

Artificial Intelligence and Soft Computing

Behavioral and Cognitive Modeling of the Human Brain

Amit Konar

Department of Electronics and Tele-communication Engineering
Jadavpur University, Calcutta, India



CRC Press

Boca Raton London New York Washington, D.C.

Artificial Intelligence and Soft Computing

Behavioral and Cognitive Modeling of the Human Brain

Amit Konar

Department of Electronics and Tele-communication Engineering
Jadavpur University, Calcutta, India



CRC Press

Boca Raton London New York Washington, D.C.

Library of Congress Cataloging-in-Publication Data

Konar, Amit.

Artificial intelligence and soft computing : behavioral and cognitive modeling of the human brain / Amit Konar.

p. cm.

Includes bibliographical references and index.

ISBN 0-8493-1385-6 (alk. paper)

1. Soft computing. 2. Artificial intelligence. 3. Brain—Computer simulation. I. Title.

QA76.9.S63 K59 1999

006.3--dc21

99-048018

CIP

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

The consent of CRC Press LLC does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press LLC for such copying.

Direct all inquiries to CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

© 2000 by CRC Press LLC

No claim to original U.S. Government works

International Standard Book Number 0-8493-1385

Library of Congress Card Number 99-048018

Printed in the United States of America 2 3 4 5 6 7 8 9 0

Printed on acid-free paper

Artificial Intelligence and Soft Computing

Behavioral and Cognitive Modeling of the Human Brain

Amit Konar

Department of Electronics and Tele-communication Engineering
Jadavpur University, Calcutta, India



CRC Press

Boca Raton London New York Washington, D.C.

Library of Congress Cataloging-in-Publication Data

Konar, Amit.

Artificial intelligence and soft computing : behavioral and cognitive modeling of the human brain / Amit Konar.

p. cm.

Includes bibliographical references and index.

ISBN 0-8493-1385-6 (alk. paper)

1. Soft computing. 2. Artificial intelligence. 3. Brain—Computer simulation. I. Title.

QA76.9.S63 K59 1999

006.3—dc21

99-048018

CIP

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

The consent of CRC Press LLC does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press LLC for such copying.

Direct all inquiries to CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

© 2000 by CRC Press LLC

No claim to original U.S. Government works

International Standard Book Number 0-8493-1385

Library of Congress Card Number 99-048018

Printed in the United States of America 2 3 4 5 6 7 8 9 0

Printed on acid-free paper

PREFACE

The book, to the best of the author's knowledge, is the first text of its kind that presents both the traditional and the modern aspects of 'AI and Soft Computing' in a clear, insightful and highly comprehensive writing style. It provides an in-depth analysis of the mathematical models and algorithms, and demonstrates their applications in real world problems of significant complexity.

1. About the book

The book covers 24 chapters altogether. It starts with the behavioral perspective of the 'human cognition' and covers in detail the tools and techniques required for its intelligent realization on machines. The classical chapters on search, symbolic logic, planning and machine learning have been covered in sufficient details, including the latest research in the subject. The modern aspects of soft computing have been introduced from the first principles and discussed in a semi-informal manner, so that a beginner of the subject is able to grasp it with minimal effort. Besides soft computing, the other leading aspects of current AI research covered in the book include non-monotonic and spatio-temporal reasoning, knowledge acquisition, verification, validation and maintenance issues, realization of cognition on machines and the architecture of AI machines. The book ends with two case studies: one on 'criminal investigation' and the other on 'navigational planning of robots,' where the main emphasis is given on the realization of intelligent systems using the methodologies covered in the book.

The book is unique for its diversity in contents, clarity and precision of presentation and the overall completeness of its chapters. It requires no mathematical prerequisites beyond the high school algebra and elementary differential calculus; however, a mathematical maturity is required to follow the logical concepts presented therein. An elementary background of data structure and a high level programming language like Pascal or C is helpful to understand the book. The book, thus, though meant for two semester courses of computer science, will be equally useful to readers of other engineering disciplines and psychology as well as for its diverse contents, clear presentation and minimum prerequisite requirements.

In order to make the students aware of the applied side of the subject, the book includes a few homework problems, selected from a wide range of topics. The problems supplied, in general, are of three types: i) numerical, ii) reflexive and iii) provocative. The numerical problems test the students'

understanding of the subject. The reflexive type requires a formulation of the problem from its statement before finding its solution. The provocative type includes the well-known problems of modern AI research, the solution to some of which are known, and some are open ended. With adequate hints supplied with the problems, the students will be able to solve most of the numerical and reflexive type problems themselves. The provocative type, however, requires some guidance from the teacher in charge. The last type of problems is included in the text to give the research-oriented readers an idea of the current trend in AI research. Graduate students of AI will also find these problems useful for their dissertation work.

The book includes a large number of computer simulations to illustrate the concepts presented in logic programming, fuzzy Petri nets, imaging and robotics. Most of the simulation programs are coded in C and Pascal, so that students without any background of PROLOG and LISP may understand them easily. These programs will enhance the students' confidence in the subject and enable them to design the simulation programs, assigned in the exercise as homework problems. The professionals will find these simulations interesting as it requires understanding of the end results only, rather than the formal proofs of the theorems presented in the text.

2. Special features

The book includes the following special features.

i) Unified theme of presentation: Most of the existing texts on AI cover a set of chapters of diverse thoughts, without demonstrating their inter-relationship. The readers, therefore, are misled with the belief that AI is merely a collection of intelligent algorithms, which precisely is not correct. The proposed book is developed from the perspective of cognitive science, which provides the readers with the view that the psychological model of cognition can be visualized as a cycle of 5 mental states: sensing, acquisition, perception, planning and action, and there exists a strong interdependence between each two sequential states. The significance of search in the state of perception, reasoning in the state of planning, and learning as an intermediate process between sensing and action thus makes sense. The unified theme of the book, therefore, is to realize the behavioral perspective of cognition on an intelligent machine, so as to enable it act and think like a human being. Readers will enjoy the book especially for its totality with an ultimate aim to build intelligent machines.

ii) Comprehensive coverage of the mathematical models: This probably is the first book that provides a comprehensive coverage of the mathematical

models on AI and Soft Computing. The existing texts on “mathematical modeling in AI” are beyond the scope of undergraduate students. Consequently, while taking courses at graduate level, the students face much difficulty in studying from monographs and journals. The book, however, bridges the potential gap between the textbooks and advanced monographs in the subject by presenting the mathematical models from a layman’s understanding of the problems.

iii) Case studies: This is the only book that demonstrates the realization of the proposed tools and techniques of AI and Soft Computing through case studies. The readers, through these case studies, will understand the significance of the joint usage of the AI and Soft Computing tools and techniques in interesting problems of the real world. Case studies for two distinct problems with special emphasis to their realization have been covered in the book in two separate chapters. The case study I is concerned with a problem of criminal investigation, where the readers will learn to use the soft computing tools in facial image matching, fingerprint classification, speaker identification and incidental description based reasoning. The readers can build up their own systems by adding new fuzzy production rules and facts and deleting the unwanted rules and facts from the system. The book thus will serve the readership from both the academic and the professional world. Electronic and computer hobbyists will find the case study II on mobile robots very exciting. The algorithms of navigational planning (in case study II), though tested with reference to “Nomad Super Scout II robot,” have been presented in generic form, so that the interested readers can code them for other wheel-based mobile robots.

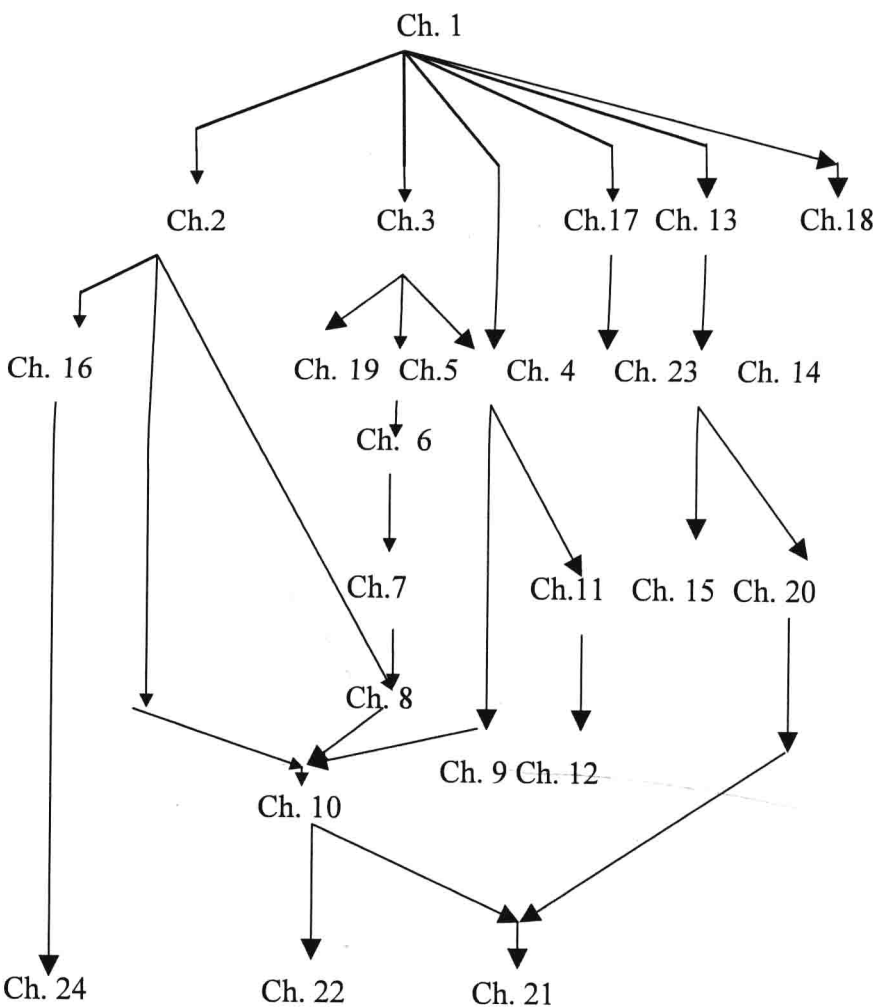
iv) Line Diagrams: The book includes around 190 line diagrams to give the readers a better insight to the subject. Readers will enjoy the book for they directly get a deeper view of the subject through diagrams with a minimal reading of the text.

3. Origin of the book

The book is an outgrowth of the lecture materials prepared by the author for a one semester course on “Artificial Intelligence,” offered to the graduate students in the department of Electronics and Telecommunication Engineering, Jadavpur University, Calcutta. An early version of the text was also used in a summer-school on “AI and Neural Nets,” offered to the faculty members of various engineering colleges for their academic development and training. The training program included theories followed by a laboratory course, where the attendees developed programs in PROLOG, Pascal and C with the help of sample programs/toolkit. The toolkit is included in the book on a CD and the procedure to use it is presented in Appendix A.

4. Structural organization of the book

The structural organization of the book is presented below with a dependency graph of chapters, where Ch. 9 → Ch. 10 means that chapter 10 should be read following chapter 9, for example.



ABOUT THE AUTHOR

Amit Konar is a Reader in the Department of Electronics and Telecommunication Engineering, Jadavpur University, Calcutta. He received a Ph.D. (Engineering) degree in Artificial Intelligence from the same university in 1994 and has been teaching the subject of Artificial Intelligence to the graduate students of his department for the last 10 years. Dr. Konar has supervised a number of Ph.D. and M.E. theses on different aspects of machine intelligence, including logic programming, neural networks, cognitive systems, stochastic and fuzzy models of uncertainty, fuzzy algebra, image understanding, architecture of intelligent machines and navigational planning of mobile robots. He has published more than 60 papers in international journals and conferences. He is an invited contributor of a book chapter in an edited book published by Academic Press. Dr. Konar is a recipient of the 1997 Young Scientist Award, offered by the All India Council for Technical Education (AICTE) for his significant contributions in Artificial Intelligence and Soft Computing.

ACKNOWLEDGMENT

The author gratefully acknowledges the contributions of many people, who helped him in different ways to complete the book. First and foremost, he wishes to thank his graduate students attending the course entitled “AI and Pattern Recognition” in ETCE department, Jadavpur University during the 1993-1999 sessions. Next, he would like to thank the scholars working for their Ph.D. degree under his supervision. In this regard, the author acknowledges the contribution of Ms. Jaya Sil, a recipient of the Ph.D. degree in 1996, for spending many of her valuable hours on discussion of the Bayesian and Markov models of knowledge representation. The other scholars, to whom the author is greatly indebted for sharing their knowledge in different areas of AI, are Mr. Srikant Patnaik, Mr. Biswajit Paul, Mrs. Bijita Biswas, Ms. Sanjukta Pal, Ms. Alakananda Bhattacharya and Ms. Parbati Saha. The contributions of Mr. Patnaik in chapter 24, Mr. Paul in chapter 14, Ms. Biswas in chapter 23, Ms. Pal in chapter 16, Ms. Bhattacharya in chapter 22 and Ms. Saha in chapter 10 need special mention. Among his scholars, the author wants to convey his special thanks to Mr. Patnaik, who helped him in many ways, which simply cannot be expressed in a few sentences.

The author acknowledges the contribution of his friend Mr. Dipak Laha, a faculty member of the Mechanical Engineering department, Jadavpur University, who helped him in understanding the many difficult problems of scheduling. He also would like to thank his friend Dr. Uday Kumar Chakraborty, a faculty member of the Computer Science department, Jadavpur University, for teaching him the fundamentals in Genetic Algorithms. The author gives a special thanks to Ms. Sheli Murmu, his student and now a colleague, who helped him in correcting many syntactical errors in the draft book. He also wants to thank his graduate students including Mr. Diptendu Bhattacharya, Ms. Bandana Barman, and Mr. Srikrishna Bhattacharya for their help in drawing many figures and in the technical editing of this book. The author also wishes to thank his ex-student Ms. Sragdhara Dutta Choudhury, who helped him draw a very simple but beautiful sketch of the ‘classroom’ figure in chapter 6.

The architectural issues of knowledge based systems, which is the main theme of chapter 22, is the summary of the M.E. thesis (1991-1992) of Mr. Shirshendu Halder, who critically reviewed a large number of research papers and interestingly presented the pros and cons of these works in his thesis.

The author owes a deep gratitude to Prof. A. K. Mandal of the department of Electronics and Telecommunication Engineering, Jadavpur University, for teaching him the subject of AI and providing him both technical and moral support as a teacher, Ph.D. thesis adviser and colleague.

He is also indebted to Prof. A.K. Nath of the same department for encouraging him to write a book and spending long hours in valuable discussion. The author would like to thank his teacher Prof. A. B. Roy of the department of Mathematics, Jadavpur University, who inspired his writing skill, which later enabled him to write this book. He remembers his one-time project supervisor Prof. T. K. Ghosal of the Department of Electrical Engineering, Jadavpur University, for his constructive criticism, which helped him develop a habit of checking a thought twice before deliberating. The author also gratefully acknowledges his unaccountable debt to his teacher Mr. Basudeb Dey, who taught him the basis to uncover the mysteries from the statement of arithmetic problems, without which the author could never have been able to reach his present level of maturity in mathematics.

The author wants to convey a special vote of thanks to his colleagues Prof. S. K. Choudhury and Dr. B. Gupta for their kind gesture of attending his classes on AI for a complete semester, which helped him to make necessary corrections in the book.

Among his friends and well-wishers, the author would like to mention Mr. Gourishankar Chattopadhyay, Mr. Bisweswar Jana, Mrs. Dipa Gupta, Mr. P. K. Gupta and Prof. P.K. Sinha Roy, without whose encouragement and inspiration the book could not have taken its present shape. His ex-students Ms. Sanghamitra Sinha of Sun Microsystems, USA, Ms. Indrani Chakraborty of MIE University, Japan, Mr. Ashim Biswas of HCL Technologies, NOIDA, India and Dr. Madhumita Dasgupta of Jadavpur University, India helped him in many ways improve the book.

The author would like to thank Ms. Nora Konopka, Acquisition Editor, and staff members of CRC Press LLC for their kind cooperation in connection with writing this book. He would also like to thank Prof. L. C. Jain of the University of South Australia, Adelaide, for active cooperation and editorial guidance on this book.

Lastly, the author wishes to express his deep gratitude to his parents, who always stood by him throughout his life and guided him in his time of crisis. He also wishes to thank his wife Srilekha for her tolerance of his indifference to the family life and her assistance in many ways for the successful completion of the book. The author is equally grateful to his in-laws and especially his brother-in-law, Mr. Subrata Samanta, for their inspiration and encouragement in writing this book.

September 17, 1999

Jadavpur University

Amit Konar

10

To my parents, Mr. Sailen Konar and Mrs. Minati Konar, who brought me up despite the stress and complexities of their lives and devoted themselves to my education;

To my brother Sanjoy, who since his childhood shouldered the responsibility of running our family smoothly;

To my wife Srilekha, who helped me survive and inspired me in many ways to write and complete this book in the present form;

To my students in various parts of the world, who through their forbearance allowed me to improve my teaching skills;

To my teachers, who taught me the art of reacting to a changing environment; and

To millions of the poor and down-trodden people of my country and the world, whose sacrifice and tolerance paved the royal road of my education,, and whose love and emotion, smile and tears inspired me to speak their thoughts in my words.

Amit Konar

Contents

Chapter 1: Introduction to Artificial Intelligence and Soft Computing

- 1.1 Evolution of Computing
- 1.2 Defining AI
- 1.3 General Problem Solving Approaches in AI
- 1.4 The Disciplines of AI
 - 1.4.1 The Subject of AI
 - Learning Systems
 - Knowledge Representation and Reasoning
 - Planning
 - Knowledge Acquisition
 - Intelligent Search
 - Logic Programming
 - Soft Computing
 - Fuzzy Logic
 - Artificial Neural Nets
 - Genetic Algorithms
 - Management of Imprecision and Uncertainty
 - 1.4.2 Applications of AI Techniques
 - Expert Systems
 - Image Understanding and Computer Vision
 - Navigational Planning for Mobile Robots
 - Speech and Natural Language Understanding
 - Scheduling
 - Intelligent Control
- 1.5 A Brief History of AI
 - 1.5.1 The Classical Period
 - 1.5.2 The Romantic Period
 - 1.5.3 The Modern Period
- 1.6 Characteristic Requirement for the Realization of Intelligent Systems
 - 1.6.1 Symbolic and Numeric Computation on Common Platform
 - 1.6.2 Non-Deterministic Computation
 - 1.6.3 Distributed Computing
 - 1.6.4 Open System
- 1.7 Programming Languages for AI
- 1.8 Architecture for AI Machines
- 1.9 Objective and Scope of the Book
- 1.10 Summary
 - Exercises
 - References

Chapter 2: The Psychological Perspective of Cognition

- 2.1 Introduction
- 2.2 The Cognitive Perspective of Pattern Recognition
 - 2.2.1 Template- Matching Theory
 - 2.2.2 Prototype-Matching Theory
 - 2.2.3 Feature-based Approach for Pattern Recognition
 - 2.2.4 The Computational Approach
- 2.3 Cognitive Models of Memory
 - 2.3.1 The Atkinson-Shiffrin's Model
 - 2.3.2 Debates on the Atkinson-Shiffrin's Model
 - 2.3.3 Tulving's Model
 - 2.3.4 The Parallel Distributed Processing Approach
- 2.4 Mental Imagery
 - 2.4.1 Mental Representation of Imagery
 - 2.4.2 Rotation of Mental Imagery
 - 2.4.3 Imagery and Size
 - Kosslyn's View
 - Moyer's View
 - Peterson's View
 - 2.4.4 Imagery and Their Shape
 - 2.4.5 Part-whole Relationship in Mental Imagery
 - 2.4.6 Ambiguity in Mental Imagery
 - 2.4.7 Neuro Physiological Similarity between Imagery and Perception
 - 2.4.8 Cognitive Maps of Mental Imagery
- 2.5 Understanding a Problem
 - 2.5.1 Steps in Understanding a Problem
- 2.6 A Cybernetic View to Cognition
 - 2.6.1 The States of Cognition
- 2.7 Scope of Realization of Cognition in Artificial Intelligence
- 2.8 Summary
 - Exercises
 - References

Chapter 3: Production Systems

- 3.1 Introduction
- 3.2 Production Rules
- 3.3 The Working Memory
- 3.4 The Control Unit / Interpreter
- 3.5 Conflict Resolution Strategies
- 3.6 An Alternative Approach for Conflict Resolution

- 3.7 An Illustrative Production System
- 3.8 The RETE Match Algorithm
- 3.9 Types of Production Systems
 - 3.9.1 Commutative Production System
 - 3.9.2 Decomposable Production System
- 3.10 Forward versus Backward Production Systems
- 3.11 General Merits of a Production System
 - 3.11.1 Isolation of Knowledge and Control Strategy
 - 3.11.2 A Direct Mapping onto State-space
 - 3.11.3 Modular Structure of Production Rules
 - 3.11.4 Tracing of Explanation
- 3.12 Knowledge Base Optimization in a Production System
- 3.13 Conclusions
 - Exercises
 - References

Chapter 4: Problem Solving by Intelligent Search

- 4.1 Introduction
- 4.2 General Problem Solving Approaches
 - 4.2.1 Breadth First Search
 - 4.2.2 Depth First Search
 - 4.2.3 Iterative Deepening Search
 - 4.2.4 Hill Climbing
 - 4.2.5 Simulated Annealing
- 4.3 Heuristic Search
 - 4.3.1 Heuristic Search for OR Graphs
 - 4.3.2 Iterative Deepening A* Algorithm
 - 4.3.3 Heuristic Search on AND-OR Graphs
- 4.4 Adversary Search
 - 4.4.1 The MINIMAX Algorithm
 - 4.4.2 The Alpha-Beta Cutoff Procedure
- 4.5 Conclusions
 - Exercises
 - References

Chapter 5: The Logic of Propositions and Predicates

- 5.1 Introduction
- 5.2 Formal Definitions
- 5.3 Tautologies in Propositional Logic
- 5.4 Theorem Proving by Propositional Logic
 - 5.4.1 Semantic Method for Theorem Proving