Preface

The successful deployment of large swarms of robots in the real world is tied to their ability to take decisions autonomously. While decision making is generally conceived as the cognitive ability of individual agents to select a belief based only on their preferences and available information, collective decision making is a decentralized cognitive process, whereby an ensemble of agents gathers, shares, and processes information as a single organism and makes a choice that is not attributable to any of its individuals. Collective decision making can be seen as a means of designing and understanding swarm robotics systems. A principled selection of the rules governing this cognitive process allows the designer to define, shape, and foresee the dynamics of the swarm.

This book has been written to provide a formal understanding of the many ways in which robot swarms can take discrete collective decisions and, based on this understanding, to put forward a principled methodology to design collective decision-making strategies. The content of this book is aimed at scholars with little or no previous knowledge of collective decision making in robot swarms as well as experts in the field of swarm robotics looking for a freestanding reference work on the subject. This book is a result of the author's doctoral studies performed at the Université libre de Bruxelles, and its development is based on the author's Ph.D. dissertation "*The Best-of-n Problem in Robot Swarms*."

In the first part of this book, we introduce the reader to the topic of self-organized collective decision making and then focus on discrete consensus achievement. We formalize the best-of-n problem, define a taxonomy of its possible variants, and use this framework to survey the swarm robotics literature. Successively, we identify a set of mechanisms that are essential for a swarm to take a successful collective decision in the best-of-n problem: option exploration, opinion dissemination, modulation of positive feedback, and individual decision-making mechanism. By leveraging on this understanding, we put forward a modular and model-driven design methodology that allows the designer to compose collective decision-making strategies and to study their dynamics at different level of abstractions. In the second part of this book, we showcase the proposed design methodology. We compose three different collective decision-making strategies, the Indirect Modulation of Majority-based Decisions, the Direct Modulation of Voter-based Decisions, and the Direct Modulation of Majority-based Decisions, and study their performance using both deterministic and stochastic mathematical models. Our analysis of these strategies focuses on the trade-off between the speed at which a swarm takes a collective decision and its accuracy in selecting the optimal option. In the third part of this book, we show how the designed strategies can be readily applied to different real-world scenarios. We pursue this aim by detailing the results of two series of robot experiments. In the first series, we use a swarm of 100 robots to tackle a site-selection scenario where the objective of the swarm is to select which site has the highest quality. In the second series, we show instead how the same strategies apply to a collective perception scenario whereby the objective of the swarm is to decide which feature of an environment is the most spread. Finally, we conclude with a summary of the scientific contributions of this book and discuss possible future direction of research.

Tempe, AZ, USA Gabriele Valentini

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Valentini, G.
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