Control architectures for co-operative control of mobile robots

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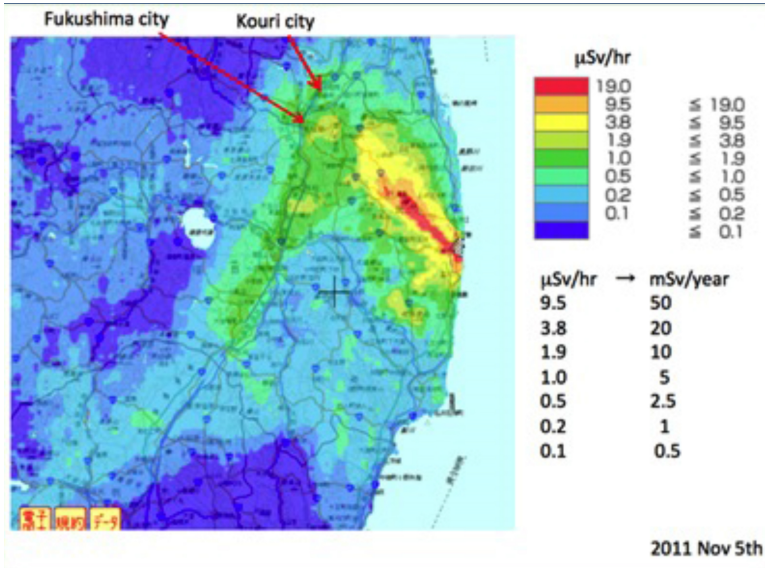
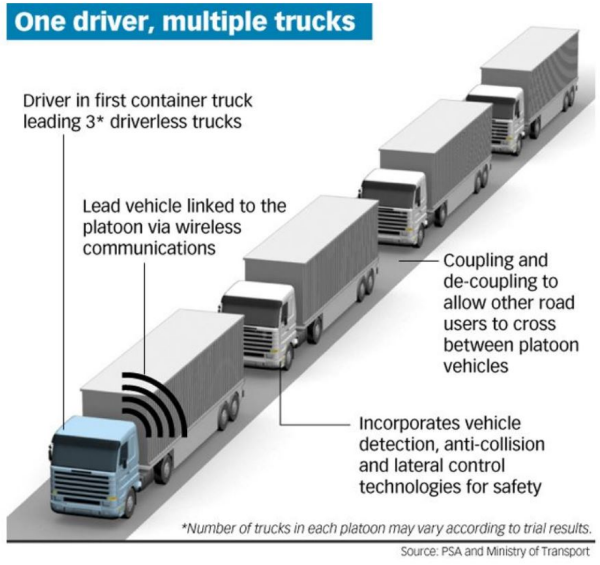
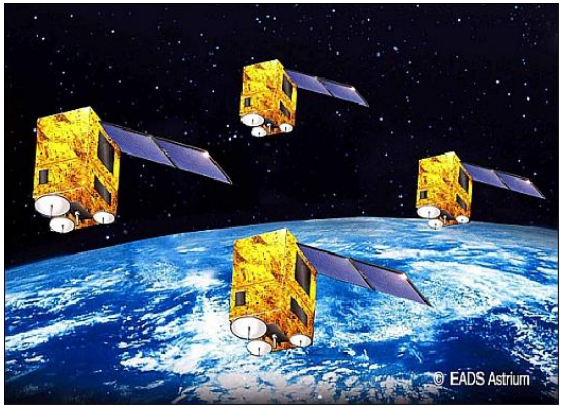
Motivating Scenarios

Fukushima Disaster (2011)

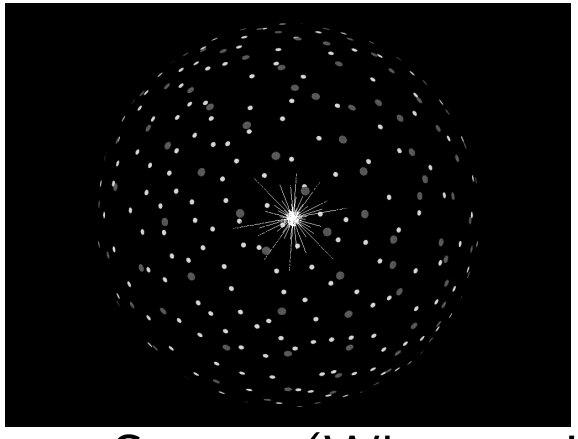


Truck Platoon Competition (2016)





. EADS Astrium



Dyson Swarm (Why not !)

Abstracting to a Mathematical Problem

Problem Statement:

Design distributed control algorithms for large networks of mobile robots such that the group shows a desirable behavior.

- Desirable behaviors we consider:
  - Consensus and/or Formation stabilization
  - Flocking with/without source seeking
- Complexity in solving the problem can stem through:
  - Complicated dynamics of individual agents
  - Commplicated Interconnection structure and intractible design algorithms for large networks

Approaching the problem: Divide and Conquer

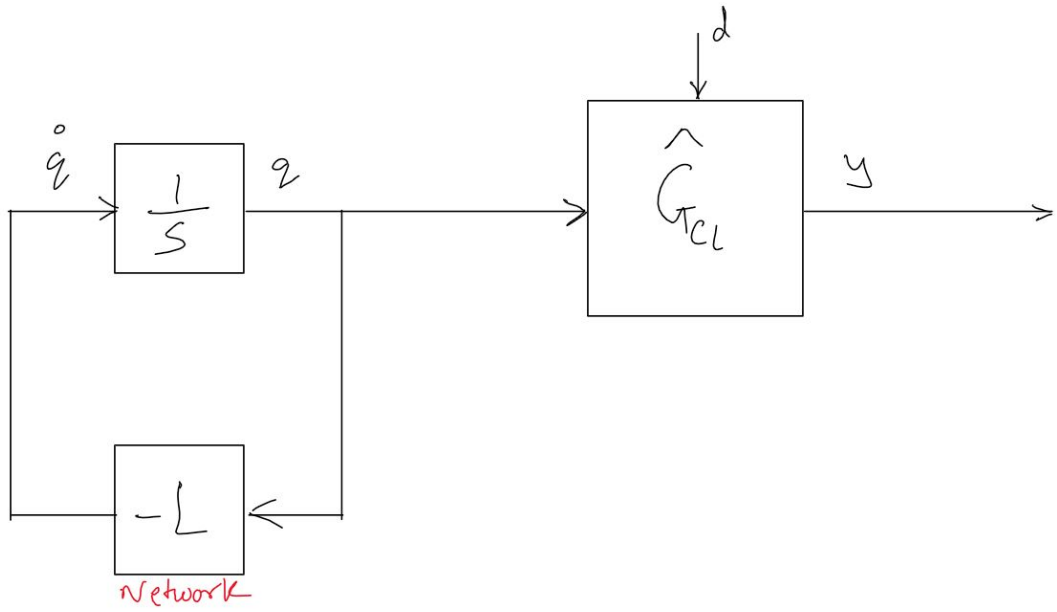
Available literature on

- Control of single complex agent dynamics (e.g LPV, control of differetially flat systems, dynamic inversion)
- Distributed control of large networks of "simple" agent dynamics (e.g single and double intergrators) -> Consensus and Flocking algorithms

Consider as building blocks

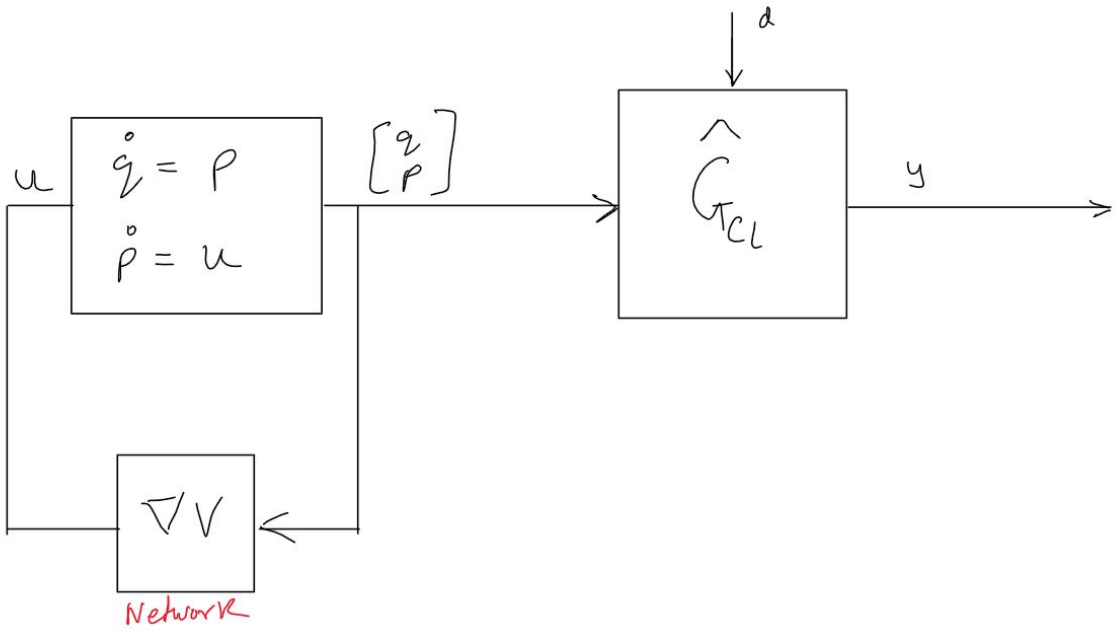
- Closed-loop system G_{cl} with some guaranteed performance measure such as the induced $\mathcal{L}_2 - \mathcal{L}_2$ or $\mathcal{L}_2 - \mathcal{L}_\infty$ norms
- Consensus or Flocking algorithms for "simple" systems

Consensus/ Formation with a decoupled architecture: "Small" disturbances and "good" tracking



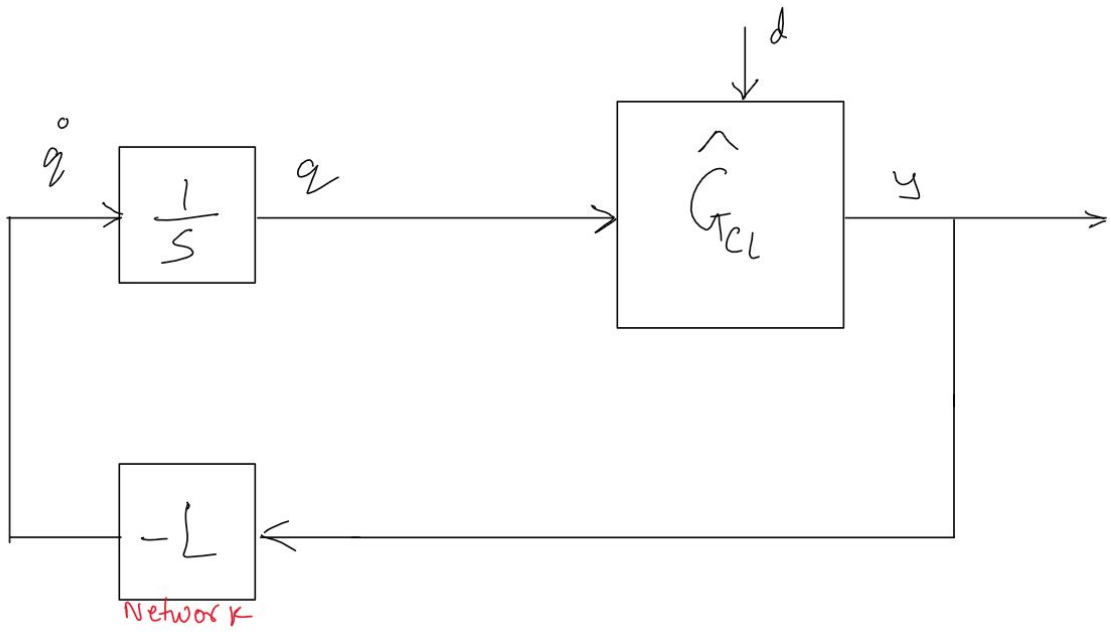
- Can bound the $||q - y||_{\mathcal{L}_\infty}$ to get an idea about how far the true trajectories given a bound on the disturbance
- C. Hespe, A. Datar, and H. Werner, "Distributed control of mobile lti and lpv agents using induced $\mathcal{L}_2$ to $\mathcal{L}_\infty$ norms."
- Discrete-time, positive systems theory-> ACC Submission

Flocking with a decoupled architecture: "slow" flocking and "good" tracking



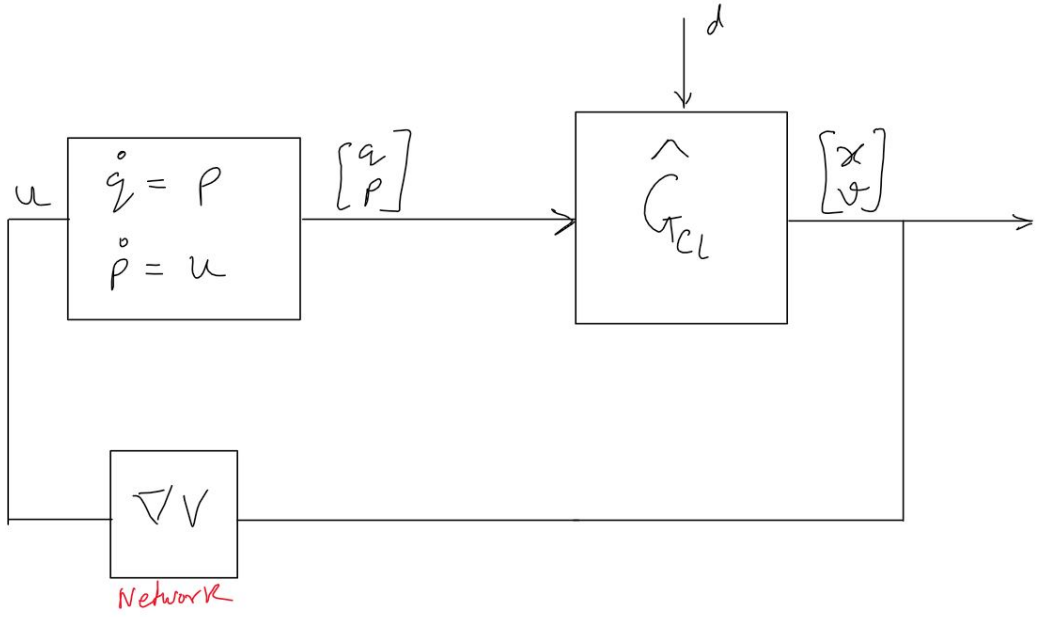
- Experimental work: Datar, Adwait, Paulsen, Peter and Werner, Herbert (2020): Flocking Towards the Source: Indoor Experiments with Quadrotors. In 2020 European Control Conference (ECC) (pp. 1638-1643).
- Local Velocity Controller
- No Analysis yet

Consensus with a Coupled architecture



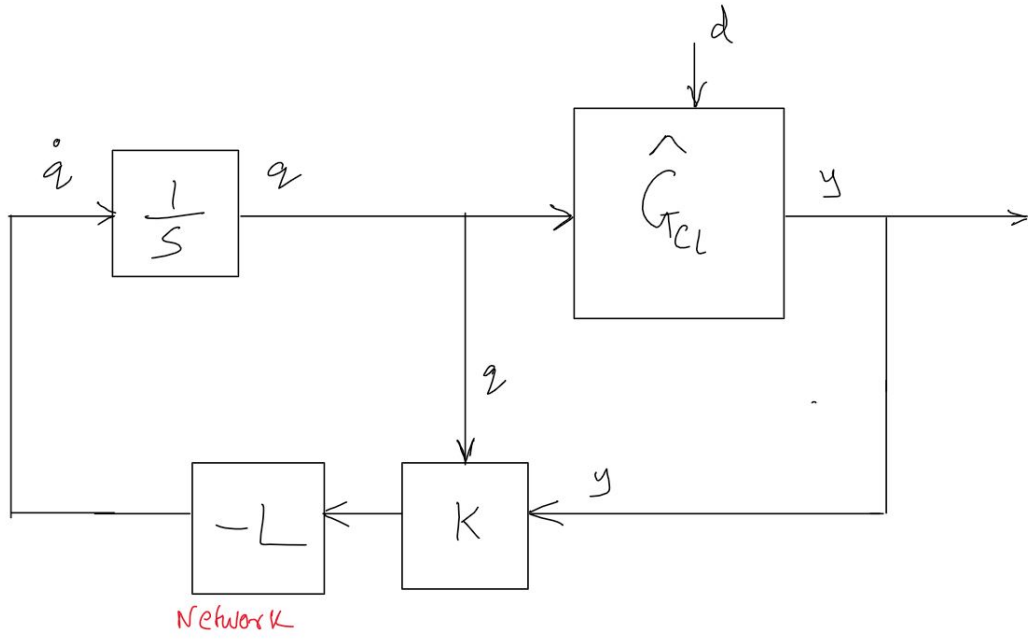
- Can show stability (boundedness without assymptotic stability)
- Input output stability via a small-gain argument (Hespe's M. Thesis)
- Singular perturbation theory with a time-scale separation to prove assymptotic stability

Flocking with a Coupled architecture



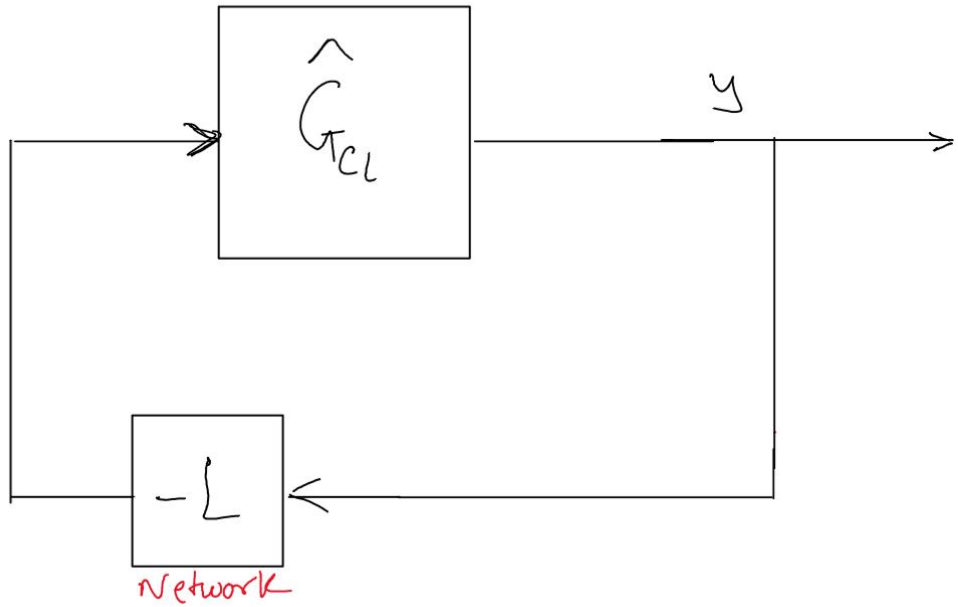
- Attallah, Aly and Datar, Adwait and Werner, Herbert (2020): Flocking of Linear Parameter Varying Agents: Source Seeking Application with Underwater Vehicles. In 21st IFAC World Congress
- No assymptotic stability yet

A more heuristic and practical architecture



- Heuristic: Works well in Simulation
- No analysis yet

Another commonly observed architecture



- Lot of literature on Stability Analysis for LTI systems
- Some of our past literature on Stability Analysis for LPV systems
- Some recent work on Passivity based analysis by Mark Spong and others

Thank you