Preface

In the past decades, scientists and engineers have been faced with the development and management of an ever-increasing number of distributed systems made of many interconnected components: e.g., the Internet, integrated power grids, transportation networks, cyber-physical systems, fleet of autonomous vehicles, etc. All these systems are complex systems in the sense that they are dynamical systems made of many interacting parts that under certain conditions give rise to spontaneous self-organization. In many cases, their overall collective organization has not been specifically *designed* but instead grew dynamically out of some needs and requirements at the local level: e.g., local area networks, power grid extensions, new road or airport developments, etc.

As humans, we are also becoming increasingly more interconnected: physically thanks to transportation networks, and virtually with the advent of social networking platforms and associated practices. In addition, the unprecedented growth of dense urban environments led to the realization of the crucial need to *control* and regulate dynamic collective behaviors: be they vehicles on the road, airplanes in the vicinity of airports, and even human crowds in high-density areas.

Through self-organization, these complex systems made up of artificial or living units are capable of collectively performing tasks that greatly outperform each individual agent's ability. Thus, the whole becomes greater than the sum of its parts such that the group harnesses swarm intelligence to produce robust and flexible collective actions. On the other hand, under certain conditions, these emergent properties may trigger a disruptive process—often cascading and catastrophic—such as a collapse in collective operation or cooperation, jamming, etc.

This book is about one specific class of complex systems, namely swarming systems in the biological realm, or also multiagent networked systems in the engineering realm. Swarms represent one of nature's most sophisticated achievements in collective operation. As scientists, we are only starting to unlock the secrets of the awe-inspiring dynamics and displays of biological swarms. As engineers, we envision a future filled with specifically designed artificial swarms performing complex tasks with astonishing effectiveness, robustness, and flexibility.

Devising control laws and design principles for artificial swarms requires a thorough overarching understanding of swarms. This scientific endeavor is truly interdisciplinary as elements from biology, physics, network science, complexity theory, control, information theory, and computation are necessary. This book aims at emphasizing the connections between all these disciplines in order to provide a holistic approach toward the design and control of swarm dynamics.

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