the last decades, there has been increasing interest in developing multi-robot systems such as cooperating multi-arm systems or multi-fingered hands, multi-leg walking machine and multi-robot transportation systems. Similar to open chain manipulators or single-arm systems, one can find a large number of researches in the area of multi-robot systems. Due to the complexity, object grasping and transferring in a cycle of multi-robot manipulation is an issue that has been studied seriously by the researchers.

In order to achieve stable grasp, suitable forces are needed to be specified. These forces must satisfy the equilibrium and friction conditions, the constraints introduced by joint actuators, as well as the inward normal contact forces. Two fundamental problems in grasping are; grasp analysis and grasp synthesis. In grasp analysis researchers try to find appropriate conditions for form/force closure grasps, while in grasp synthesis, researchers focus on finding optimality criteria and algorithms for computing the contact locations.

There are large numbers of papers in literature both in grasp analysis and grasp synthesis. Works done by Reulaux, **1963**, and Salisbury and Roth, **1983**, are the early works in grasp analysis where they introduced the concept of force/form closure and several contact types [1-2]. Mishra et al., **1987**, proposed necessary and sufficient conditions for force-closure grasp with friction point contacts (FPCs) [3]. Bicchi, **1995**, translated the force-closure problem into the stability of an ordinary differential equation [4]. Implementing the well-known force-closure conditions that the origin of the wrench space lies in the interior of the convex hull of primitive wrenches, Liu, **1999**, developed a ray-shooting based algorithm using the duality of polytopes with the linearization of the friction cone [5]. Because of its high efficiency in 3D work space and no limitation on the contact number of a grasp, Zheng and Qian, **2006**, enhanced the ray-shooting approach proposed by Liu to complete the exactness, increase the efficiency and extend the scope [6].

In grasp synthesis, Mishra et al. in 1987, [3], Park and Starr in 1992, [7], Tung and Kak in 1996, [8], Liu in 2000, [9], Zhu and Ding in 2006, [10], Morales et al. in 2006, [11], Al-Gallaf in 2006, [12], and many other researchers, [13-18], presented various optimality criteria and efficient algorithms for different multi-fingered robotic applications and different types of manipulated object. The common assumption in the mentioned researches is considering fixed contact between finger tip and the manipulated object during the cooperating manipulation.

Considering sliding contacts, Kao and Cutkosky, 1993, compared theoretical and experimental sliding motions for a sheet of paper or similar objects on a planar surface, by a two-fingered hand, using static equilibrium equations [19]. Chong et al., 1993, proposed a motion/force planning algorithm for multi-fingered hands manipulating an object of an arbitrary

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