Part D

Manipula

Part D Manipulation and Interfaces

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Part D Manipulation and Interfaces, is separated into two subparts; the first half is concerned with manipulation where frameworks of modeling, motion planning, and control of grasp and manipulation of an object are addressed, and the second half is concerned with interfaces where physical human–robot interactions are handled. Humans can achieve grasping and manipulation of an object dexterously through hand–arm coordination. An optimum control skill for such a redundant system is naturally and gradually acquired through experience in our daily life. Especially, fingers play an important role for expressing human dexterity. Without dexterous fingers, it is hard for us to handle any daily tool, such as a pencil, keyboard, cup, knife, or fork. This dexterity is supported with active and passive compliance as well as the multiple sensory organs existing at the fingertip. Such dexterous manipulation enables us to clearly differentiate humans from other animals. Thus, manipulation is one of the most important functions for humans. We eventually acquired the current shape of finger, the sensory organs, and skill for manipulation, through a long history of evolution, over more than six million years. While both humans and robots are largely different in terms of actuators, sensors, and mechanisms, achieving dexterous manipulation like that of a human in a robot is a challenging subject in robotics. As we overview current robot technology, however, we observe that the dexterity of robots is still far behind that of humans. With this overview, we now provide a brief synopsis of each chapter in the first half of Part D.

Chapter 26, Motion for Manipulation Tasks, discusses algorithms that generate motion for manipulation tasks at the arm level, especially in an environment, by using the configuration space formalism. While in previous chapters (6 and 7) the focus was on specific algorithmic techniques for robot motion, this chapter is focused on a specific application for robot manipulation.

Chapter 27, Contact Modeling and Manipulation, provides contact modeling based on soft as well as rigid contacts. Kinematics and mechanics with friction are precisely handled under rigid-body contact. The selection matrix H is introduced to understand the force and velocity constraints at the contact interface. Pushing manipulation is also addressed by using the concept of the friction limit surface.

Chapter 28, Grasping, discusses, based on the closure property, grasping with many examples, supposing multifingered robotic hands. A strong constraint for grasping is the unilateral characteristic, where a fingertip can push but not pull an object through a contact point. Kinematics and closure issues are addressed under this unilateral constraint.

Chapter 29, Cooperative Manipulators, addresses the strategies for controlling both the motion of cooperative system and the interaction forces between the manipulators and the grasped object when two manipulator arms firmly grasp an common object. It should be noted that this chapter allows the bilateral constraint where both directional force and moment are permissible.

Without dexterity like that of humans, future robots will not be able to work instead of humans in environments where human cannot enter. In this sense, the implementation of dexterity into robots is one of the highlights of future robot design. Chapters 26–29 provide a good hint for enhancing dexterity for robots.

The second half of Part D addresses interfaces where humans control a robot or multiple robots through direct or indirect contact with robot(s). We now provide a brief synopsis of each chapter in the second half of Part D.

Chapter 30, Haptics, discusses robotics devices that allow human operators to experience the sense of touch in remote or virtual environment. In haptic device design, two classes of haptic devices are discussed. One is an admittance haptic device that senses the force applied by the operator and constrains the operator's position to match the appropriate deflection of a simulated object or surface; the other is an impedance haptic device that senses the position of the operator and then applies a force vector to the operator according to the computed behavior of the simulated object or surface.

Chapter 31, Telerobotics, starts with a discussion on the classification of three different concepts: direct control where all slave motions are directly controlled by the user via the master interface, shared control where task execution is shared between direct control and local sensory control, and supervisory control where the user and slave are connected loosely with strong local autonomy. Various control issues such as time delay are also addressed.

Chapter 32, Networked Telerobotics, includes three components: a user, where anyone with an Internet connection is allowed, a web server on which an Internet-compatible server software can run, and a robot including a robot manipulator, mobile robot, or any device that can change its environment. The Internet is a powerful tool for controlling a robot (or robots), since it is the most popular communication media. We may see an enormous market for this in the future, and great care is required to ensure security.

Chapter 33, Exoskeletons for Human Performance Augmentation, deals with power-assist systems where human power is enhanced by wearing a robotic suit. In a human–robot system, we can consider that the distance between the human and the robot is zero as an extreme case. Design of hardware and control issues are precisely discussed by taking the Berkeley Lower Extremity Exoskeleton (BLEEX) as an example.

In both Telerobotics (Chap. 31) and Networked Telerobotics (Chap. 32), an appropriate distance between the human and robot is kept, while in both Haptics (Chap. 30) and Exoskeletons (Chap. 33), direct contact between human and robot is made. One of the main issues is how to maintain appropriate control performance of the system in the presence of humans or a time lag between humans and robots.