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Neuro-Control and its Applications

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SERIES EDITORS' FOREWORD

The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering. The rapid development of control technology impacts all areas of the control discipline. New theory, new controllers, actuators, sensors, new industrial processes, computer methods, new applications, new philosophies, ..., new challenges. Much of this development work resides in industrial reports, feasibility study papers and the reports of advance collaborative projects. The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination.

Sigeru Omatu, Marzuki Khalid, and Rubiyah Yusof have pursued the new developments of fuzzy logic and neural networks to present a series volume on neuro-control methods. As they demonstrate in the opening pages of their book, there is an explosion of interest in this field. Publication and patent activity in these areas are ever growing according to international databases and hence, this volume is timely.

The presentation of the material follows a complementary pattern. Reviews of existing control techniques are given along side an exposition of the theoretical constructions of fuzzy logic controllers, and controllers based on neural networks. This is an extremely useful methodology which yields rewards in the applications chapters. The series of applications includes one very thorough experimental sequence for the control of a hot-water bath. Here, the results from four controllers (including PI and GPC) are compared. The results from this and the other applications are quite thought provoking, rounding out a useful and comprehensive volume.

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PREFACE

Recent progress in neural network theory and fuzzy logic theory provides us with new tools for modeling, estimation, and control of complex nonlinear systems while traditional and conventional control theory does the same for only linear systems. In order to achieve results that not only control theorists but also industrial practitioners can use to solve difficult real control problems which are basically nonlinear, noisy, and complex, this book provides hands-on approaches to intelligent control, with special focus on neuro-control.

Neuro-control is a control scheme using artificial neural networks which are based on the biological brain information processing mechanism. The neural network approach has superior characteristics when compared with conventional computers. Some of them are; (1) easier pattern information processing, (2) self-organization, (3) distributed memory, (4) parallel processing architecture, and (5) learning. However, conventional computers of the Von Neumann type have the following properties; (1') symbolic expression, (2') logical representation, (3') local memory, (4') serial processing architecture, and (5') sequential algorithmic programming. Therefore, if we use neural networks for control, we can expect that the neuro-controllers have at least some of the properties and advantages as discussed above. To this end, research works on neuro-control have already achieved some of the objectives and features of intelligent control such as parallel and distributed processing, and self-organizing and learning capabilities.

This book discusses various types of neuro-control paradigms based on the backpropagation algorithm which is a supervised learning technique derived by the steepest descent (gradient) method. The neuro-controller can realize a nonlinear control algorithm which is robust to noise, complexities, and variations in the plant. Some of the examples on the applications of the neuro-control techniques to real control problems given in this book should enable the reader to have some idea of how the techniques are implemented. The neuro-control methodologies and their experimental performances are also compared with those of conventional and traditional control methods. This would enable the reader to understand the similarities and differences between the new neuro-control approach and the other control approaches. It would also allow the reader to decipher the advantages and disadvantages of the different control techniques and to select their best features and characteristics for the development of a truly intelligent and efficient control system. In due course, these new neuro-control techniques will be available

to domestic appliances and industrial control systems, similar to the fuzzy logic revolution in recent years.

This book has been organized as follows: Chapter 1 presents an overview of intelligent control and more specifically introduction to the definition of neuro-control. Chapter 2 introduces the reader some aspects of biological neural networks and their relation to artificial neural networks. The backpropagation algorithm is thoroughly discussed in this chapter which forms the main algorithm of the neuro-control schemes presented in this book.

Chapter 3 deals with traditional control techniques which include several adaptive control techniques and also fuzzy logic control. This chapter is intended to allow the reader to understand some basic concepts of the more popular control techniques that are available today such as self-tuning control, generalized predictive control, and fuzzy logic. The discussion on these traditional control techniques can be used as a basis of comparison to the neuro-control techniques that are discussed in Chapter 4. Chapter 4 starts with an overview of the neuro-control techniques that have been much cited in the literature. The rest of the chapter discusses various neuro-control schemes from our viewpoint based on the backpropagation algorithm. Several simulation examples based on some of the neuro-control paradigms are given in this chapter. Chapter 5 deals specifically with four different neuro-control applications. Developments of the neuro-control schemes on real processes are described. The performances of these neuro-controllers are also compared with several traditional control schemes implemented on the same processes. From the experimental results the neuro-control schemes show considerable robustness and encouraging advantages not found in many traditional control approaches. We believe that these neuro-control schemes have strong potential for many real world applications in the near future.

We have also included a program list written in Borland C++ (runs on Borland C++ Version 3.1 Environment). The program can be used to train a multilayered neural network model the inverse dynamics of a plant from its input-output characteristics. After training the neural network can be configured to be used as a direct controller to the plant.

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