In the past few years the topic of cooperative motion of multiple agents has attracted serious attention. Cooperative motion appears in various problems, such as formation control of multiple vehicles, flocking of animals, and consensus and synchronization problems of communication networks [1]–[3]. With the rapid advance of technology, cooperative control of multivehicle systems has become increasingly interesting in applications such as autonomous underwater vehicles, space-based interferometers, and automated highway systems, as well as in homeland security and military applications. By cooperating with each other, a team of inexpensive vehicles can accomplish complex, dangerous, or high-precision tasks that cannot be performed by a single vehicle. In control design for multivehicle systems, communication and connectivity constraints pose the main challenges. Consequently, distributed control is widely adopted in order to efficiently handle such constraints.

Consensus problems have a long history in the field of computer science, especially in automata theory and distributed computation [4]. “Consensus” means that the states of all agents agree on certain quantities of interest. Consensus analysis is relevant to motion control of multiple autonomous mobile agents regarding their interconnection topology. To achieve consensus, each vehicle in the group must communicate with its neighbors in a coordinated fashion. A typical characteristic of systems of cooperative multiple agents is that information exchange is local due to limitations in the communication bandwidth and the sensor range. A critical problem for cooperative control is thus to design an appropriate neighbor-based distributed control instead of a centralized control such that all the vehicles can achieve consensus under limited information exchange and dynamic interaction topology.

The book under review is a research monograph that incorporates the authors’ main work in multivehicle cooperative control using distributed consensus algorithms. The book involves both theoretical analysis and engineering applications in distributed coordination of multiple ground robots, spacecraft, and unmanned aerial vehicles.

The theoretical results focus on several distributed consensus algorithms for single-integrator systems, double-integrator systems, and attitude dynamics of a rigid body. Rigorous convergence analyses are provided for the cases where the communication network is limited, directed, noisy, or dynamically changing. The consensus-based design algorithms are also applied to several practical cooperative control problems.

**CONTENTS OF THE BOOK**

The book comprises six parts and six appendices and is divided into 14 chapters. The first seven chapters present the theoretical results on distributed consensus algorithms, where the dynamics of the vehicles are first order, second order, and rigid body, respectively. The last seven chapters focus on applications of cooperative control, including rendezvous and formation control of multiple wheeled mobile robots, spacecraft formation flying, and cooperative fire-perimeter tracking and surveillance for multiple unmanned autonomous vehicles (UAVs). Some notes are provided at the end of each chapter concerning derivations of key results. The appendices introduce relevant concepts, which further increases readability.

Part I (Chapter 1) gives an overview of existing consensus algorithms on cooperative control of multiple vehicles. Part II (chapters 2 and 3) introduces consensus algorithms for single-integrator dynamics. Both continuous- and discrete-time consensus algorithms are considered under either fixed or dynamical interaction topologies. Chapter 2 shows that consensus can be achieved asymptotically if and only if the adjacent graph has a direct spanning tree. For the case of dynamical topology, if the union of the directed graphs on a series of uniformly bounded and consecutive time intervals has a spanning tree, then consensus can be achieved, Chapter 3 generalizes the results in Chapter 2 to the case of a reference state.

Part III (chapters 4 and 5) is similar to that of Part II. Chapter 4 extends the consensus algorithms for single-integrator dynamics in Chapter 2 to...
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double-integrator dynamics and shows that the extension is nontrivial. It is proved that having a spanning tree is a necessary rather than a sufficient condition for consensus of second-order systems. The choice of consensus control gains turns out to be important to the stability of multiagent systems. Two additional consensus algorithms are considered, namely, consensus with bounded control inputs and without relative state derivative measurements based on a passivity approach. Chapter 5 extends the algorithms in Chapter 4 to a reference model.

Part IV (chapters 6 and 7) focuses on consensus algorithms for rigid body attitude dynamics represented by quaternions. In Chapter 6, attitude consensus of multiple rigid bodies is considered in three cases in which it is essential that the rigid bodies maintain attitude during formation maneuvers. The algorithms in this chapter are extensions of those in chapters 2–5, but they are nontrivial extensions due to the inherent nonlinearity of rigid body attitude dynamics. Compared to the attitude control of a single rigid body, the major contribution of this chapter lies in the analysis of the relative information exchange among multiple rigid bodies. Chapter 7 extends the consensus algorithms in Chapter 6 to relative attitude maintenance and reference attitude tracking problems of multiple rigid bodies. In essence, Chapter 6 can be considered as a special case of Chapter 7.

Part V (Chapter 8) presents several consensus-based design methodologies for distributed multivehicle cooperative control. The approach includes four ingredients, 1) cooperation objective and constraints, 2) coordination variable and coordination function, 3) centralized cooperation scheme, and 4) consensus building. At the end of the chapter an overview is given on the existing research on formation control and UAV cooperation.

In Part VI (chapters 9–14), the consensus algorithms are applied to multivehicle cooperative control problems. Chapter 9 applies the consensus-based design scheme described in Section 8.4.1 to rendezvous and axial alignment of multiple wheeled mobile robots. The experimental results show effectiveness and robustness of the consensus algorithms.

In Chapter 10, the authors apply the design scheme in Section 8.4.1 to formation control of multiple wheeled mobile robots with a virtual leader. The experiments are carried out on a multirobot experimental platform. Chapter 11 presents a decentralized behavioral approach to formation maneuvers for a group of wheeled mobile robots. Chapter 12 applies the design scheme to deep spacecraft formation flying. The multiple spacecraft formation flying has applications in space-based interferometers and military surveillance. Chapter 13 investigates the feasibility of using multiple UAVs to cooperatively monitor and track the propagation of large forest fires. A real-time algorithm is used for tracking the perimeter of fires with on-board infrared sensors. Chapter 14 explores cooperative control for aerial surveillance of multiple UAVs, which is successfully flight-tested on small (48-in wingspan) UAVs.

CONCLUSIONS
Monographs on cooperative control of multivehicle systems are scarce, although numerous research papers on this topic have appeared in recent years. This book gives a systematic analysis of distributed consensus problems of multivehicle cooperative control and summarizes the main recent work of the authors. The book is well written, and all of the main theoretical results are given together with rigorous mathematical proofs. This book can be a very useful reference for Ph.D. students and researchers in automatic control.

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REFERENCES