Network-decentralised control, coordination and estimation

Problem Background

Complex large-scale systems composed of naturally decoupled subsystems have to be stabilised/controlled/coordinated to enforce the desired global behaviour, by a set of local control agents that interconnect the subsystems and thus introduce coupling. A centralised controller that acts on, and has information about, the whole system is often impossible to implement, due to the size, the geographical sparsity and the complexity of the overall system. We can then resort to network-decentralised control strategies, where each control agent, affecting a subset of the subsystems (local action), has access to the state of these subsystems only (local information), and still the aim is to govern the global behaviour. We can also synthesise network-decentralised observers for groups of agents that exchange information about local measurements, according to a communication graph, to estimate their own state (e.g., position in a localisation problem).

Suggested Readings

- The smallest eigenvalue of the generalised Laplacian matrix, with application to network-decentralised estimation for homogeneous systems, IEEE TNSE, 2016
- Compartmental flow control: decentralization, robustness and optimality, Automatica, 2016
- Network-decentralised control strategies for stabilization, IEEE TAC, 2015
- Network-decentralized robust congestion control with node traffic splitting, CDC 2014
- Structured-LMI conditions for stabilizing network-decentralized control, CDC 2013

Your Profile

- Motivated and independent
- Good knowledge of linear algebra and systems control
- Possibly, familiar with robust/networked control (topic 1)
- or with nonlinear systems and modelling (topic 2)
- Programming experience (Matlab or others)

Structural analysis of biological systems

Problem Background

Can a class of systems necessarily give rise to a particular qualitative behaviour, regardless of parameter values? This is indeed the case for many natural and biological systems: although plagued by huge uncertainties and parameter variations, their global behaviour (arising from the complex interplay of local interactions) is often astoundingly robust to environmental changes and perturbations. Structural analysis aims at assessing whether a class of systems always enjoys a given property, due to its structure (topology of the interaction graph) and not to specific parameter values. The problem is formally approached by considering a system structure (associated with a graph topology) along with qualitative assumptions (positivity of the variables, monotonicity of the functions).

Suggested Readings

- Piecewise-linear Lyapunov functions for structural stability of biochemical networks, Automatica 2014
- A structural classification of candidate oscillatory and multistationary biochemical systems, Bulletin of Mathematical Biology 2014
- Determining the structural properties of a class of biological models, CDC 2012

Your Assignment

- “Verification” of structural properties: given a graph structure, generate random functions satisfying the assumptions and check that the property always holds.

Your Focus, Your Choice

All projects can involve interesting mathematical/theoretical aspects and/or practical research (computer simulations or, for the first topic, lab activities). The second topic is interdisciplinary, but very well suited for control engineers!