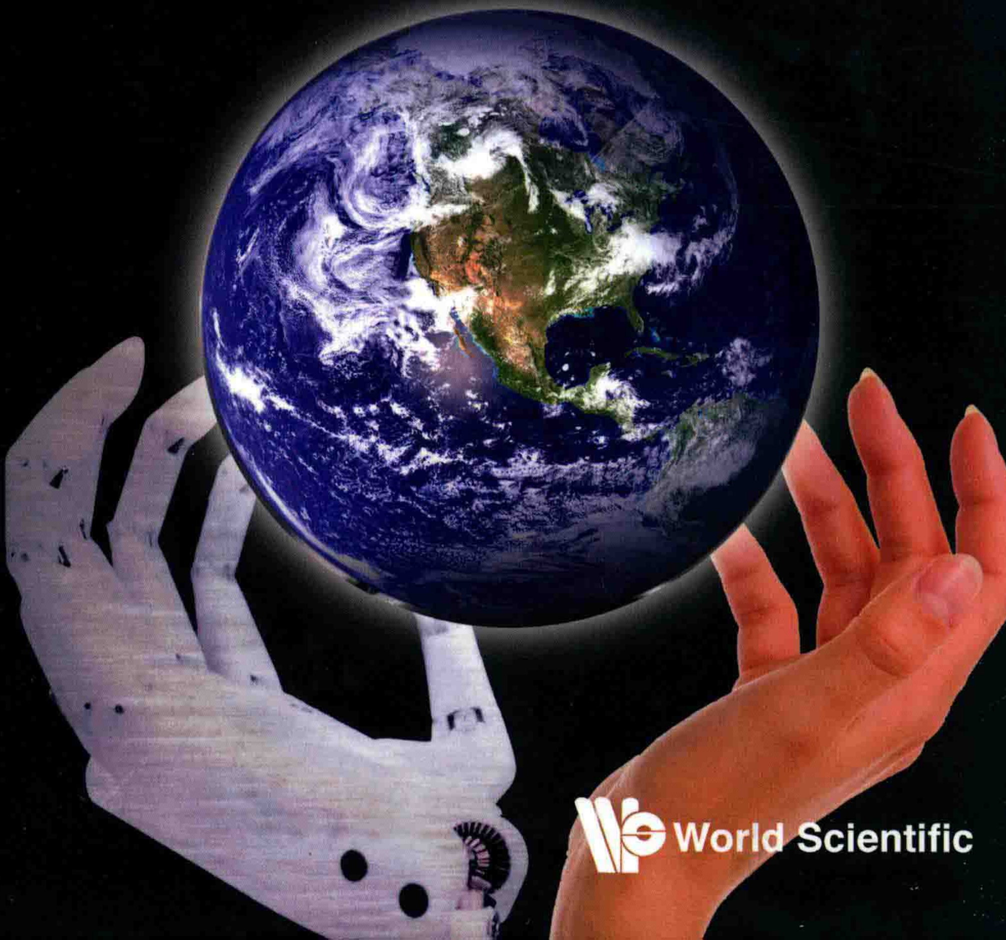
Haruhisa Kawasaki

ROBOT HANDS AND MULTI-FINGERED HAPTIC INTERFACES

Fundamentals and Applications



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About the Author

Prof. Haruhisa Kawasaki (born on 27th June 1949) is a Professor in the Department of Mechanical Engineering, Faculty of Engineering (1994–present), and the Kawasaki & Mouri Laboratory in Gifu University, Japan. He is a Senior Member of IEEE, and a Fellow of the Japan Society of Mechanical Engineers, the Robotics Society of Japan, and the Virtual Reality Society of Japan. Prof. Kawasaki is also a member of the Society of Instrument and Control Engineers. His current research interests include Robot Control, Humanoid Robot Hands, Haptic interfaces, Virtual Reality Systems, Hand Rehabilitation Support Systems, and Computer Algebra of Robotics.

Prof. Kawasaki was the National Organization Committee Chair of IFAC SYROCO 2009. Among many other awards and honors, in 2004 he received the Best Paper Award at the World Automation Congress; in 2006, he was honored with a Minister Award from the Ministry of Education, Culture, Sports, Science and Technology of Japan; in 2009, he was the recipient of the Governor Award of the Japan Institute of Invention and Innovation; in 2010, he was given the Industry–Academia–Government Collaboration Promotion Award by the Ministry of Internal Affairs and Communications, as well as a Robotics and Mechatronics Academic Achievement Award from the Robotics and Mechatronics Division of JSME (the Japan Society of Mechanical Engineers); in 2013, he won the IEEE/ASME Transactions on Mechatronics (TMCH) Best Paper Award.

Prior to his academic career, Prof. Kawasaki was a research engineer (1974–1990) at Nippon Telegraph and Telephone Corporation, Japan. From 1990–1994, Prof. Kawasaki served as a Professor in the Kanazawa Institute of Technology Japan. Prof. Kawasaki received his M.Sc. and Ph.D. in Aeronautical Engineering from Nagoya University, Japan, in 1974 and 1986 respectively.

Preface

Multi-fingered robot hands are expected to replace human hands in the dexterous manipulation of objects. When a robot grasps an object, its fingers come into contact with the surface of the object, and its hand motion is constrained by that contact. For dexterous manipulation, a basic understanding of the contact model between a finger and an object, the motion constraint during contact and the dynamics of these constraints is important. Furthermore, the dynamics of robot hands are non-linear, and require control methods that take constraints into consideration.

Haptic interfaces are used to present force and tactile feeling to humans in cases of robot telecontrol, when manipulating objects in a virtual reality (VR) environment, playing games with tactile feeling, and so on. Multi-fingered haptic interfaces have tremendous potential to provide realistic sensations of touch to human fingertips and to cover the workspace of the human arm. Haptic interfaces are one of the major applications for multi-fingered hand robots, but science and technology based on human tactile perception are needed to design and control multi-fingered haptic interfaces.

This book briefly compares human hands and robot hands, discusses the design of robot hands, contact models at grasping, kinematic models of constraint, dynamic models of the multi-fingered hand, the stability theorem of non-linear control systems, robot hand control, design and control of multi-fingered haptic interfaces, application systems using multi-fingered haptic interfaces, and telecontrol of robot hands using a multi-fingered haptic interface.

This book is intended mainly for readers who have already studied basic robot arm engineering. There are many books related to robot arms and non-linear control. To understand robot hand manipulation, however, readers must study kinematic constraint models of fingers, hand dynamics with constraints, stability theorems of non-linear control, and multi-fingered hand control — This book is designed to specifically and comprehensively address these subjects. *Robot Hands and Multi-Fingered Haptic Interfaces* will benefit readers' understanding of the full range of issues regarding robot hand manipulation. Furthermore, the design and control of multi-fingered haptic interfaces are necessary to telecontrol multi-fingered robot hands.

A Brief Rundown of the Chapters

This book is organized into eight chapters:

Chapter 1 — *The Human Hand and the Robotic Hand*: This chapter describes the outline including the structure of the human hand, human grasping, and the structure of a humanoid robot hand called the Gifu Hand. Furthermore, it presents the configuration of a multi-fingered haptic interface called the HIRO, which is a new application of the robot hand.

Chapter 2 — *Kinematics of Multi-Fingered Hands*: Here, we present basic kinematics in terms of the grasp by a multi-fingered robot hand, including contact models, forms of grasps, constraint conditions, manipulable grasps, and so on.

Chapter 3 — *Kinematic Constraint and Controllability*: When a robot grasps an object, the robot hand comes into contact with the surface of the object, and the object in turn, is in contact with its environment and is influenced by it (e.g. friction and gravitational force). Robot hand motion is constrained by these contacts. This chapter presents fundamentals of holonomic and non-holonomic constraints, and the controllability of the constraint system.

Chapter 4 — *Robot Dynamics*: This chapter reviews basic methodologies for dynamics in robot hands. The dynamic model is widely used in the simulation of robot motion, analysis of robot hand structures, and design of control algorithms. When a robot hand with multiple fingers grasps an object, the hand motion is restricted in order to keep contact with the object. A dynamics model with constraint is derived.

Chapter 5 — *Stability Theorem of Non-Linear Control Systems*: Robots are non-linear dynamical systems. This chapter describes the fundamentals of the stability theorem for non-linear autonomous systems and non-linear non-autonomous systems.

Chapter 6 — *Robot Hand Control*: The cooperative control of multiple fingers is a basic technology of dexterous manipulation. In most control laws, it is assumed that the dynamics' parameters are known. However, it is often difficult to find the exact dynamics of the system. In addition, the dynamics parameters will vary depending on the object being manipulated. This chapter describes impedance control for manipulating an object with multiple fingers, computed torque control, and adaptive control based on estimated dynamics parameters.

Chapter 7 — *Multi-Fingered Haptic Interface*: This chapter focuses on the fundamentals of haptic interface control, and on hand manipulability-based control for multi-fingered haptic interfaces that equip haptic arms. Applications that use a multi-fingered haptic interface, including a hand-rehabilitation support system, a measurement system for breast engorgement, a surgery training system using plural devices, a breast palpation training system, and a skill-transfer system, are presented.

Chapter 8 — *Teleoperation of Robot Hands*: Teleoperation technology generally uses a master–slave system, where the 'master' is a haptic interface operated by a human, and the 'slave' is a remotely located robot. The slave then moves according to motions generated through the master system. Human biological signals have also been used as a type of master system for the command of robots. One typical application is the myoelectric controlled hand. This chapter presents the fundamentals of the master–slave system, teleoperation of robot hands through a multi-fingered haptic interface, and prophetic hand control by surface electromyogram (sEMG).

Answers to the Exercises are presented in the back-matter of the book.

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Haruhisa Kawasaki.

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