

Chapter 16

Robotic Grippers, Grasping, and Grasp Planning

Seyed Javad Mousavi

Tarbiat Modares University, Iran

Ellips Masehian

Tarbiat Modares University, Iran

ABSTRACT

Utilizing robotic hands for manipulating objects and assembly requires one to deal with problems like immobility, grasp planning, and regrasp planning. This chapter integrates some essential subjects on robotic grasping: the first section presents a concise taxonomy of robotic grippers and hands. Then the basic concepts of grasping are provided, including immobility, form-closure, and force-closure, 2D and 3D grasping, and Coulomb friction. Next, the principles of grasp planning, measures of grasping quality, pre-grasp, stable grasps, and regrasp planning are presented. The chapter presents comparisons for robotic grippers, a new classification of measures of grasp quality, and a new categorization of regrasp planning approaches.

INTRODUCTION

Mechatronics Engineering concerns with a wide spectrum of technologies, puts forth new concepts in modern product design, and provides methodologies not only for producing high-quality products, but also for their maintenance and application. In other words, the whole period of the product lifecycle is considered. Mechatronics can be viewed as a width synergy of the techniques and

technologies that deal with precise and intelligent mechanisms, smart sensors, moving devices (e.g., robots, AGVs, etc.), real-time control, biomimetics, etc. In this field, engineers encounter with a wide range of systems, devices, tools, robots, and information (Habib, 2008). Therefore, when the product lifecycle is concerned, the role of robots in reducing production costs, improving quality, and increasing production speed become more significant.

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A vital part of any industrial robot is its end-effector, which is a gripper, hand or tool devised for performing the task entrusted to the robot. Accomplishing a given task successfully depends on correct and effective planning of the end-effector movements, and that's why robot and tool path planning has been and currently is on the focus of many robotics researchers. Specifically, when the end-effector is in the form of a human hand, such a planning becomes a challenge since it must be able to stably hold and manipulate objects and parts.

Performing tasks like automated grasping, manipulating, and placing of parts by robotic hands requires advanced skills in object identification, pose analysis, motion planning, effective and stable grasp calculation, and precise execution. In this regard, planning reliable and effective grasping for robot end-effectors like grippers and hands becomes indispensable.

Utilizing robotic hands for manipulating objects and assembly parts needs dealing with problems like immobility, grasp planning, and regrasp planning. Immobility is a state in which a series of kinematic constraints prevent an object from translation along orthogonal axes or rotation about any arbitrary axis. Grasping addresses whether or not an object is being held in form-closure or force-closure, and grasp planning specifies how form- and force-closure grasps can be done, defines an objective function, and optimizes the grasping based on that function. A problem may occur when the position of an object in a feasible grasping does not match with its final and required placement position, and that is when an additional grasping is needed from another direction or position. This is called regrasping, and planning for it is known as regrasp planning, which can be done in various ways.

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Next the principles of grasp planning, measures of grasping quality, pre-grasp, stable grasps and regrasp planning are presented.

The purpose in writing this chapter has been to present a unified treatise on the principles and state of the art of grasping and grasp planning as a guide to the interested researchers who wish to explore this vibrant research field.

ROBOTIC GRIPPERS

A robotic gripper is a type of end-effector that comes into contact with the workpiece and hold or manipulates it. The varieties of robotic grippers can be divided into four main categories: mechanical grippers, vacuum and magnetic grippers, universal grippers, and multi-fingered hands. End-effectors are inspired from either tools with extended capabilities, or human hand and fingers, although there have been some new creations with novel mechanisms. In the following each category is explained in brief (Praveen, 2013).

1. **Mechanical Grippers:** Based on their mechanisms, mechanical grippers exist in the following main types:
 - a. **Linkage Grippers:** In this type no gears and racks are used and their movement is caused by inward and outward connection of joints and junctions. The outer jaw opens and closes as a result of the movement of internal joints (Figure 1a).
 - b. **Gear and Rack Grippers:** In this type the movement of the gripper's jaw is caused by motion of a gear which in turn moves the racks being in contact with it (Figure 1b).
 - c. **Cam-Actuated Grippers:** In this type the motion of cams produce translational movements of links in contact with them, and results in gripping. A variety of cam profiles can be used for

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