

A NEW APPROACH ON DYNAMIC ANALYSIS AND CONTROL SYNTHESIS OF OBJECT GRASPING BY MANIPULATORS

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ABSTRACT

Almost all of the researches on object grasping by manipulators and cooperating robots consider no slippage between end-effectors and object, however it can occur. This paper presents dynamics analysis and control synthesis of a manipulator moving an object on a horizontal surface using contact force of end-effector considering slipping condition. Equality and inequality equations of frictional contact conditions are replaced by a single second order differential equation with switching coefficients in order to facilitate the dynamical modeling. Using this modeling of friction, a set of reduced order form is obtained for equations of motion of the system and a new method is proposed to control end-effector slippage on the object.

KEY WORDS

Frictional grasping, Slippage control, Simulation, Modeling.

1. Introduction

Grasp analysis and grasp synthesis are two major categories in the study of grasp planning. Many papers exist on testing and planning force-closure grasps. In grasp analysis, researches have been focused on finding appropriate conditions for force-closure grasps. Early, 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, and also allow for the manipulation of the object by the fingers while maintaining the grasp, using screw theory [1]. With the linearization of the friction cone, Liu developed a ray-shooting based algorithm using the duality of polytopes [2]. Zheng and Qian enhanced the ray-shooting approach proposed by Liu to complete the exactness, increase the efficiency and extend the scope [3]. Using linear matrix inequality representation of nonlinear friction cone constraints, Han et al. reformulated the force-closure problem as the feasibility problem of a semi-definite or max-det problem and used an interior point algorithm for it [4].

In grasp synthesis, researchers mostly deal with optimal grasping and try to: 1) determine optimality criteria and 2)

derive methods and algorithms for computing contact locations with respect to the optimality criteria and subject to accessibility constraints. Liu presented an efficient algorithm for computing all n-finger form-closure grasps on a polygonal object based on a new sufficient and necessary condition for form-closure. With this new condition, it is possible to transfer the problem of computing the form-closure grasp in R^3 to one in R^1 [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 grasps on planar unknown objects using visual perception [7]. Al-Gallaf presented a novel neural network for dexterous hand-grasping inverse kinematics mapping used in force optimization. He showed that the proposed optimization is globally convergent to the optimal grasping force [8]. Liu et al. proposed a complete and efficient algorithm for searching form-closure grasps of n hard fingers on the surface of a three-dimensional object represented by discrete points [9].

All of the above researches consider no slip in grasping, and control systems try to keep control forces lied in the friction cone. However slippage can occur during the grasping maneuver due to many reasons, such as changes in the object geometry, friction coefficient, etc. None of the previous researches perform good analysis of slipping phenomena in these cases. In this research, dynamic analysis and control synthesis of a manipulator moving an object on a surface using contact forces and considering slipping condition has been performed. The system under consideration is a platform for further extension to grasping analysis of a cooperative manipulator carrying out an object while slipping condition can occur.

2. Dynamic analysis

The system under consideration is shown in Figure 1