Studies on Controller Networks

Shinsaku Izumi

Abstract

While feedback systems using a single controller have been mainly considered in the systems and control field, systems with networked controllers, *i.e.*, a controller network, have received much attention in recent years. In such systems, the nodes of the network cooperatively determine control inputs by sharing information with their neighbors. This scheme enables us to make control systems robust against failures. Furthermore, the controller network has great potential for engineering applications, *e.g.*, wireless control systems, smart grids, and multi-robot systems.

The main purpose of this thesis is to give solutions to some problems in the controller network design. More precisely, we address the following problems.

First, we consider a problem of finding a controller network to stabilize linear plants under the assumption that its network topology is fixed but unknown. As a solution to the problem, a controller network acting as a state feedback controller is proposed. We then prove that the resulting feedback system is stable if the gains of networked controllers are appropriately chosen. With this result, we can obtain a controller network which is robust against changes in the network topology. In addition, the relation between the stabilizing gain and the network topology is clarified, which provides useful information to design the gain in an easy way.

Second, we provide a framework of real-time pricing, *i.e.*, to control the total power consumption of consumers by changing power prices in real-time, based on the controller network. In the proposed framework, each power source has a local controller, and estimates the total power consumption by exchanging information on the required power with its neighbors. The problem addressed here is to design the local controllers and a power price controller such that the total power consumption tracks a given reference input under a constraint on the range of the power price. For this problem, we first derive a necessary condition for its solvability. This enables us to estimate the price needed to achieve tracking a given reference input. Then, we propose a solution to the problem and

show that it achieves the real-time pricing. With this result, we can achieve the real-time pricing without collecting information on the power consumption from all the consumers.

Finally, we address a problem of designing a controller network for the robotic mass games, that is, to let robots organize themselves into a formation displaying a given grayscale image. By fusing ideas of the coverage control and the halftone image processing, we derive a solution to the problem. The performance of our solution is demonstrated by numerical experiments with standard images. Moreover, we give extensions to the cases of r-disk proximity networks and a variable number of player robots. The former enables us to achieve the mass games even though the communication range of the robots is limited. The latter improves the visual quality of the resulting formations.