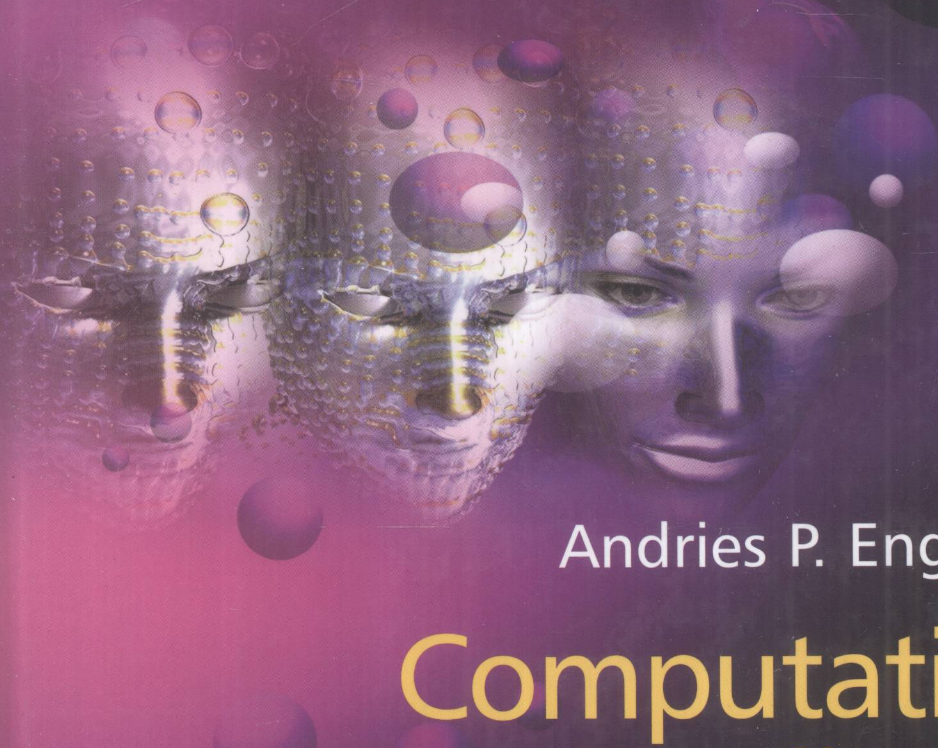
Second Edition



Andries P. Engelbrecht

Computational Intelligence

An Introduction

Companion Website

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Computational Intelligence

An Introduction

Second Edition

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BICENTENNIAL 1807 WILEY 2007 BICENTENNIAL

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Jossey-Bass, 989 Market Street, San Francisco, CA 94103-1741, USA

Wiley-VCH Verlag GmbH, Boschstr. 12, D-69469 Weinheim, Germany

John Wiley & Sons Australia Ltd, 42 McDougall Street, Milton, Queensland 4064, Australia

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01, Jin Xing Distripark, Singapore 129809

John Wiley & Sons Canada Ltd, 6045 Freemont Blvd, Mississauga, Ontario, L5R 4J3, Canada

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Library of Congress Cataloging-in-Publication Data

Engelbrecht, Andries P.
Computational intelligence : an introduction / Andries P. Engelbrecht. – 2nd ed.
p. cm.
Includes bibliographical references.
ISBN 978-0-470-03561-0 (cloth)
1. Computational intelligence. 2. Neural networks (Computer science) 3. Evolutionary programming (Computer science) I. Title.
Q342.E54 2007
006.3–dc22

2007021101

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 978-0-470-03561-0 (HB)

Typeset by the author
Printed and bound in Great Britain by Antony Rowe Ltd, Chippenham, Wiltshire
This book is printed on acid-free paper responsibly manufactured from sustainable forestry in which at least two trees are planted for each one used for paper production.

Computational Intelligence

To my parents, Jan and Magriet Engelbrecht,
without whose loving support
this would not have happened.

Preface to the Second Edition

Man has learned much from studies of natural systems, using what has been learned to develop new algorithmic models to solve complex problems. This book presents an introduction to some of these technological paradigms, under the umbrella of computational intelligence (CI). In this context, the book includes artificial neural networks, evolutionary computation, swarm intelligence, artificial immune systems, and fuzzy systems, which are respectively models of the following natural systems: biological neural networks, evolution, swarm behavior of social organisms, natural immune systems, and human thinking processes.

Why this book on computational intelligence? Need arose from a graduate course, where students did not have a deep background of artificial intelligence and mathematics. Therefore the introductory perspective is essential, both in terms of the CI paradigms and mathematical depth. While the material is introductory in nature, it does not shy away from details, and does present the mathematical foundations to the interested reader. The intention of the book is not to provide thorough attention to all computational intelligence paradigms and algorithms, but to give an overview of the most popular and frequently used models. For these models, detailed overviews of different implementations are given. As such, the book is appropriate for beginners in the CI field. The book is also applicable as prescribed material for a third year undergraduate course.

In addition to providing an overview of CI paradigms, the book provides insights into many new developments on the CI research front to tempt the interested reader. As such, the material is useful to graduate students and researchers who want a broader view of the different CI paradigms, also researchers from other fields who have no knowledge of the power of CI techniques, e.g. bioinformaticians, biochemists, mechanical and chemical engineers, economists, musicians and medical practitioners.

The book is organized in six parts. Part I provides a short introduction to the different CI paradigms and a historical overview. Parts II to VI cover the different paradigms, and can be reviewed in any order.

Part II deals with artificial neural networks (NN), including the following topics: Chapter 2 introduces the artificial neuron as the fundamental part of a neural network, including discussions on different activation functions, neuron geometry and learning rules. Chapter 3 covers supervised learning, with an introduction to different types of supervised networks. These include feedforward NNs, functional link NNs, product unit NNs, cascade NNs, and recurrent NNs. Different supervised learning algorithms are discussed, including gradient descent, conjugate gradient methods, LeapFrog and

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particle swarm optimization. Chapter 4 covers unsupervised learning. Different unsupervised NN models are discussed, including the learning vector quantizer and self-organizing feature maps. Chapter 5 discusses radial basis function NNs. Reinforcement learning is dealt with in Chapter 6. Much attention is given to performance issues of supervised networks in Chapter 7. The focus of the chapter is on accuracy measures and ways to improve performance.

Part III introduces several evolutionary computation models. Topics covered include: an overview of the computational evolution process and basic operators in Chapter 8. Chapter 9 covers genetic algorithms, Chapter 10 genetic programming, Chapter 11 evolutionary programming, Chapter 12 evolution strategies, Chapter 13 differential evolution, Chapter 14 cultural algorithms, and Chapter 15 covers coevolution, introducing both competitive and symbiotic coevolution.

Part IV presents an introduction to two types of swarm-based models: Chapter 16 discusses particle swarm optimization, while ant algorithms are discussed in Chapter 17.

Artificial immune systems are covered in Part V, with the natural immune system being discussed in Chapter 18 and a number of artificial immune models in Chapter 19.

Part VI deals with fuzzy systems. Chapter 20 presents an introduction to fuzzy logic with a discussion of membership functions. Fuzzy inferencing systems are explained in Chapter 21, while fuzzy controllers are discussed in Chapter 22. An overview of rough sets is given in Chapter 23.

Throughout the book, assignments are given to highlight certain aspects of the covered material and to stimulate thought. Some example applications are given where they seemed appropriate to better illustrate the theoretical concepts.

The accompanying website of this book, which can be located at http://ci.cs.up.ac.za, provides algorithms to implement many of the CI models discussed in this book. These algorithms are implemented in Java, and form part of an opensource library, CIlib, developed by the Computational Intelligence Research Group in the Department of Computer Science, University of Pretoria. CIlib (http://cilib.sourceforge.net) is a generic framework for easy implementation of new CI algoithms, and currently contains frameworks for particle swarm optimization, neural networks, and evolutionary computation. Lists with acronyms and symbols used in the book can also be downloaded from the book's website.

As a final remark, it is necessary to thank a number of people who have helped to produce this book. First of all, thanks to my mother, Magriet Engelbrecht, who has helped with typing and proofreading most of the text. Also, thanks to Anri Henning who spent a number of nights proofreading the material. The part on artificial immune systems was written by one of my PhD students, Attie Graaff. Without his help, this book would not have been so complete. Lastly, I thank all of my postgraduate students who have helped with the development of CIlib.

Pretoria, South Africa

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