INTERNATIONAL JOURNAL OF ROBOTICS
(THEORY AND APPLICATIONS)
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# Modifying a Conventional Grasping Control Approach for Undesired Slippage Control in Cooperating Manipulator Systems

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ARTICLE INFO

*Keywords:*
cooperating systems,
grasping, slippage control,
frictional point contact

ABSTRACT

There have been many researches on object grasping in cooperating systems assuming no object slippage and stable grasp and the control system is designed to keep the contact force inside the friction cone to prevent the slippage. However undesired slippage can occur due to environmental conditions and many other reasons. In this research, dynamic analysis and control synthesis of a cooperating system, considering slipping conditions are performed. Equality and inequality equations of the frictional contact conditions are replaced by a single second order differential equation with switching coefficients in order to facilitate the dynamical modeling and control synthesis. Using this new modeling of friction, a conventional approach in grasping control is modified and presented to control any undesired slippage of the end-effectors on the object.

## 1- Introduction

Grasping is an important issue in cooperating systems such as multi-fingered hands and multiple robots. Numerous reports can be found on grasp planning. Researches on grasp planning focus on two category problems: grasp analysis and grasp synthesis. In grasp analysis, most of the researchers have focused on finding appropriate conditions for force-closure grasps. Early, Reulaux introduced the notion of force-closure and form-closure [1]. Using screw theory, Salisbury and Roth developed several different types of finger contacts and showed which finger configurations allow complete immobilization of the gripped object relative to the fingers as well as manipulation of the object while maintaining the grasp [2]. With the linearization of the friction cone, Liu developed a ray-shooting based algorithm using the duality of polytopes [3]. Zheng and Qian enhanced the ray-shooting approach proposed by Liu to complete the exactness, increase the efficiency, and extend the scope [4]. With this, the general problem of determining if a grasp is force closure is considered to be completely solved.

Having sufficient conditions for force closure, grasp synthesis deals with optimal grasping. This synthesis consists of: 1) determination of the optimality criteria and, 2) derivation of methods and algorithms for computing contact locations with respect to the optimality criteria and accessibility constraints. Liu et al. introduced several candidate grasp quality functions and formulated the grasp synthesis problem as a max-transfer, max-normal-grasping-force, and a min-analytical-center problem [5]. Based on the geometric condition of the closure property, Zhu and Ding presented a numerical test to quantify how far a grasp is from losing form/force closure. They also developed an iterative algorithm for computing optimal force-closure grasps [6]. Morales et al. addressed the problem of designing a practical system able to grasp real objects with a three-fingered robot hand. They presented a general approach for synthesizing two and three-finger