Stability and decentralized stabilization of complex networks by small gain approach

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Abstract

Large-scale networks appear in many applications such as power networks, platooning, logistics, production and transport networks, teleoperations, multi-agent systems of autonomous vehicles, etc. Their stability and stabilization are crucial in most engineering tasks on the one hand, and design of general mathematical theories resolving these problems is rather challenging especially in the nonlinear case.

The notion of input-to-state stability (ISS), was introduced by E.D. Sontag in 1989 as an extension of the classical asymptotic stability property. It became very fruitful for stability analysis of complex systems composed of several simpler subsystems such that the output of each simple subsystem affects the input of some other subsystems and can potentially destroy the stability of the neighbors. Indeed, one can expect that, if every basic subsystem is ISS and its output does not disturb the inputs of the other subsystems too much, then the entire network is also stable. The problem is how to describe this "too much" most efficiently, and the answer is summarized in the so-called small-gain theorems.

Small-gain theorems are rather efficient in various decentalized or distributed control problems. For instance, suppose that we want to stabilize a large-scale network composed of $N = 10^3$ or $N = 10^6$ interconnected agents, and the output of each agent works as a destabilizing disturbance for its neighbors. However, the feedback as a function of all the N states would be irrelevant of course. Then it is natural to look for a decentalized feedback due to the complexity of the network, so that each agent with its feeback needs to know only its own state and perhaps the states of its "neighbors". Then the challenge is design a feebdack with a suitable gain assignment for each agent to satisfy the corresponding small gain condition.

The talk surveys classical works devoted to the nonlinear small gain theorems with their applications in decentralized nonlinear control and then we discuss and analyze some recent works co-authored by the speaker and generalizations of their classical predecessors along the same lines.

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