Preface

In the past decades, recurrent neural networks have been widely investigated by many scientific and engineering communities. In particular, Hopfield neural network, originally designed for real-time optimization, triggers the studies on recurrent neural networks as a powerful online optimization tool. Recurrent neural network-based optimization methods have become independent research direction in online optimization field. It was later found that the kinematic control of robot arms can be formulated as a constrained convex quadratic programming (QP) problem, which can be efficiently solved via neural network approaches. Although many results have been reported on the kinematic control of a single robot arm, there are much less existing results on the cooperative control (especially fully distributed cooperative control) of multiple robot arms. It should be noted that the cooperation of multiple robot arms becomes demanding when tasks in industry to be completed by robot arms become more complex. In view of the successful applications of neural networks on the kinematic control of a single robot arm, it is interesting to extend existing results to the case with multiple robot arms.

In this book, mainly focusing on the cooperative control of multiple robot arms, we design, propose, develop, analyze, model, and simulate various decentralized or distributed neural network models and algorithms. We first present a neural network model for the visual servoing of a single robot arm so as to provide some basic ideas about the kinematic control of robot arms for the potential readers. Then, we move on to the cooperative control of multiple robot arms. Specifically, we investigated neural network models and algorithms for decentralized control of a group of multiple robot arms with a star control topology, hierarchical control topology, and fully distributed control topology, respectively. For all the models and algorithms, the corresponding theoretical analyses are presented, and the corresponding modeling is illustrated. Besides, the related computer simulations with various illustrative examples (most of which are related to the PUMA 560 industrial robot arm) are performed to show the effectiveness of the recurrent neural network models in achieving the cooperative control of multiple robot arms.

The idea for this book on solving cooperative control of multiple robot arms was conceived during the classroom teaching as well as the research discussion in the laboratory and at international scientific meetings. Most of the materials in this book are derived from the authors' papers published in journals, such as IEEE Transactions on Neural Networks and Learning Systems. It is worth pointing out that since the early 1980s, research on recurrent neural networks has undergone exponential growth, and many new theoretical concepts and tools (including the authors' ones) have been obtained. Meanwhile, the new results have already been successfully applied to solving practical problems. To make the contents clear and easy to follow, in this book, each part (and even each chapter) is written in a relatively self-contained manner.

This book is divided into the following four chapters.

Chapter 1—In this chapter, the kinematic control of a single robot arm with an eye-in-hand camera for visual servoing is investigated by using neural networks. The visual servoing problem is formulated as a constrained quadratic program, which is then solved via a recurrent neural network. By this approach, the visual servoing with respect to a static point object is achieved with the feature coordinate errors in the image space converging to zero. Besides, joint angle and velocity limits of the robot arm are satisfied, which thus enhances the safety of the robot arm during the visual servoing process. The performance of the approach is guaranteed via theoretical analysis and validated via a simulative example.

Chapter 2—In this chapter, the decentralized robot arm cooperation problem with a star control topology is studied. The problem is formulated as a constrained quadratic program, and then a recurrent neural network with independent modules is presented to solve the problem in a distributed manner. Each module in the neural network controls a single manipulator in real time without explicit communication with others, and all the modules together collectively solve the common task. The global stability of the presented neural network and the optimality of the neural solution are proven in theory. Application-orientated simulations demonstrate the effectiveness of the method.

Chapter 3—In this chapter, the decentralized robot arm cooperation with a hierarchical control topology is studied. We present in this chapter a novel strategy capable of solving the problem even though there exist some manipulators unable to access the command signal directly. The cooperative task execution problem can be formulated as a constrained quadratic programming problem. By replacing the command signal with estimations with neighbor information, the control law becomes to work in the partial command coverage situation. We then prove in theory that the system indeed also globally stabilizes to the optimal solution of the constrained quadratic optimization problem. Simulations demonstrate the effectiveness of the method presented in this chapter.

Chapter 4—In this chapter, the cooperative kinematic control of multiple robot arms with a fully distributed control topology by using distributed recurrent neural networks is considered. The problem is formulated as a constrained game, where energy consumptions for each robot arm, saturations of control input, and the topological constraints imposed by the communication graph are taken into account. An implicit form of the Nash equilibrium for the game is obtained by converting the problem into its dual space. Then, a distributed dynamic controller based on recurrent neural networks is devised to drive the system toward the desired Nash equilibrium to seek the optimal solution of the cooperative control. Global stability and solution optimality of the neural networks are proved in theory. Simulations demonstrate the effectiveness of the method presented in this chapter.

In summary, this book mainly presents methods and algorithms for the cooperative control of multiple robot arms via neural networks, together with the corresponding theoretical analysis and simulative examples. This book is written for graduate students and academic and industrial researchers in the field of control, robotics, neural networks, simulation, and modeling. This book covers the kinematic modeling and control of serial robot arms. It provides not only rigorous theoretical analysis on the neural network-based methods and algorithms for robot arm control, but also many intuitive simulation examples about a type of classical industrial robot arms called PUMA 560. We do hope that this book will benefit the readers, in terms of knowing the basic ideas in the kinematic modeling of serial robot arms, recurrent neural networks, cooperative control of multiple robot arms. We also hope that the presented new advancements in the field of neural networks and cooperative control of robot arms could trigger new theoretical tools and practical applications.

At the end of this preface, it is worth pointing out that, in this book, some distributed methods for the cooperative control of multiple robot arms and their applications are provided. The ideas in this book may trigger more studies and researches in neural networks and robotics, especially neural network-based cooperative control of multiple robot arms. There is no doubt that this book can be extended. Any comments or suggestions are welcome, and the authors can be contacted via e-mail: shuaili@polyu.edu.hk (Shuai Li).

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