

Dexterous Manipulation of Objects by Single Fingers and Pairs of Fingers with Soft-Tips

Pham Thuc Anh Nguyen

Recently, a good number of robots works in automation lines of factories to improve quality and efficiency of manufacturing and more importantly, to replace human in difficult tasks that may jeopardize human safety and health. However, in executing tasks that human does in everyday life such as grasping things, packing them in boxes, cleaning a window, etc, which require a certain level of dexterity and versatility, complex multi-joint robots and even multifingered robot hands are rather clumsy. It is claimed that the clumsiness of robots is due to our limited knowledge involving to fundamental problems such as formulation of mathematical models in a full form of dynamics of the overall system and design of effective feedback paths connecting from sensing to motor control at joints.

The goal of the thesis is to realize dexterity and flexibility like human fingers into a system of single multi DOF finger and typical pairs of multi DOF fingers. Two fundamental problems: 1) formulation of mathematical models of dynamics and 2) design of sensory feedback control laws are solved. The noteworthy characteristics of concerned fingers are that their finger-tips are covered by soft and deformable material and hence they interact with objects and environment by soft- and area-contacts. The thesis consists of two main parts: 1) controlling of the interacting force between a single soft-tip finger and an unmoved object and 2) stable grasping and object manipulation by a pair of multi-DOF fingers with soft tips.

In the first part, it is pointed out that the characteristics of reproducing force with respect to the maximum displacement of a soft finger-tip is nonlinear. Then, by extending the impedance control scheme to cope with such nonlinear dynamics, both the controls of setpoint contact force and tracking of periodic contact force are established.

In the second part, dynamics of the overall system of a pair of fingers manipulating an object are derived and a computer simulation method for object manipulation under geometric constraints due to area contacts between the object and finger-tips is presented. It is shown that there are various feedback connections from sensing to action for such complex nonlinear dynamics if the rotation angle of the object can be measured. Finally, it is verified by computer simulations that a principle of linear superposition of such feedback signals is effective and practical in realizing dynamic stable grasping together with controls of the posture and position of the mass center of the object.