Cognitive Intelligence and Robotics

Cognitive Intelligence refers to the natural intelligence of humans/animals involving the brain to serve the necessary biological functioning to perform an intelligent activity. Although tracing a hard boundary to distinguish intelligent activities from others remains controversial, most of the common behaviors/activities of living organisms that cannot be fully synthesized by artificial means are regarded as intelligent. Thus the act of natural sensing and perception, understanding of the environment and voluntary control of muscles, blood-flow rate, respiration rate, heartbeat, and sweating rate, which can be performed by lower level mammals, indeed, are intelligent. Besides the above, advanced mammals can perform more sophisticated cognitive tasks, including logical reasoning, learning and recognition and complex planning/coordination, none of which could be realized artificially to the level of a baby, and thus are regarded as cognitively intelligent.

The series aims at covering two important aspects of the brain science. First, it would attempt to uncover the mystery behind the biological basis of cognition with special emphasis on the decoding of stimulated brain signals/images. The coverage in this area includes neural basis of sensory perception, motor control, sensory-motor coordination and also understanding the biological basis of higher-level cognition, such as memory and learning, reasoning and complex planning. The second objective of the series is to publish brain-inspired models of learning, perception, memory and coordination for realization on robots to enable them to mimic the cognitive activities performed by the living creatures. These brain-inspired models of machine intelligence would supplement the behavioral counterparts, studied in traditional AI.

The series includes textbooks, monographs, contributed volumes and even selected conference proceedings.

More information about this series at http://www.springer.com/series/15488

Pratyusha Rakshit · Amit Konar

Principles in Noisy Optimization

Applied to Multi-agent Coordination

Springer

Pratyusha Rakshit
Department of Electronics and Telecommunication Engineering
Jadavpur University
Kolkata, West Bengal, India

Amit Konar
Department of Electronics and Telecommunication Engineering
Jadavpur University
Kolkata, West Bengal, India

ISSN 2520-1956 ISSN 2520-1964 (electronic)
Cognitive Intelligence and Robotics
ISBN 978-981-10-8641-0 ISBN 978-981-10-8642-7 (eBook)
https://doi.org/10.1007/978-981-10-8642-7

Library of Congress Control Number: 2018952870

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

This book to the best of the authors' knowledge and belief is the first comprehensive title on *noisy optimization* that provides a clear and precise introduction to the subject with a detailed overview of the present state of the art on the topic. The motivation of the book is twofold. On the one side, it addresses the issue of optimization in the presence of noise. On the other side, it aims at applying principles of noisy optimization in multi-agent coordination, a well-known problem of recent interest. The most interesting component of the book is to ensure noisy optimization by invoking machine learning algorithms.

The book is primarily meant for graduate students of electrical, electronic, and computer engineering and also researchers migrating from other domains of science and engineering to noisy optimization. The book does not require a prerequisite of mathematics beyond undergraduate level and thus can be picked up easily with minimum effort. A background of a first course in programming is desirable to understand a section of the book, but not mandatory. The book includes a lot of interesting examples and illustrations to give the readers a thrill of enjoying it like a scientific novel.

The book includes seven chapters. Chapter 1 begins with the foundation on optimization. It introduces classical calculus-based optimization techniques and then demonstrates the problems encountered by the calculus-based techniques for discontinuous, non-smooth functions. The latter part of the chapter reviews optimization from the point of view of population-based search strategies. The principle of a general derivative-free optimization technique is outlined, followed by the illustrative studies on *genetic algorithm*, *differential evolution*, and *particle swarm optimization*. Next, the chapter addresses the issues of *multi-objective optimization*. It first emphasizes the essence of the multi-objective optimization and then outlines the scope of handling multiple objectives. The chapter also covers two important criteria, called Pareto-optimality and non-dominated sorting, required in designing multi-objective optimization algorithms. Finally, the chapter ends with a discussion on the performance analysis of evolutionary algorithms and a list of possible applications.

Chapter 2 deals with the agency in the context of coordination. It begins with defining agents and their characterization. Four different architectures of agents are outlined. They include *logic-based architecture*, *subsumption architecture*, *belief–desire–intention architecture*, and *layered architecture*. Next, the chapter deals with the agent's classes based on their functionality. Five categories of agents are discussed. The categories include *simple reflex agents*, *model-based reflex agents*, *goal-based agents*, *utility-based agents*, and *learning agents*. The subsequent part of the chapter is concerned with multi-agent system and coordination. The chapter includes coordination of both homogeneous and heterogeneous agents. It also covers the scope of learning and optimization in agent coordination. The chapter ends with a discussion on agent coordination in the presence of measurement noise.

Chapter 3 provides a detailed overview of evolutionary algorithms in the presence of noise. It surveys the following five strategies adopted in the existing literature to handle the noisy optimization problems: (i) determination of sample size of the trial solutions, (ii) effective fitness evaluation of the trial solutions, which might contain noisy samples, (iii) dynamic population size (also called implicit averaging), (iv) improving evolutionary search dynamics, and (v) selection of quality solutions, avoiding deceptive trial solutions. The most important aspect of the chapter lies in the thorough discussion of the alternative approaches to serve individual strategy. The chapter also examines a list of benchmarks for performance analysis. It ends with a review of open problems.

Chapter 4 is an original contribution by the authors. The essence of the chapter is to emphasize the notion of learning, in particular *reinforcement learning*, in noisy optimization. Although virtually any evolutionary or swarm algorithm can be taken up as the framework, we here selected the well-known *differential evolution* algorithm primarily for its simplicity and fewer control parameters. The study includes a new strategy for adaptive sampling using a special form of reinforcement learning, called *stochastic learning automata*. The chapter also utilizes the scope of *modified probabilistic crowding-based niching* to handle the noisy optimization problems. The chapter also overviews a case study on multi-robot path-planning in the presence of measurement noise from the sensors used in robots and employs the underlying principles narrated in the chapter to solve the problem in real time. The chapter comes to an end with a summarization of the main issues and results obtained thereof.

Chapter 5 deals with multi-objective optimization in the presence of noise. The chapter begins with a review of the well-known *differential evolution algorithm for multi-objective optimization* (DEMO). Next, DEMO is extended for optimization in the presence of noise, hereafter called *differential evolution for noisy multi-objective optimization* (DENMO). The performance of DENMO is analyzed using a standard set of benchmarks and compared with that of the state-of-the-art noisy optimization algorithms. The subsequent part of the chapter describes the handling of the box-pushing problem by twin robots in the presence of sensory (measurement) noise. Finally, the chapter reports the summary of the main results in the concluding section.

Chapter 6 provides an extension of the classical swarm/evolutionary algorithms to improve their noise-tolerant characteristics. The basic algorithms used in the present swarm/evolutionary framework include *particle swarm optimization*, *artificial bee colony*, and *firefly algorithm*. Both single- and multi-objective optimization algorithms are considered for extension of their noise handling characteristics by the principles introduced in the previous chapters. Experiments have been conducted to study the performance of the extended algorithms with the standard ones with respect to their noise-tolerant behavior. The main results obtained are summarized at the end of the chapter.

Chapter 7 is the concluding chapter of the book. It self-reviews the chapters with respect to the present state-of-the-art research and also indicates the future direction of research in the broad disciplines of noisy optimization and its applications.

Kolkata, India

Pratyusha Rakshit
Amit Konar

Contents

About the Authors

Dr. Pratyusha Rakshit received her B. Tech. in electronics and communication engineering (ECE) from the Institute of Engineering and Management, India, in 2010, and M.E. in control engineering from the Electronics and Telecommunication Engineering (ETCE) Department, Jadavpur University, India, in 2012. She was awarded her Ph.D. (engineering) from Jadavpur University, India, in 2016. From August 2015 to November 2015, she was Assistant Professor in the ETCE Department, Indian Institute of Engineering Science and Technology, India. She is currently Assistant Professor in the ETCE Department, Jadavpur University. She was awarded gold medals for securing the highest percentage of marks in B.Tech. in ECE and among all the courses of M.E., respectively, in 2010 and 2012. She was the recipient of CSIR Senior Research Fellowship, INSPIRE Fellowship, and UGC UPE-II Junior Research Fellowship. Her principal research interests include artificial and computational intelligence, evolutionary computation, robotics, bioinformatics, pattern recognition, fuzzy logic, cognitive science, and human–computer interaction. She is the author of over 50 papers published in top international journals and conference proceedings. She serves as Reviewer in IEEE-TFS, IEEE-SMC: Systems, Neurocomputing, Information Sciences, and Applied Soft Computing.

Dr. Amit Konar is currently Professor in the ETCE Department, Jadavpur University, Kolkata. He is the author of over 350 publications, including books/monographs, peer-reviewed chapters, and papers, all published by leading international publishers. He is Associate Editor of several prestigious journals, including IEEE Transactions, Elsevier, Springer, and IOS Press. He has supervised 25 Ph.D. theses on artificial intelligence and undertaken several prestigious research projects, including UGC's departmental research support (DRS) scheme, DIT's national project on Perception Engineering, and UGC's excellence program in Cognitive Science. He was the recipient of AICTE-accredited 1997–2000 Career Award for young teachers. He has been nominated as Fellow of National Academy of Engineering on December 12, 2015. His current research interests include human–computer interfacing, cognitive neuroscience, robotics, and machine intelligence.