# Modeling and Control of 2-D and 3-D Object Grasping and Manipulation under Nonholonomic constraints

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Robot hands mimicking a human hand have always drawn much attention from many robotics researchers. In fact, human hand has interesting characteristics such as redundancy in joint degrees of freedom, soft finger tip, rolling contact, and fingers-thumb opposability. According to survey papers, the traditional researches of robot hands mainly concentrated on static or quasi-static grasp. Among them, most works dealt with open loop control based upon motion planning of all finger joints and the object and employed the computed torque method. Furthermore, rolling constraints between finger tips and the object surfaces were not dealt with in dynamic analysis but static one. On the other hand, it is well known that finger-thumb opposability played a vital role in evolution of homo-sapience. However in robotics, any control method based on finger-thumb opposition had not drawn much attention until very recent years.

This thesis aims to derive a mathematical model that expresses motion of a pair of multi-joint robot fingers with hemi-spherical rigid or soft ends grasping and manipulating a 2-D rigid object with parallel or non-parallel flat surfaces or a 3-D rigid object with parallel ones under the gravity effect. This multi-body dynamics with constraints can express motion of the fingers and object physically interactive to each other. According to a simple control signal constructed from finger-thumb opposition called ``blind grasping'' without using object information or external sensing, it is shown that the closed-loop dynamics converges to some equilibrium state satisfying force/torque balance under the gravity effect by the theoretical proof of stability, the numerical simulation results, and the actual experiment ones.

A noteworthy difference of controls between 2-D and 3-D cases is that the instantaneous axis of rotation of a 2-D object is fixed but that of any 3-D object is changeable throughout its movement, which induces a non-holonomic constraint. A further extra nonholonomic constraint is shown to arise from assuming that spinning does no more arise around the opposing axis connecting two contact points. This thesis aims at ordering these non-holonomic constraints and Euler-Lagrange equations and proposing an algorithm to carry out numerical simulation of the overall system motion. By using this simulator, a class of control input signals constructed without using object parameters or external sensing (visual or tactile) is found, which realize precision prehension in a blind manner.