Preface

This book describes a unifying framework to networked teleoperation systems cutting across multiple research fields including networked control system for linear and nonlinear forms, bilateral teleoperation, trilateral teleoperation, multilateral teleoperation, cooperative teleoperation, and some teleoperation application examples. Networked control has been deeply studied at the intersection of systems & control and robotics for a long time, and many scholarly books on the topic have been already published. Nevertheless, the approach remains active even in several new research fields, such as bilateral teleoperation, single master and multiple slaves, trilateral teleoperation, and multilateral teleoperation. Indeed, all the targeted problems of this book are rather new from a historical point of view and, to the best of our knowledge, there is no book or article covering such a broad class of problems within a unified teleoperation framework.

Although networked teleoperation control and applications have attracted much research attention in the past decade, many fundamental problems are still either unexplored or less well understood. In particular, there still lacks a comprehensive framework that can cope with all the core issues in a systematic way. This motivated us to write the current monograph.

The book presents theoretical explorations on several fundamental problems for several kinds of teleoperations. By integrating fresh concepts and state-of-the-art results to form a systematic approach for the motion control and identification, a fundamental theoretical framework is formed toward teleoperation systems.

This book shall educate readers about the fundamental advances in the networked teleoperation research area. It is expected that the reader will require limited background knowledge to understand the various concepts and results outlined in the book. Besides elegantly unifying disparate problems, the networked teleoperation control approach also leads to practical advantages over other approaches, which will also be a benefit to readers. In the teleoperation part, readers will observe the inherent robustness of the networked controller against communication delays. Finally, a notable feature of this book is to provide not only theoretical results and techniques but also experimental case studies on a testbed of robotic systems, which is anticipated to highly motivate young students and researchers.

The book has been organized into the following chapters.

Chapter 1 introduces the teleoperation system description, background, and motivation of the study and presents several general concepts and fundamental observations which provide a sound basis for the book.

Chapter 2 concisely reviews the necessary mathematics including linear algebra, controllability and observability, stability theory, linear matrix inequalities, stochastic systems, and time-delay systems.

Chapter 3 describes the kinematics and dynamics of the robotic system system. The kinematics and dynamics equations for both master and slave robots are derived in order to give the fundamentals of simulation. Moreover, based on the derived networked model, continuous time delay model and random time delay model are also derived in the chapter, which are used to derive the corresponding controllers.

In Chap. 4, nonlinear control method is developed for the networked bilateral teleoperation system with rigid joints, and a model-based PD control is investigated for the underactuated teleoperation system with flexible joints. Both controls have considered motion synchronization and robust stability in bilateral teleoperation with time-varying delay.

In Chap. 5, adaptive hybrid position/force controls of bilateral teleoperation system in the joint space and operational space are both investigated in the presence of dynamical uncertainties, where the motion (velocities/positions) and force of the master and the slave in the two spaces are synchronized when the slave is subject to holonomic constraints.

In Chap. 6, adaptive neural network control for single-master-multi-slaves teleoperation is presented systematically for the remote control of coordinated multiple mobile manipulators which carry a common object in the presence of uncertainties and disturbances.

In Chap. 7, position and force coordination are both considered in the systematic framework of trilateral teleoperation, the communication delays are assumed to be stochastic, and dynamical uncertainties are assumed to be imprecise.

In Chap. 8 adaptive fuzzy control for multilateral teleoperation of two cooperating robotic manipulators manipulating an object with constraint trajectory/force is discussed, in the presence of dynamics uncertainties and random-network-induced delays. The inter-connected dynamics consisting of two master robots and two cooperating slave robots have been formulated, and Markov processes are used to model these random-network-induced delays.

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We are greatly indebted to our parents and families for their love, support, and sacrifice over the years. It is our pleasure to dedicate the book to them for their invisible yet invaluable contribution.

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