COORDINATION AND CONTROL OF MULTI-AGENT SYSTEMS

086730

Daniel Zelazo

October 25, 2025

ORGANIZATIONAL MATTERS

Instructor

Daniel Zelazo

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Lady Davis 755

`https://connect-lab-technion.github.io/`

Office Hours: TBD (or by appointment)

Course Schedule

Wednesdays, 09:30-12:30

Hybrid (Zoom and In-Person)

Ullman 504

Course Website: Moodle (backup `https://connect-lab-technion.github.io/courses/nds2025/NDS2025_index.html`)

GRADING POLICY

Homeworks: 30%

- 4-6 assignments
- working in groups encouraged
- submission individually
- solutions must be typed (English; LaTeX preferred but not required)

Midterm Project: 25%

- Take-home project
- One week to complete
- To be completed individually (NO collaboration!)
- Nominally scheduled for middle of semester

Final Project: 45%

- TBD - details to follow

COURSE SCHEDULE

Course Introduction (today)

Unit 1

-Graph Theory

Unit 2

-Consensus Protocols

Unit 3

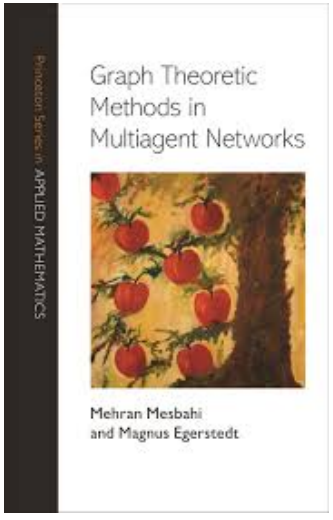
-Formation Control

Unit 4

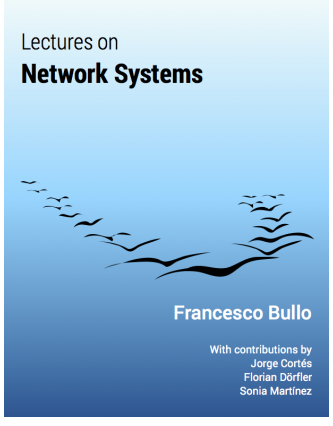
- Advanced Topics

SUGGESTED READINGS

Course Notes (moodle)

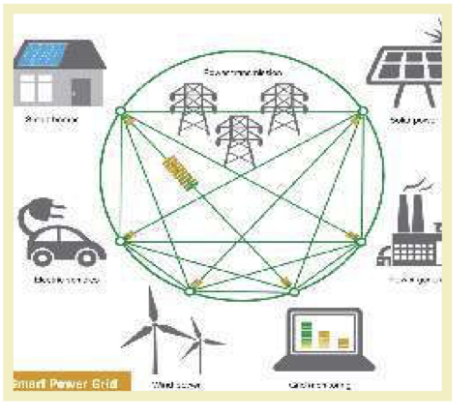


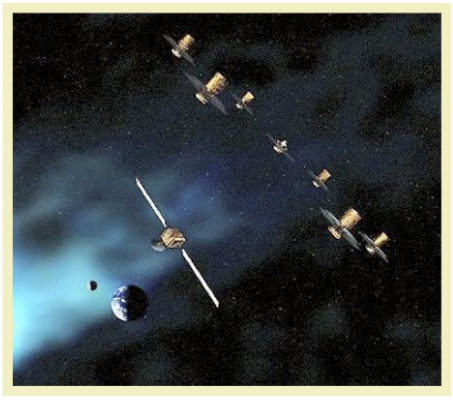
M. Mesbahi and M. Egerstedt, *Graph Theoretic Methods in Multiagent Networks*, Princeton University Press, 2010.

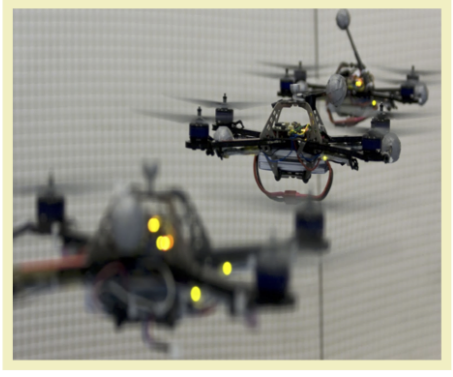


F. Bullo, *Lectures on Network Systems*,
`http://motion.me.ucsb.edu/book-lns/`

NETWORKED DYNAMIC SYSTEMS



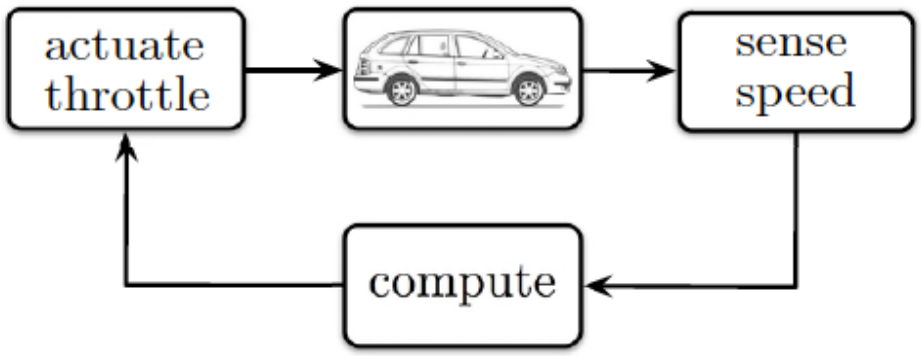


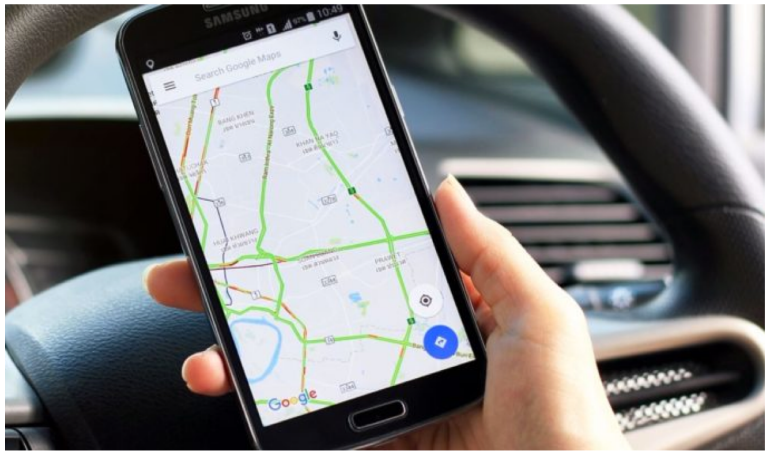


how do we analyze these systems

how do we design these systems

THE BASELINE IN THIS COURSE





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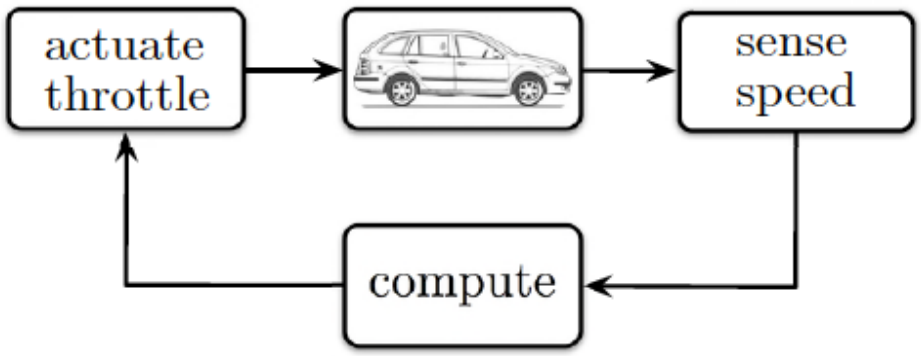

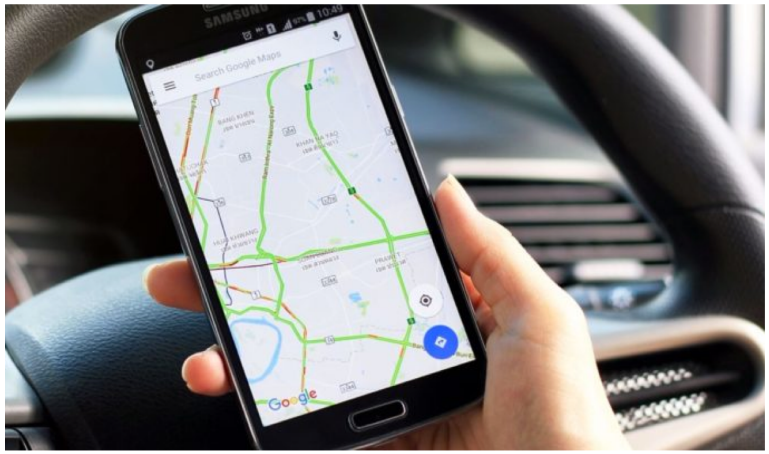

"simple" control systems and optimization methods are "well understood"

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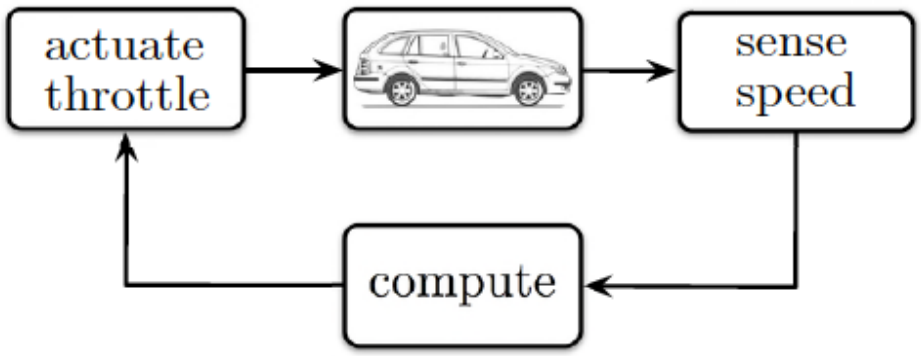

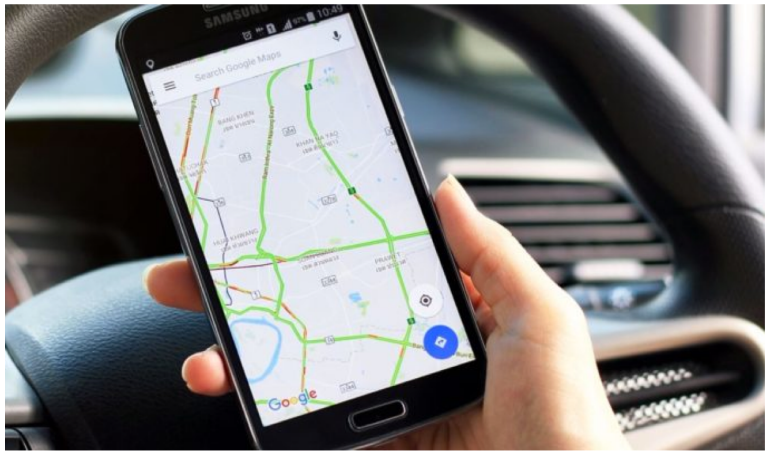

"simple" control systems and optimization methods are "well understood"

"complexity" can enter in many ways

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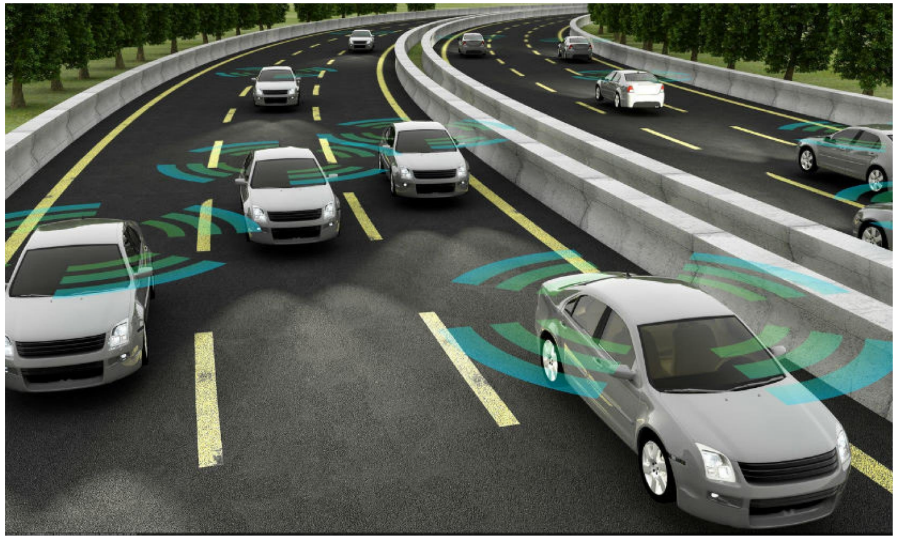

complex “interactions” between sensing, control, and objectives

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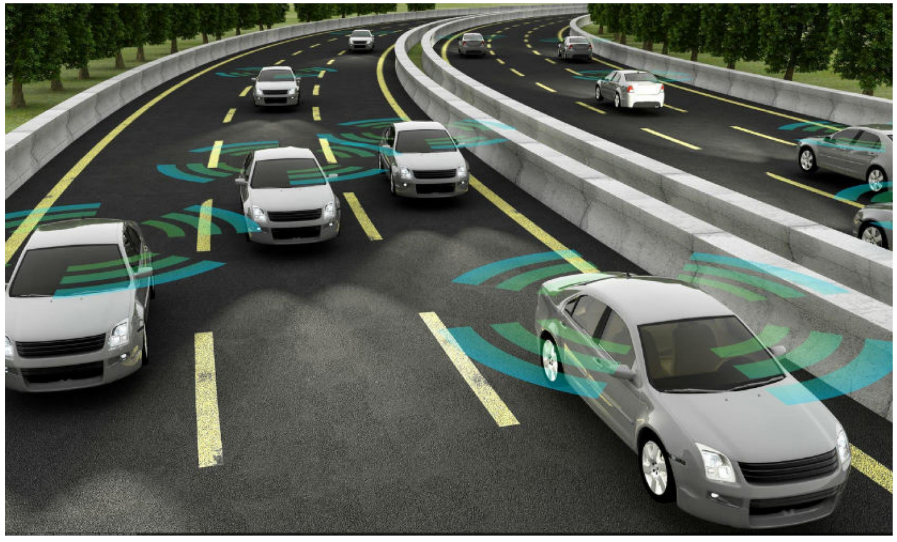


complex “interactions” between sensing, control, and objectives

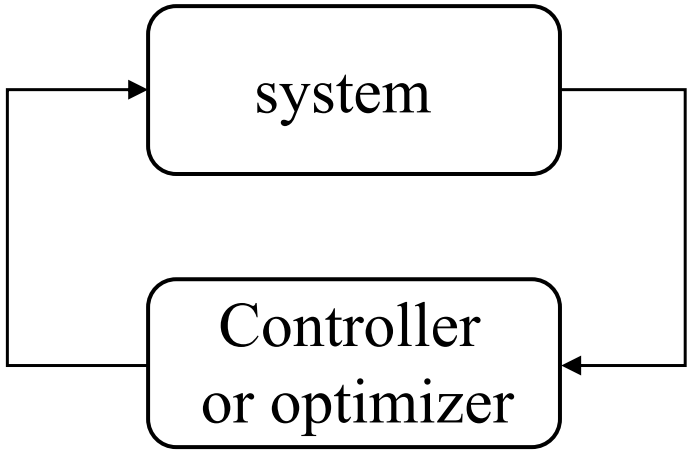
interactions: physical, logical, functional, and societal

THE BASELINE IN THIS COURSE

complex “interactions” between control and optimization systems

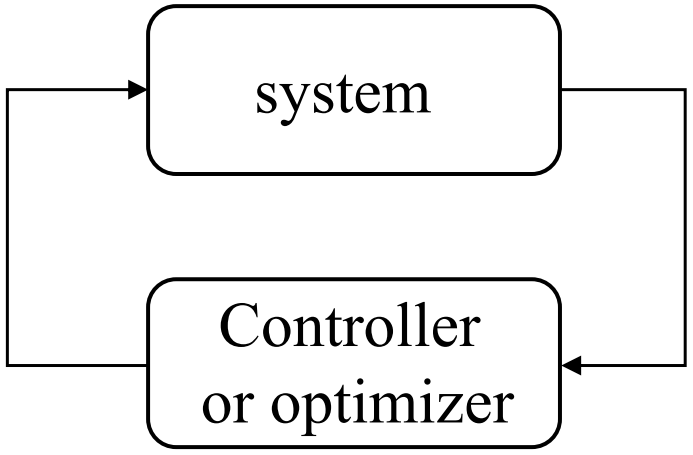
interactions: physical, logical, functional, and societal

THE CENTRALIZED CONTROL SYSTEM



Controller: When deviating from a linear SISO system, “complexity” arises

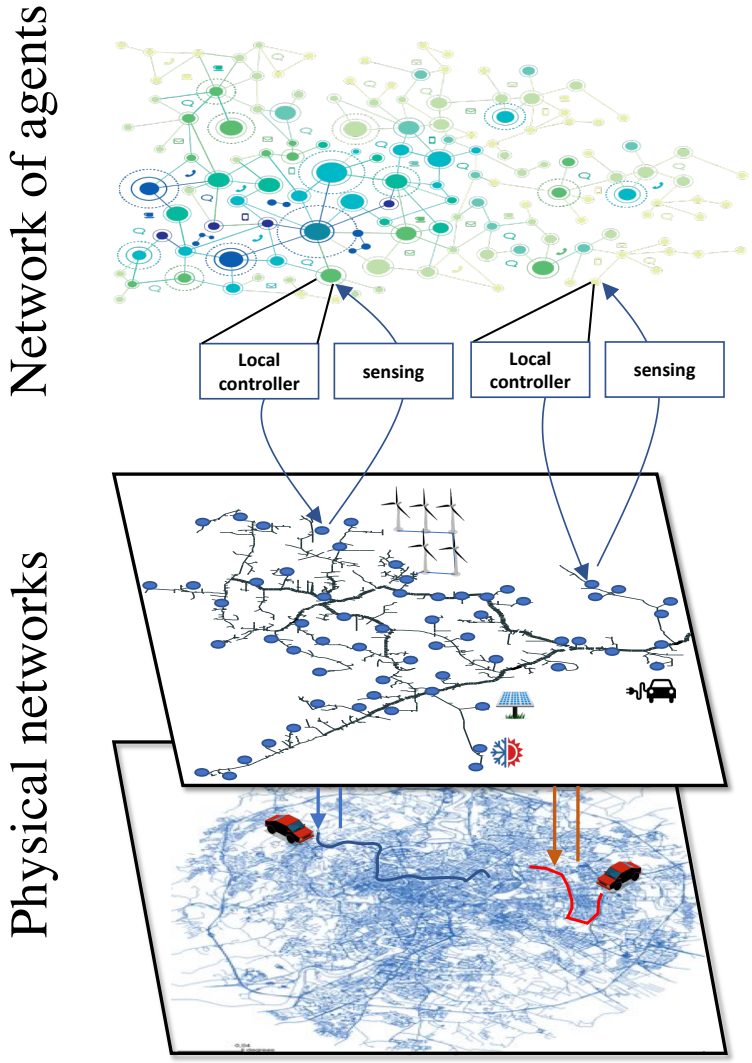
THE CENTRALIZED CONTROL SYSTEM



Controller: When deviating from a linear SISO system, “complexity” arises

- Computational: most centralized approaches do not scale to large systems
- Modeling and stability: more complicated system classes
- Implementation and analysis: distributed, asynchronous, etc.

DISTRIBUTED CONTROL SYSTEM

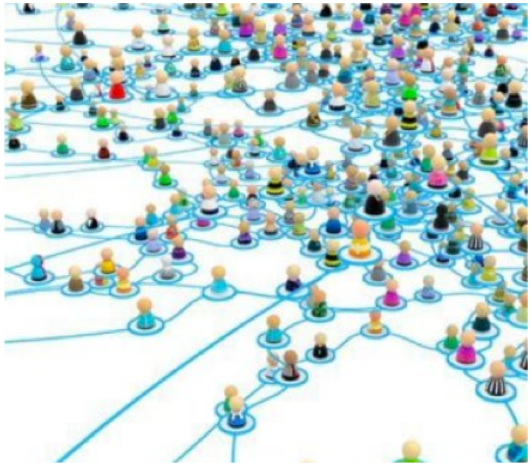


Large-scale physical systems, engineered **multi-agent systems**, and their interconnection in **cyber-physical systems**.

Key features:

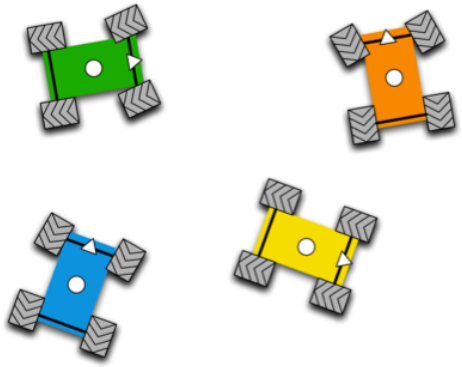
- Complex interactions
- Concept of “network constraint”
- Concept of network-level stability and performance

EXAMPLES IN SCIENCE AND TECHNOLOGY



Social networks

Self-organization



Robotics networks

Smart power systems

Transportation systems

Pervasive computing

DISTRIBUTED CONTROL SYSTEM

Challenges:

- More complicated systems and controller classes
- Interaction through a physical network
  - Network “constraints” (engineering, physical)
  - “Conflicting” objectives
  - Stability, scalability, pervasive measurement of inputs
- Interaction through sensing/communication network
  - cyber-physical issues (sampled-data, channels, computation, etc.)
  - interaction through complex network (large, ad hoc, time-varying, etc.)
  - partial information sets (non-coop. games, etc.)
  - limited sensing, communication, & computation capabilities

COURSE GOALS

Modeling of multi-agent systems

- dynamics
- interconnections

Analysis of multi-agent systems

- stability and performance
- steady-state properties

Synthesis of multi-agent systems

- control design
- interconnection design

Applications of multi-agent systems

- distributed averaging
- synchronization
- formation control
- localization