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Swarm Intelligence

Introduction and Applications

Springer

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For María and Marc
(Christian Blum)

For Janine
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Preface

Swarm intelligence is a modern artificial intelligence discipline that is concerned with the design of multiagent systems with applications, e.g., in optimization and in robotics. The design paradigm for these systems is fundamentally different from more traditional approaches.

Instead of a sophisticated controller that governs the global behavior of the system, the swarm intelligence principle is based on many unsophisticated entities that cooperate in order to exhibit a desired behavior. Inspiration for the design of these systems is taken from the collective behavior of social insects such as ants, termites, bees, and wasps, as well as from the behavior of other animal societies such as flocks of birds or schools of fish. Colonies of social insects have mesmerized researchers for many years. However, the principles that govern their behavior remained unknown for a long time. Even though the single members of these societies are unsophisticated individuals, they are able to achieve complex tasks in cooperation. Coordinated behavior emerges from relatively simple actions or interactions between the individuals.

For example, ants, termites and wasps are able to build sophisticated nests in cooperation, without any of the individuals having a global master plan of how to proceed. Another example is the foraging behavior that ants or bees exhibit when searching for food. While ants employ an indirect communication strategy via chemical pheromone trails in order to find shortest paths between their nest and food sources, bee colonies are very efficient in exploiting the richest food sources based on scouts that communicate information about new food sources by means of a so-called waggle dance. For more examples and a more detailed description of the fascinating biological role models that inspired swarm intelligence applications see Chaps. 1 and 2 of this book.

Scientists have applied these principles to new approaches, for example, in optimization and the control of robots. Characterizing properties of the resulting systems include robustness and flexibility. The field of research that is concerned with collective behavior in self-organized and decentralized systems is now referred to as *swarm intelligence*. The term swarm intelligence was first used by Beni and colleagues in the context of cellular robotic sys-

tems where simple agents organize themselves through nearest neighbor interactions. Meanwhile, the term swarm intelligence is used for a much broader research field, as documented in the seminal book *Swarm Intelligence—From Natural to Artificial Systems* by Dorigo, Theraulaz, and Bonabeau, published by Oxford University Press. However, since the appearance of the abovementioned book in 1999, the literature on swarm intelligence topics has grown significantly. This was the motivation for editing this book, whose intention is to provide an overview of swarm intelligence to novices of the field, and to provide researchers from the field with a collection of some of the most interesting recent developments. In order to achieve this goal we were able to convince some of the top researchers in their respective domains to write chapters on their work.

Introductory chapters in the first part of the book are on biological foundations of swarm intelligence, optimization, swarm robotics, and applications in new-generation telecommunication networks. Optimization and swarm robotics are nowadays two of the domains where swarm intelligence principles have been applied very successfully. A third and very popular application domain concerns routing and loadbalancing in telecommunication networks. The second part of the book contains chapters on more specific topics of swarm intelligence research such as the evolution of robot behavior, the use of particle swarms for dynamic optimization, organic computing, and the decentralized traffic flow in production networks.

Finally, we hope that the readers enjoy reading this book, and, most importantly, that they learn something new by seeing things from a new perspective.

Barcelona, Odense   *Christian Blum*
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