

## Swarm Intelligence And Ant Colony Optimisation

This book provides a new forum for the dissemination of knowledge in both theoretical and applied research on swarm intelligence (SI) and artificial neural network (ANN). It accelerates interaction between the two bodies of knowledge and fosters a unified development in the next generation of computational model for machine learning. To the best of our knowledge, the integration of SI and ANN is the first attempt to integrate various aspects of both the independent research area into a single volume.

This book presents advances in alternative swarm development that have proved to be effective in several complex problems. Swarm intelligence (SI) is a problem-solving methodology that results from the cooperation between a set of agents with similar characteristics. The study of biological entities, such as animals and insects, manifesting social behavior has resulted in several computational models of swarm intelligence. While there are numerous books addressing the most widely known swarm methods, namely ant colony algorithms and particle swarm optimization, those discussing new alternative approaches are rare. The focus on developments based on the simple modification of popular swarm methods overlooks the opportunity to discover new techniques and procedures that can be useful in solving problems formulated by the academic and industrial communities. Presenting various novel swarm methods and their practical applications, the book

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helps researchers, lecturers, engineers and practitioners solve their own optimization problems.

The two-volume set of LNCS 10385 and 10386, constitutes the proceedings of the 8th International Conference on Advances in Swarm Intelligence, ICSI 2017, held in Fukuoka, Japan, in July/August 2017. The total of 133 papers presented in these volumes was carefully reviewed and selected from 267 submissions. The paper were organized in topical sections as follows: Part I: theories and models of swarm intelligence; novel swarm-based optimization algorithms; particle swarm optimization; applications of particle swarm optimization; ant colony optimization; artificial bee colony algorithms; genetic algorithms; differential evolution; fireworks algorithm; brain storm optimization algorithm; cuckoo search; and firefly algorithm. Part II: multi-objective optimization; portfolio optimization; community detection; multi-agent systems and swarm robotics; hybrid optimization algorithms and applications; fuzzy and swarm approach; clustering and forecast; classification and detection; planning and routing problems; dialog system applications; robotic control; and other applications.

This book constitutes the refereed proceedings of the 5th International Workshop on Ant Colony Optimization and Swarm Intelligence, ANTS 2006, held in Brussels, Belgium, in September 2006. The 27 revised full papers, 23 revised short papers, and 12 extended abstracts presented were carefully reviewed and selected from 115 submissions.

Social insects--ants, bees, termites, and wasps--can be

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viewed as powerful problem-solving systems with sophisticated collective intelligence. Composed of simple interacting agents, this intelligence lies in the networks of interactions among individuals and between individuals and the environment. A fascinating subject, social insects are also a powerful metaphor for artificial intelligence, and the problems they solve--finding food, dividing labor among nestmates, building nests, responding to external challenges--have important counterparts in engineering and computer science. This book provides a detailed look at models of social insect behavior and how to apply these models in the design of complex systems. The book shows how these models replace an emphasis on control, preprogramming, and centralization with designs featuring autonomy, emergence, and distributed functioning. These designs are proving immensely flexible and robust, able to adapt quickly to changing environments and to continue functioning even when individual elements fail. In particular, these designs are an exciting approach to the tremendous growth of complexity in software and information. Swarm Intelligence draws on up-to-date research from biology, neuroscience, artificial intelligence, robotics, operations research, and computer graphics, and each chapter is organized around a particular biological example, which is then used to develop an algorithm, a multiagent system, or a group of robots. The book will be an invaluable resource for a broad range of disciplines.

From nature, we observe swarming behavior in the form of ant colonies, bird flocking, animal herding, honey

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bees, swarming of bacteria, and many more. It is only in recent years that researchers have taken notice of such natural swarming systems as culmination of some form of innate collective intelligence, albeit swarm intelligence (SI) - a metaphor that inspires a myriad of computational problem-solving techniques. In computational intelligence, swarm-like algorithms have been successfully applied to solve many real-world problems in engineering and sciences. This handbook volume serves as a useful foundational as well as consolidatory state-of-art collection of articles in the field from various researchers around the globe. It has a rich collection of contributions pertaining to the theoretical and empirical study of single and multi-objective variants of swarm intelligence based algorithms like particle swarm optimization (PSO), ant colony optimization (ACO), bacterial foraging optimization algorithm (BFOA), honey bee social foraging algorithms, and harmony search (HS). With chapters describing various applications of SI techniques in real-world engineering problems, this handbook can be a valuable resource for researchers and practitioners, giving an in-depth flavor of what SI is capable of achieving.

The two-volume set of LNCS 10941 and 10942 constitutes the proceedings of the 9th International Conference on Advances in Swarm Intelligence, ICSI 2018, held in Shanghai, China, in June 2018. The total of 113 papers presented in these volumes was carefully reviewed and selected from 197 submissions. The papers were organized in topical sections as follows: theories and models of swarm intelligence; ant colony

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optimization; particle swarm optimization; artificial bee colony algorithms; genetic algorithms; differential evolution; fireworks algorithms; bacterial foraging optimization; artificial immune system; hydrologic cycle optimization; other swarm-based optimization algorithms; hybrid optimization algorithms; multi-objective optimization; large-scale global optimization; multi-agent systems; swarm robotics; fuzzy logic approaches; planning and routing problems; recommendation in social media; prediction, classification; finding patterns; image enhancement; deep learning.

In the era globalisation the emerging technologies are governing engineering industries to a multifaceted state. The escalating complexity has demanded researchers to find the possible ways of easing the solution of the problems. This has motivated the researchers to grasp ideas from the nature and implant it in the engineering sciences. This way of thinking led to emergence of many biologically inspired algorithms that have proven to be efficient in handling the computationally complex problems with competence such as Genetic Algorithm (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), etc. Motivated by the capability of the biologically inspired algorithms the present book on "Swarm Intelligence: Focus on Ant and Particle Swarm Optimization" aims to present recent developments and applications concerning optimization with swarm intelligence

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techniques. The papers selected for this book comprise a cross-section of topics that reflect a variety of perspectives and disciplinary backgrounds. In addition to the introduction of new concepts of swarm intelligence, this book also presented some selected representative case studies covering power plant maintenance scheduling; geotechnical engineering; design and machining tolerances; layout problems; manufacturing process plan; job-shop scheduling; structural design; environmental dispatching problems; wireless communication; water distribution systems; multi-plant supply chain; fault diagnosis of airplane engines; and process scheduling. I believe these 27 chapters presented in this book adequately reflect these topics.

The ultimate goal of this book is to design simplified structure and low order robust control algorithms for different dynamic systems with wide range of system parameters variation. These algorithms are based on QFT,  $H_2$ ,  $H_\infty$  and interval tools which represent the most popular and well developed robust techniques. The swarm intelligence methods which adopt the collective behaviour of an organized group of animals, as they strive to survive are used to simplify the robust design procedure and obtain the optimal values of the controller parameters.

These optimization methods will be used to find the optimal controllers subject to QFT,  $H_2$ ,  $H_\infty$  and interval tools constraints. More specifically, the

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algorithms inspired by birds and ants which are the Particle Swarm Optimization (PSO) method and the Ant Colony Optimization (ACO) methods are used in this book.

This book constitutes the thoroughly refereed post-conference proceedings of the 1st International Conference on Swarm Intelligence Based Optimization, ICSIBO 2014, held in Mulhouse, France, in May 2014. The 20 full papers presented were carefully reviewed and selected from 48 submissions. Topics of interest presented and discussed in the conference focuses on the theoretical progress of swarm intelligence metaheuristics and their applications in areas such as: theoretical advances of swarm intelligence metaheuristics, combinatorial, discrete, binary, constrained, multi-objective, multi-modal, dynamic, noisy, and large-scale optimization, artificial immune systems, particle swarms, ant colony, bacterial foraging, artificial bees, fireflies algorithm, hybridization of algorithms, parallel/distributed computing, machine learning, data mining, data clustering, decision making and multi-agent systems based on swarm intelligence principles, adaptation and applications of swarm intelligence principles to real world problems in various domains.

An overview of the rapidly growing field of ant colony optimization that describes theoretical findings, the major algorithms, and current applications. The

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complex social behaviors of ants have been much studied by science, and computer scientists are now finding that these behavior patterns can provide models for solving difficult combinatorial optimization problems. The attempt to develop algorithms inspired by one aspect of ant behavior, the ability to find what computer scientists would call shortest paths, has become the field of ant colony optimization (ACO), the most successful and widely recognized algorithmic technique based on ant behavior. This book presents an overview of this rapidly growing field, from its theoretical inception to practical applications, including descriptions of many available ACO algorithms and their uses. The book first describes the translation of observed ant behavior into working optimization algorithms. The ant colony metaheuristic is then introduced and viewed in the general context of combinatorial optimization. This is followed by a detailed description and guide to all major ACO algorithms and a report on current theoretical findings. The book surveys ACO applications now in use, including routing, assignment, scheduling, subset, machine learning, and bioinformatics problems. AntNet, an ACO algorithm designed for the network routing problem, is described in detail. The authors conclude by summarizing the progress in the field and outlining future research directions. Each chapter ends with bibliographic material, bullet points setting

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out important ideas covered in the chapter, and exercises. Ant Colony Optimization will be of interest to academic and industry researchers, graduate students, and practitioners who wish to learn how to implement ACO algorithms.

This two-volume set LNCS 9712 and LNCS 9713 constitutes the refereed proceedings of the 7th International Conference on Swarm Intelligence, ICSI 2016, held in Bali, Indonesia, in June 2016. The 130 revised regular papers presented were carefully reviewed and selected from 231 submissions. The papers are organized in 22 cohesive sections covering major topics of swarm intelligence and related areas such as trend and models of swarm intelligence research; novel swarm-based optimization algorithms; swarming behaviour; some swarm intelligence algorithms and their applications; hybrid search optimization; particle swarm optimization; PSO applications; ant colony optimization; brain storm optimization; fireworks algorithms; multi-objective optimization; large-scale global optimization; biometrics; scheduling and planning; machine learning methods; clustering algorithm; classification; image classification and encryption; data mining; sensor networks and social networks; neural networks; swarm intelligence in management decision making and operations research; robot control; swarm robotics; intelligent energy and communications systems; and intelligent

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and interactive and tutoring systems.

The two-volume set of LNCS 10385 and 10386, constitutes the proceedings of the 8th International Conference on Advances in Swarm Intelligence, ICSI 2017, held in Fukuoka, Japan, in July/August 2017. The total of 133 papers presented in these volumes was carefully reviewed and selected from 267 submissions. The paper were organized in topical sections as follows: Part I: theories and models of swarm intelligence; novel swarm-based optimization algorithms; particle swarm optimization; applications of particle swarm optimization; ant colony optimization; artificial bee colony algorithms; genetic algorithms; differential evolution; fireworks algorithm; brain storm optimization algorithm; cuckoo search; and firefly algorithm. Part II: multi-objective optimization; portfolio optimization; community detection; multi-agent systems and swarm robotics; hybrid optimization algorithms and applications; fuzzy and swarm approach; clustering and forecast; classification and detection; planning and routing problems; dialog system applications; robotic control; and other applications.

This book and its companion volume, LNCS vol. 8794 and 8795 constitute the proceedings of the 5th International Conference on Swarm Intelligence, ICSI 2014, held in Hefei, China in October 2014. The 107 revised full papers presented were carefully reviewed and selected from 198 submissions. The

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papers are organized in 18 cohesive sections, 3 special sessions and one competitive session covering all major topics of swarm intelligence research and development such as novel swarm-based search methods; novel optimization algorithm; particle swarm optimization; ant colony optimization for travelling salesman problem; artificial bee colony algorithms; artificial immune system; evolutionary algorithms; neural networks and fuzzy methods; hybrid methods; multi-objective optimization; multi-agent systems; evolutionary clustering algorithms; classification methods; GPU-based methods; scheduling and path planning; wireless sensor networks; power system optimization; swarm intelligence in image and video processing; applications of swarm intelligence to management problems; swarm intelligence for real-world application.

This book provides theoretical and practical knowledge on AI and swarm intelligence. It provides a methodology for EA (evolutionary algorithm)-based approach for complex adaptive systems with the integration of several meta-heuristics, e.g., ACO (Ant Colony Optimization), ABC (Artificial Bee Colony), and PSO (Particle Swarm Optimization), etc. These developments contribute towards better problem-solving methodologies in AI. The book also covers emerging uses of swarm intelligence in applications such as complex adaptive systems, reaction-diffusion computing, and diffusion-limited aggregation, etc. Another emphasis is its real-world applications. We give empirical examples from real-world problems and show that the

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proposed approaches are successful when addressing tasks from such areas as swarm robotics, silicon traffics, image understanding, Voronoi diagrams, queuing theory, and slime intelligence, etc. Each chapter begins with the background of the problem followed by the current state-of-the-art techniques of the field, and ends with a detailed discussion. In addition, the simulators, based on optimizers such as PSO and ABC complex adaptive system simulation, are described in detail. These simulators, as well as some source codes, are available online on the author's website for the benefit of readers interested in getting some hands-on experience of the subject. The concepts presented in this book aim to promote and facilitate the effective research in swarm intelligence approaches in both theory and practice. This book would also be of value to other readers because it covers interdisciplinary research topics that encompass problem-solving tasks in AI, complex adaptive systems, and meta-heuristics.

This book not only discusses the important topics in the area of machine learning and combinatorial optimization, it also combines them into one. This was decisive for choosing the material to be included in the book and determining its order of presentation. Decision trees are a popular method of classification as well as of knowledge representation. At the same time, they are easy to implement as the building blocks of an ensemble of classifiers. Admittedly, however, the task of constructing a near-optimal decision tree is a very complex process. The good results typically achieved by the ant colony optimization algorithms when dealing with combinatorial optimization problems suggest the possibility of also using that approach for effectively constructing decision trees. The underlying rationale is that both problem classes can be presented as graphs. This fact leads to option of considering a larger spectrum of solutions than those based

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on the heuristic. Moreover, ant colony optimization algorithms can be used to advantage when building ensembles of classifiers. This book is a combination of a research monograph and a textbook. It can be used in graduate courses, but is also of interest to researchers, both specialists in machine learning and those applying machine learning methods to cope with problems from any field of R&D.

This book constitutes the proceedings of the 11th International Conference on Advances in Swarm Intelligence, ICSI 2020, held in July 2020 in Belgrade, Serbia. Due to the COVID-19 pandemic the conference was held virtually. The 63 papers included in this volume were carefully reviewed and selected from 127 submissions. The papers are organized in 12 cohesive topical sections as follows: Swarm intelligence and nature-inspired computing; swarm-based computing algorithms for optimization; particle swarm optimization; ant colony optimization; brain storm optimization algorithm; bacterial foraging optimization; genetic algorithm and evolutionary computation; multi-objective optimization; machine learning; data mining; multi-agent system and robotic swarm, and other applications.

This book constitutes the proceedings of the 11th International Conference on Swarm Intelligence, ANTS 2018, held in Rome, Italy, in October 2018. The 24 full papers and 12 short papers presented in this volume were carefully reviewed and selected from 69 submissions. They are devoted to the field of swarm intelligence as a whole, without any bias towards specific research directions.

his two-volume set LNCS 12689-12690 constitutes the refereed proceedings of the 12th International Conference on Advances in Swarm Intelligence, ICSI 2021, held in Qingdao, China, in July 2021. The 104 full papers presented in this volume were carefully reviewed and selected from 177 submissions. They cover topics such as: Swarm Intelligence

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and Nature-Inspired Computing; Swarm-based Computing Algorithms for Optimization; Particle Swarm Optimization; Ant Colony Optimization; Differential Evolution; Genetic Algorithm and Evolutionary Computation; Fireworks Algorithms; Brain Storm Optimization Algorithm; Bacterial Foraging Optimization Algorithm; DNA Computing Methods; Multi-Objective Optimization; Swarm Robotics and Multi-Agent System; UAV Cooperation and Control; Machine Learning; Data Mining; and Other Applications.

This book and its companion volume, LNCS vols. 7928 and 7929 constitute the proceedings of the 4th International Conference on Swarm Intelligence, ICSI 2013, held in Harbin, China in June 2013. The 129 revised full papers presented were carefully reviewed and selected from 268 submissions. The papers are organized in 22 cohesive sections covering all major topics of swarm intelligence research and developments. The following topics are covered in this volume: analysis of swarm intelligence based algorithms, particle swarm optimization, applications of particle swarm optimization algorithms, ant colony optimization algorithms, biogeography-based optimization algorithms, novel swarm-based search methods, bee colony algorithms, differential evolution, neural networks, fuzzy methods, evolutionary programming and evolutionary games.

The series of biannual international conferences “ANTS – International Conference on Ant Colony Optimization and Swarm Intelligence”, now in its sixth edition, was started ten years ago, with the organization of ANTS’98. As some readers might recall, the first edition of ANTS was titled “ANTS’98 – From Ant Colonies to Artificial Ants: First International Workshop on Ant Colony Optimization.” In fact, at that time the focus was mainly on ant colony optimization (ACO), the first swarm intelligence algorithm to go beyond a pure scientific interest and to enter the realm of real-world

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applications. Interestingly, in the ten years after the first edition there has been a growing interest not only for ACO, but for a number of other studies that belong more generally to the area of swarm intelligence. The rapid growth of the swarm intelligence field is attested by a number of indicators. First, the number of sessions and participants to the ANTS conferences has steadily increased over the years. Second, a number of international conferences in computational intelligence and related disciplines organize workshops on subjects such as swarm intelligence, ant algorithms, ant colony optimization, and particle swarm optimization. Third, IEEE started organizing, in 2003, the IEEE Swarm Intelligence Symposium (in order to maintain unity in this growing field, we are currently

establishing a cooperation agreement between IEEE SIS and ANTS so as to have 1 IEEE SIS in odd years and ANTS in even years). Last, the Swarm Intelligence journal was born. The aim of this book is to understand the state-of-the-art theoretical and practical advances of swarm intelligence. It comprises seven contemporary relevant chapters. In chapter 1, a review of Bacteria Foraging Optimization (BFO) techniques for both single and multiple criteria problem is presented. A survey on swarm intelligence for multiple and many objectives optimization is presented in chapter 2 along with a topical study on EEG signal analysis. Without compromising the extensive simulation study, a comparative study of variants of MOPSO is provided in chapter 3. Intractable problems like subset and job scheduling problems are discussed in chapters 4 and 7 by different hybrid swarm intelligence techniques. An attempt to study image enhancement by ant colony optimization is made in chapter 5. Finally, chapter 7 covers the aspect of uncertainty in data by hybrid PSO.

This book constitutes the refereed proceedings of the 4th

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International Workshop on Ant Colony Optimization and Swarm Intelligence, ANTS 2004, held in Brussels, Belgium in September 2004. The 22 revised full papers, 19 revised short papers, and 9 poster abstracts presented were carefully reviewed and selected from 79 papers submitted. The papers are devoted to theoretical and foundational aspects of ant algorithms, ant colony optimization and swarm intelligence and deal with a broad variety of optimization applications in networking and operations research.

Ants communicate information by leaving pheromone tracks. A moving ant leaves, in varying quantities, some pheromone on the ground to mark its way. While an isolated ant moves essentially at random, an ant encountering a previously laid trail is able to detect it and decide with high probability to follow it, thus reinforcing the track with its own pheromone. The collective behavior that emerges is thus a positive feedback: where the more the ants following a track, the more attractive that track becomes for being followed; thus the probability with which an ant chooses a path increases with the number of ants that previously chose the same path. This elementary ant's behavior inspired the development of ant colony optimization by Marco Dorigo in 1992, constructing a meta-heuristic stochastic combinatorial computational methodology belonging to a family of related meta-heuristic methods such as simulated annealing, Tabu search and genetic algorithms. This book covers in twenty chapters state of the art methods and applications of utilizing ant colony optimization algorithms. New methods and theory such as multi colony ant algorithm based upon a new pheromone arithmetic crossover and a repulsive operator, new findings on ant colony convergence, and a diversity of engineering and science applications from transportation, water resources, electrical and computer science disciplines are presented.

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Over the past two decades, swarm intelligence has emerged as a powerful approach to solving optimization as well as other complex problems. Swarm intelligence models are inspired by social behaviours of simple agents interacting among themselves as well as with the environment, e.g., flocking of birds, schooling of fish, foraging of bees and ants. The collective behaviours that emerge out of the interactions at the colony level are useful in achieving complex goals. The main aim of this research book is to present a sample of recent innovations and advances in techniques and applications of swarm intelligence. Among the topics covered in this book include: particle swarm optimization and hybrid methods, ant colony optimization and hybrid methods, bee colony optimization, glowworm swarm optimization, and complex social swarms, application of various swarm intelligence models to operational planning of energy plants, modeling and control of nanorobots, classification of documents, identification of disease biomarkers, and prediction of gene signals. The book is directed to researchers, practicing professionals, and undergraduate as well as graduate students of all disciplines who are interested in enhancing their knowledge in techniques and applications of swarm intelligence.

This book constitutes the proceedings of the 9th International Conference on Swarm Intelligence, held in Brussels, Belgium, in September 2014. This volume contains 17 full papers, 9 short papers, and 7 extended abstracts carefully selected out of 55 submissions. The papers cover empirical and theoretical research in swarm intelligence such as: behavioral models of social insects or other animal societies, ant colony optimization, particle swarm optimization, swarm robotics systems.

The two-volume set (LNCS 6728 and 6729) constitutes the refereed proceedings of the International Conference on

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Swarm Intelligence, ICSI 2011, held in Chongqing, China, in June 2011. The 143 revised full papers presented were carefully reviewed and selected from 298 submissions. The papers are organized in topical sections on theoretical analysis of swarm intelligence algorithms, particle swarm optimization, applications of pso algorithms, ant colony optimization algorithms, bee colony algorithms, novel swarm-based optimization algorithms, artificial immune system, differential evolution, neural networks, genetic algorithms, evolutionary computation, fuzzy methods, and hybrid algorithms - for part I. Topics addressed in part II are such as multi-objective optimization algorithms, multi-robot, swarm-robot, and multi-agent systems, data mining methods, machine learning methods, feature selection algorithms, pattern recognition methods, intelligent control, other optimization algorithms and applications, data fusion and swarm intelligence, as well as fish school search - foundations and applications.

This book provides comprehensive details of all Swarm Intelligence based Techniques available till date in a comprehensive manner along with their mathematical proofs. It will act as a foundation for authors, researchers and industry professionals. This monograph will present the latest state of the art research being done on varied Intelligent Technologies like sensor networks, machine learning, optical fiber communications, digital signal processing, image processing and many more.

We describe in this book, hybrid intelligent systems based mainly on type-2 fuzzy logic for intelligent control. Hybrid intelligent systems combine several intelligent computing paradigms, including fuzzy logic, and bio-inspired optimization algorithms, which can be used to produce powerful automatic control

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systems. The book is organized in three main parts, which contain a group of chapters around a similar subject. The first part consists of chapters with the main theme of theory and design algorithms, which are basically chapters that propose new models and concepts, which can be the basis for achieving intelligent control with interval type-2 fuzzy logic. The second part of the book is comprised of chapters with the main theme of evolutionary optimization of type-2 fuzzy systems in intelligent control with the aim of designing optimal type-2 fuzzy controllers for complex control problems in diverse areas of application, including mobile robotics, aircraft dynamics systems and hardware implementations. The third part of the book is formed with chapters dealing with the theme of bio-inspired optimization of type-2 fuzzy systems in intelligent control, which includes the application of particle swarm intelligence and ant colony optimization algorithms for obtaining optimal type-2 fuzzy controllers. The purpose of this book is to collect contributions that are at the intersection of multi-objective optimization, swarm intelligence (specifically, particle swarm optimization and ant colony optimization) and data mining.

This book presents the basic principles and current algorithms and methods of well-known swarm intelligence algorithms and efficient improvements from typical particle swarm optimisation (PSO), ant

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colony optimisation (ACO) and fireworks algorithm (FWA) as well as other swarm intelligence algorithms for swarm robotics.

The two-volume set of LNCS 11655 and 11656 constitutes the proceedings of the 10th International Conference on Advances in Swarm Intelligence, ICSI 2019, held in Chiang Mai, Thailand, in June 2019. The total of 82 papers presented in these volumes was carefully reviewed and selected from 179 submissions. The papers were organized in topical sections as follows: Part I: Novel methods and algorithms for optimization; particle swarm optimization; ant colony optimization; fireworks algorithms and brain storm optimization; swarm intelligence algorithms and improvements; genetic algorithm and differential evolution; swarm robotics. Part II: Multi-agent system; multi-objective optimization; neural networks; machine learning; identification and recognition; social computing and knowledge graph; service quality and energy management.

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