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APPLICATIONS OF NEURAL ADAPTIVE CONTROL TECHNOLOGY

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Preface

This book comprises the results of the second workshop on Neural Adaptive Control Technology, *NACT II*, held on September 9–10, 1996 in Berlin. The workshop was organised in connection with a three-year European Union funded Basic Research Project in the ESPRIT framework, called NACT, a collaboration between Daimler-Benz (Germany) and the University of Glasgow (Scotland).

The NACT project, which began on 1 April 1994, is a study of the fundamental properties of neural network based adaptive control systems. Where possible, links with traditional adaptive control systems are exploited. A major aim is to develop a systematic engineering procedure for designing neural controllers for nonlinear dynamic systems. The techniques developed are being evaluated on concrete industrial problems from within the Daimler-Benz group of companies.

The aim of the workshop was to bring together selected invited specialists in the fields of adaptive control, nonlinear systems and neural networks. The first workshop (NACT I) took place in Glasgow in May 1995 and was mainly dedicated to theoretical issues of neural adaptive control. Besides monitoring further development of theory, the NACT II workshop was focused on industrial applications and software tools. This context dictated the focus of the book and guided the editors in the choice of the papers and their subsequent reshaping into substantive book chapters. Thus, with the project having progressed into its applications stage, emphasis is put on transfer of theory of neural adaptive engineering into industrial practice. Therefore the contributors are both renowned academics and practitioners from major industrial users of neurocontrol.

Chapter 1 of the book gives an overview of further developments and results in the NACT project. The first three sections of this chapter contain a résumé of the main goals and the project rationale. Also, the engineering background is sketched with a brief outline of the industrial problems to which the NACT techniques are being applied. This is followed by four technical sections. First, the multi-dimensional sampling approach to neural network modelling is outlined. Then issues of adaptive networks of local models and controllers are discussed. This is followed by an account of geometric control techniques using neural network plant models. The technical content of each part of the work is logically placed within the overall framework and the interrelationships between the individual parts are stated. Particular attention is given to the experimental evaluation of the techniques developed within the NACT framework. First experimental results for a test application, a longitu-

dinal automotive dynamics control problem, are given.

Chapters 2 and 3 are devoted to monitoring recent developments in the theory of neural adaptive control technology. Focus is on two major strains of theoretical research: neural control based on input-output descriptions of nonlinear systems, and the resulting stability and robustness issues; second, heterogeneous and hybrid types of nonlinear control systems. Chapter 2 is written by Hassan K. Khalil, a renowned contributor to the fields of nonlinear systems theory and adaptive control. It analyses paradigms of nonlinear control, adaptation and learning, issues that are of paramount importance for neural adaptive control. The chapter centres on input-output (NARX type) descriptions of nonlinear systems. Neural networks using both linear as well as nonlinear parameterisation are discussed and the resulting stability and convergence issues for the closed-loop control system are addressed. In particular, H.K. Khalil addresses the practically important subject of nonlinear adaptive output feedback control where only measurements of the plant outputs are used. Chapter 3 by G.A. Rovithakis et al. encompasses continuous-time neural adaptive control schemes and their application to the control of discrete-event systems, where a case study of the control of a wood processing plant demonstrates the efficiency of the technique.

Chapters 4 to 9 deal with various industrial applications of neural adaptive controllers. The applications range from biochemical systems and process control to robotics and power circuit control. Chapter 4 by C. Szepesvári and A. Lőrincz is a benchmark study on the high precision neurocontrol of a chaotic Bioreactor. This is followed by the presentation of an approach for sensor-based motion planning for a pneumatic robot arm where neural networks are used for mapping obstacles (Chapter 5, M. Zeller et al.). The control of an experimental heat exchanger based on neural networks with distributed dynamics is reported in Chapter 6 by M. Ayoubi et al. Following the space-frequency function approximation approach of Sanner and Slotine in Chapter 7, adaptive control and estimation using Gaussian radial basis functions is analysed and validated for two examples, a robotic manipulator and a nonlinear level control (J. P. Fredsted). Practical issues in the introduction of adaptive neural controllers into an industrial automation environment are discussed by A. Hambrecht and D. Neumerkel in Chapter 8. The book ends with Chapter 9, a case study on the application of neural networks for controlling electrical power circuits in railway propulsion systems (S. Scheffler, J. Böcker).

Contents

Preface	v
Neural Adaptive Control Technology	1
<i>K. J. Hunt, J. C. Kalkkuhl, Th. Götsche, R. Żbikowski, A. Dzieliński, P. J. Gawthrop, T. A. Johansen, H. Fritz</i>	
Nonlinear Control: Adaptation and Learning	95
<i>H. K. Khalil</i>	
A Neural Adaptive Control Technique for Manufacturing Scheduling	121
<i>G. A. Rovithakis, V. I. Gaganis, S. E. Perrakis, V. S. Kodogiannis, M. A. Christodoulou</i>	
Approximate Inverse-Dynamics Based Robust Control Using Static and Dynamic Feedback	151
<i>C. Szepesvári, A. Lörincz</i>	
Vision-Based Robot Motion Planning Using a Topology Representing Neural Network	181
<i>M. Zeller, K. Schulten, R. Sharma</i>	
Dynamic Multi-Layer Perceptron Networks: Application to the Nonlinear Identification and Predictive Control of a Heat Exchanger	205
<i>M. Ayoubi</i>	
Adaptive Control Using Localised Radial Basis Function Networks	231
<i>J. P. Fredsted</i>	
Implementation of Neural Adaptive Control Strategies for Industrial Automation	267
<i>A. Hambrecht, D. Neumerkel</i>	
Application of Neural Networks for Control of Four-Quadrant Converters in Railway Propulsion Systems	281
<i>S. Scheffler, J. Böcker</i>	
Index	303