# Part II
# Distributed Adaptive Control for Multi-Agent Cooperative Systems

The optimal cooperative controllers studied in Part I of the book require complete information of the system dynamics and rely on off-line solutions of matrix design equations. Adaptive control [1], [7], [10] is a powerful method for the design of dynamic controllers that are tuned online in real time to learn stabilizing feedback controllers for systems with unknown dynamics. In cooperative adaptive control, moreover, the dynamics of the agents can be heterogeneous, that is, different for each agent. The agent dynamics can also have unknown disturbances.

In Part II of the book, we show how to design cooperative adaptive controllers for multi-agent systems on graphs. The challenge is to design adaptive parameter tuning laws that are distributed in the sense that they only require information from the neighbors in the graph topology.

In Part I of the book, we studied local and global optimal control for cooperative multi-agent systems on communication using graphs. In these systems, any control protocol must be distributed in the sense that the control for each agent is allowed to depend only on information about that agent and its neighbors in the graph. In Chap. 5 we saw that this means that globally optimal controls of distributed form may not exist on a given graph. To obtain globally optimal performance using distributed protocols, the global performance index must be selected to depend on the graph topology in a certain way, specifically, through the graph Laplacian matrix.

Likewise, we shall now see in Part II of the book that adaptive control design for cooperative multi-agent systems requires the use of special Lyapunov functions that depend on the graph topology in a certain way. In adaptive controllers that are admissible for a prescribed communication graph topology, only distributed control protocols and distributed adaptive tuning laws are permitted. It is not straightforward to develop adaptive tuning laws for coopertive agents on graphs that only require information from each agent and its neighbors. The key to this is selecting special Lyapunov functions for adaptive control design that depend in specific ways on the graph topology. Such Lyapunov functions can be constructed using the concept of graph Laplacian potential, which depends on the communication graph topology. The Laplacian potential captures the notion of a virtual potential energy stored in the graph.