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PREFACE

Conventional control systems are designed using mathematical models of physical systems. A mathematical model, which describes the dynamical behavior of the system, is developed, and then control design techniques are applied to design the appropriate controller. Therefore, the mathematical model must be "simple enough" to be analyzed with available mathematical methods and "accurate enough" to describe the dynamic behavior of the system. Changes in environment and the presence of non-linearities and uncertainties are difficulties to be dealt with by the conventional control engineer.

Intelligent control, using neural networks and fuzzy systems, can be applied to non-linear dynamical systems. In our approach, intelligent control systems are defined as control systems which include low-level feedback control and high-level supervision to monitor the performance of the system output. As intelligent control methods have found their way into standard practice, they have opened the door to a wide spectrum of non-linear control applications by overcoming changes in environment, non-linearities and uncertainty in the system.

When intelligent control methods are incorporated into the feedback path in the overall system, it has often been the case that no non-linear analysis was performed to verify the behavior of the closed-loop system and quite frequently no implementation and experimental evaluation was conducted. Training algorithms (on-line versus off-line) were also misunderstood. This has limited intelligent control applications, especially in hardware control demonstrations.

This monograph proposes special learning algorithms for the control of uncertain non-linear systems. Instead of the normal back-propagation learning or delta-learning rule used in the neural network literature, adaptive-learning rules are derived using the Lyapunov method to adjust the weights of the neural network or to adjust the control representative values in fuzzy systems. Both system stability and error convergence can then be guaranteed. Stability of the overall system is certainly a prime requirement that must be met before thinking of real-world applications.

The neural and fuzzy controllers discussed in this book have a number of application benefits. They will perform effectively in changing environments

because of their ability to deal with unseen changes in mechanical systems and their model-free design will allow them to be used in many different types of mechanical systems.

When all the states of the controlled system are not available as measurements due to economic or physical constraints, a dynamic recurrent neural network need to be used for estimating the missing system states. The estimated states will be used as system states for feedback control scheme. The overall control structure requires a sort of hierarchical structure that can contain neural network as higher levels of abstraction.

The reinforcement learning methods provide a learning feature driven by the basic success or failure record of the controlled system. The key point is that the performance indicator (critic) of the controlled system is simple and that these simple signals tune or adapt a neural network controller so that its performance improves over time dramatically. Due to the simple performance indicator, the computational requirements of a neural network can be reduced significantly. It can be viewed as a hierarchical system with performance evaluator for the closed-loop system.

It is evident that if the plant has additional complications or uncertainties, more hierarchical structure must be added to the control system. It is important to provide a smooth transition between the regulator functions of the feedback controller and the supervisory functions of the human operator. In that direction, Hamilton-Jacobi-Bellman optimal neural network control is designed to provide a higher-level controllers with hierarchical designs that are similar structure to controllers designed using computer science techniques. It has shown smooth interface between feedback loops and the human user.

The material presented in this book basically follows research efforts during the previous two years at Automation and Robotics Research Institute at the University of Texas, Arlington. We would like to thank the National Science Foundation for the financial support during this research.

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