MAE-247. Cooperative Control of Multi-agent Systems

UCSD Mechanical and Aerospace Engineering, Winter 2026

Instructor: Sonia Martínez, FAH 3302, 858-822-4243, `soniamd@ucsd.edu`

Course description: This course provides an introduction to the modeling, analysis and design of the cooperative control systems. Topics include continuous-time and discrete-time evolution models, distributed algorithms, distributed linear iterations, proximity graphs, geometric optimization, invariance principles and coordination algorithms for agent aggregation, deployment, flocking, formation control, and consensus. The tools of the course will be presented through application settings such as robotic, sensor, power, transportation, social, computer, and natural networks. These examples, and many others, point to the scientific problem of how to design and model interactions so that the behavior of these complex systems can be predicted.

Prerequisites: Background knowledge of linear algebra, ODEs, dynamical systems, mathematical analysis, and mathematical reasoning. Familiarity with a simulation software or programming language.

Teaching assistant: Xuting Gao `xug003 at ucsd dot edu`

Office hours: Instructor's: Tuesdays, EBU-1 1603, 3:30pm - 4:30pm. Xuting's: Thursdays, EBU-2 174, 5-6 pm.

Lecture time and place: Tue and Thu: 9:30am – 10:50am, EBU-2 105

Textbook and course material: The course will follow a collection of lecture notes developed by the instructor in collaboration with Professors Francesco Bullo and Jorge Cortés. These lectures are based on the textbooks *Distributed Control of Robotic Networks* (`https://coordinationbook.github.io/`) and on the book *Lectures on Networked Systems* by F. Bullo (`https://fbullo.github.io/lns/`). Lecture notes will be provided in class. Occasionally, material from other sources will be taken, as referred to in these notes.

List of topics: The topics that will be covered in the course include the following (time permitting and tentatively):

Part I
- Introduction: what are multi-agent systems?
- Linear algebra
- Graph theory
- Linear iterations and agreement
- Laplacian consensus, distributed optimization, formation control, distributed estimation, virus propagation

Part II
- Distributed algorithms on networks of processors
- Proximity graphs
- Distributed algorithms on robotic networks
- Connectivity maintenance and rendezvous for multi-robot systems
- Deployment for task assignment

Assignments: The class will be evaluated based on homework (exercises may require mathematical proof development), a final project presentation, and a final exam. There will approximately be a set of homework problems per week (mostly from the main texts). Homework will be collected on Fridays. No late homework will be accepted with the exception of one assignment.

Student projects: Each student (or a pair of students, depending on enrollment) will choose a topic among the following categories and will either present an in-depth analysis of a paper in the chosen category (with a simulation of the algorithms in the paper) or develop a project based on their own research. All projects are to be presented in person in class during the last one/two weeks of the course, and all students are required to attend all others' presentations. A rubric about how presentations and project reports will be evaluated will be shared during the course. Students will have to let the instructors know of their choice by the end of week 5 of the course. Possible project topics are the following:

1. Agreement and consensus algorithms,
2. Motion patterns and multi-robot synchronization,
3. Network controllability and observability,
4. Distributed Kalman filtering, distributed estimation, distributed map building
5. Game theory and cooperative control,
6. Opinion dynamics in large networked systems,
7. Distributed operation of cyber-physical networks,
8. Privacy and resilience in multi-agent systems,
9. Distributed learning and distributed optimization in multi-agent systems,
10. Distributed reinforcement learning,
11. Distributed algorithms and mechanism design for desirable behavior of MAS,
12. Distributed data-driven control
13. Safe operation of multi-agent systems

Students are encouraged to choose a project that is relevant to their own area of research. A list of papers in these categories will be made available shortly so students can choose among them.

Class attendance: Attendance during all project presentations is required. Attendance to lectures is very much encouraged and counts toward course participation.

Grading: Your grade will tentatively be calculated as follows:

- Homework and class participation: 20%
- Final project: 50%
- Final exam: 30%

There is an extra credit of 2.5% for those who answer questions in Piazza of other students. This requires 4 endorsed answers by the instructors. The TA will grade one homework question chosen at random every time.

Collaboration policy: You are encouraged to work with other students on your assignments, and to help other students complete their assignments, provided that you comply with the following conditions:

1. Honest representation: The material you turn in for course credit must be a fair representation of your work. You are responsible for understanding and being able to explain and duplicate the work you submit.
2. Active involvement: You must ensure that you are an active participant in all collaborations, and are not merely dividing up the work or following along while another student does the work. For example, copying another student's work without actively being involved in deriving the solution is strictly prohibited.
3. Work individually or in small groups: Working in groups of more than **three** people is discouraged because it limits the amount of participation by each member of the group. In your homework solutions please indicate the names of the people you collaborated with.

4. Give help appropriately: When helping someone, it is important not to simply give them a solution, because then they may not understand it fully and will not be able to solve a similar problem next time. It's always important to take the time to help someone think through the problem and develop the solution. Often, this can be accomplished by asking them a series of leading questions.
5. If in doubt, ask your instructor: Be sure to ask in advance if you have any doubts about whether a certain type of collaboration is acceptable.

Class participation: It is very much encouraged (and expected) that students will actively participate in the classroom asking and answering questions.

Electronic devices policy: Cell phone use is not allowed during the classroom. Ipad and computer use will be limited to note taking notes or answering questions via Canvas.

Course website: A main external website will be at `http://muro.ucsd.edu/sonia/teaching/`; however, the website that will mainly be maintained is at `canvas.ucsd.edu`.

Academic honesty: No form of academic dishonesty will be tolerated. This includes the use of all forms of AI for homework/quiz/project completion. For a definition of academic dishonesty and its consequences, refer to the UCSD website `http://academicintegrity.ucsd.edu`