Chapter 10
Cooperative Control of Unknown Networked Lagrange Systems using Higher Order Neural Networks

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ABSTRACT
This chapter investigates the cooperative control problem for a group of Lagrange systems with a target system to be tracked. The development is suitable for the case that the desired trajectory of the target node is only available to a portion of the networked systems. All the networked systems can have different dynamics. The dynamics of the networked systems, as well as the target system, are all assumed unknown. A higher-order neural network is used at each node to approximate the distributed unknown dynamics. A distributed adaptive neural network control protocol is proposed so that the networked systems synchronize to the motion of the target node. The theoretical analysis shows that the synchronization error can be made arbitrarily small by appropriately tuning the design parameters.

INTRODUCTION
The topic of distributed cooperative control of multi-agent systems has gained great interest in recent years due to the advent of powerful embedded systems and communication networks. Cooperative control of multi-agent systems has broad applications in such areas as distributed reconnaissance and surveillance, multi-robot search and rescue, multi-sensor location and identification, air traffic control, and so on. Compared with the centralized cooperative control method, the distributed cooperative control strategy enjoys many advantages, such as scalability, robustness, and reliability. From the control point of view, the cooperative control of multi-agent systems can
be categorized into two classes: the cooperative regulator problem and the cooperative tracking problem. For the cooperative regulator problem, by using the fundamental ‘nearest neighbor rule,’ each agent eventually synchronizes to an unprescribed common value, which is generally a function of the initial states of the systems. For the distributed tracking problem, there exists a leader or control node in the networked systems. The control node acts as a command generator, which generates the desired reference trajectory. All other systems are required to follow the trajectory of the control node. The distributed tracking control of multi-agent systems has a wide range of applications in industry. For example, in cooperative tele-operation systems, multiple remote robot arms are required to track the trajectory of the local dominant or master robot arm. Manipulator robots are widely used in the complex and integrated production process where the flexibility, reliability, manipulability, and scalability are highly required. It is a typical example for a group of robots to transport a large-size work-piece, where the cooperative robotic manipulators are required to follow the same trajectory. The case of a group of mobile robots following a leader robot, where only the leader robot is mounted with a camera to decide the moving route, is another example where the distributed tracking control is needed.

The purpose of this chapter is to provide analysis/design techniques for the cooperative tracking control of multiple nonlinear Lagrange systems, which may include manipulator robots, ships, underwater vehicles, helicopters, or satellites. In the design of classical tracking controller, the external signal, such as the coupling information, is considered as a disturbance and its effect is minimized by the controller. However, for the distributed tracking control problem of networked Lagrange systems, the interactions between the systems generate the necessary information to achieve the purpose of tracking control. The distributed tracking control problem considered in this chapter is also different from the usual path-following problem since we consider the case where only a few of the networked Lagrange systems have access to the desired time-varying trajectory of the target system. In other words, to achieve the trajectory tracking for some Lagrange systems, which have no access to the desired trajectory information, the decision-making is only based on the neighbors’ information. Moreover, many existing results in the context of multi-agent cooperative control require that the model parameters of the agents are perfectly known or known with a small degree of uncertainty. In practice, it is hard to acquire the model parameters accurately. Therefore, we need to study the cooperative control problem in the presence of uncertain dynamics. In this chapter, we assume that the dynamics of the networked systems, as well as the target system, are all assumed unknown. Based on the universal approximation capability of Neural Networks (NN), a Higher Order Neural Network (HONN) is used at each node to approximate the distributed unknown dynamics. The design and analysis of control algorithms are provided by applying the Lyapunov stability theory.

BACKGROUND

The study of cooperative control of multi-agent systems has been ongoing for many years. Jadabaie, Lin, and Morse (2003) provided a theoretical explanation for the consensus behavior of the Vicsek model. This paper initiated a great deal of interest in research on consensus problem of multi-agent systems. A general framework of the consensus problem for the fixed or switching topologies was established in Olfati-Saber and Murray (2004). Ren and Beard (2005) extended the results in Jadabaie, et al. (2003), Olfati-Saber and Murray (2004) by providing more relaxed conditions. In particular, the use of graph theory and matrix theory produced many interesting results, such as those in Qu (2009), Chopra and Spong (2006), Ren and Beard (2008), and Wu (2007), to