Preface

The stabilization of large-scale systems has been extensively studied over last years. In the modeling of large-scale systems which are composed of interconnected subsystems, the significant uncertainty is represented by the interconnections among the subsystems. To achieve realizable control of large-scale systems, decentralized controllers must be used. It means that the structure and parameters of decentralized control have to be designed using mathematical models of subsystems in such a way that the achievement of the control goal for the overall system is guaranteed and each local controllers is independent of other large-scale system local controllers of the interconnected system. For nonlinear systems, these requirements demand new approaches to the design of decentralized control. Additional obstacles may be caused by uncertainty which complicates both design of control system and its justification.

Neural networks (NN) have become a well-established methodology as exemplified by their applications to identification and control of general nonlinear and complex systems; the use of high order neural networks for modeling and learning has recently increased. Using neural networks, control algorithms can be developed to be robust to uncertainties and modeling errors. The most used NN structures are feedforward networks and recurrent networks. The latter type offers a better-suited tool to model and control of nonlinear systems. There exist different training algorithms for neural networks, which, however, normally encounter some technical problems such as local minima, slow learning, and high sensitivity to initial conditions, among others. As a viable alternative, new training algorithms have been proposed. There already exist publications about regulation and trajectory tracking using neural networks; however, most of those works were developed for continuous-time systems. On the other hand, while extensive literature is available for linear discrete-time control system, nonlinear discrete-time control design techniques have not been discussed to the same degree. Besides, discrete-time neural networks are better fitted for real-time implementations.

Optimal nonlinear control is related to determining a control law for a given system, such that a cost functional (performance index) is minimized; it is usually formulated as a function of the state and input variables. The major drawback for optimal nonlinear control is the need to solve the associated Hamilton–Jacobi–Bellman (HJB) equation. The HJB equation, as far as we are aware, has not been solved for general nonlinear systems. It has only been solved for the linear regulator problem, for which it is particularly well suited. This book presents a novel inverse optimal control for stabilization and trajectory tracking of discrete-time decentralized nonlinear systems, avoiding the need to solve the associated HJB equation, and minimizing a cost functional. Two approaches are presented; the first one is based on passivity theory and the second one is based on a control Lyapunov function (CLF). It is worth mentioning that if a continuous-time control scheme is real-time implemented, there is no guarantee that it preserves its properties, such as stability margins and adequate performance. Even worse, it is known that continuous-time schemes could become unstable after sampling. There are two advantages to working in a discrete-time framework: (a) appropriate technology can be used to implement digital controllers rather than analog ones; (b) the synthesized controller is directly implemented in a digital processor. Therefore, the control methodology developed for discrete-time nonlinear systems can be implemented in real systems more effectively. In this book, it is considered a class of nonlinear systems, the affine nonlinear systems, which represents a great variety of systems, most of which are approximate discretizations of continuous-time systems. The main characteristic of the inverse optimal control is that the cost functional is determined a posteriori, once the stabilizing feedback control law is established. Important results on inverse optimal control have been proposed for continuous-time linear and nonlinear systems, and the discrete-time inverse optimal control has been analyzed in the frequency domain for linear systems. Different works have illustrated adequate performances of the inverse optimal control due to the fact that this control scheme benefits from adequate stability margins, while the minimization of a cost functional ensures that control effort is not wasted. On the other hand, for realistic situations, a control scheme based on a plant model cannot perform as desired, due to internal and external disturbances, uncertain parameters, and/or unmodeled dynamics. This fact motivates the development of a model based on recurrent high order neural networks (RHONN) in order to identify the dynamics of the plant to be controlled. A RHONN model is easy to implement, has relatively simple structure, and has the capacity to adjust its parameters online. This book establishes a neural inverse optimal controller combining two techniques: (a) inverse optimal control and (b) an online neural identifier, which uses a recurrent neural network, trained with an extended Kalman filter, in order to determine a model for an assumed unknown nonlinear system.

To this end, simulations and real-time implementation for the schemes proposed in this book are presented, validating the theoretical results, using the following prototypes: two DOF robot manipulator, five DOF redundant robot, seven DOF Mitsubishi PA10-7CE robot arm, KUKA youBot mobile robot and Shrimp mobile robot.

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September 2016

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http://www.springer.com/978-3-319-53311-7

Decentralized Neural Control: Application to Robotics
Garcia-Hernandez, R.; Lopez-Franco, M.; Sánchez, E.N.;
Alanis, A.Y.; Ruz-Hernandez, J.A.
2017, XV, 111 p. 54 illus., 3 illus. in color., Hardcover
ISBN: 978-3-319-53311-7