ECE209AS (Fall 2025)
Computational Robotics

Lecture 0: About this course
September 25, 2025

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Today's agenda

1. About me
2. About this course
3. Project teaming

My history

- PhD research in:
    - MEMS process development, devices, and systems
    - Micro autonomous air vehicles localization and control
    - Wireless communications protocols and hardware
- Postdoctoral research in:
    - Integrated robotic design and design automation
    - Functional specification of robotics
    - Robotics for education

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The Laboratory for Embedded Machines and Ubiquitous Robotics

- Overarching research interests:
  - How do we enable robots everywhere?
  - What can we do once we have that?

- Projects:
  - Distributed state estimation, localization, mapping
  - Computationally efficient motion planning
  - Network-aware multi-robot planning
  - Accessible printable robots
  - Design automation / democratization of engineering
  - Robotics for education

LEMUR

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Today's agenda

Goals of this class

This course will cover the fundamentals of computational techniques in robotics research.

Conferences

Robotics and Automation (ICRA), Intelligent Robots and Systems (IROS), Robotics Science and Systems (RSS), ...

Journals

Science Robotics, Soft Robotics, Nature Machine Intelligence, IEEE Transactions on Robotics (T-RO), ...

At the end of this course, you should be able to:

- Follow the state of the art in robotics research
- Identify and formulate meaningful robotics problems
- Develop, analyze, and evaluate solutions

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Course vision

Anti-goal of this class:

- This course will **not** cover how to use robotics tools, software packages, programming languages, etc. This is **not** a tutorial, workshop, or vocational training.

This is a stepping stone to robotics research.

- You'll be expected to read, think, and innovate along the way to solving meaningful, open-ended problems.
- Our focus will be on collaborative engineering

Engineering philosophy

- Engineering is a combination of technology and communication. Class policies will reflect that.
- In research, the important contribution is the process; the existance of results is necessary to validate the process
- Answer the What, How, Why of the results:
  - **What** did you produce?
  - **How** did you do it?
  - **Why** that way?
- . . . and again for the process:
  - **What** is to be learned / understood from this?
  - **How** can this be generalized / applied to other problems?
  - **Why** should anyone (everyone) care?

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Class structure

- This will be a “flipped classroom” style course:
  - Pre-recorded lectures to watch on your own time
  - Interactive, collaborative problem solving during class time
- Bring your laptop, and expect to be using it for the duration of the class period
  - Let me know after class today if this will pose a problem
- Participation is mandatory!

Baseline schedule

- One pre-recorded lecture set per week, ~2-3 hours of video.
  - This will mostly target mathematical derivations.
- One problem set per week, expected to be filled out concurrently to watching the lecture.
  - Did you get the high level concepts of the presented material?
- Several weekly collaborative challenge problems built on those concepts, which may include:
  - coding implementations of known concepts,
  - extensions of known concepts to new applications, and
  - open-ended research problems.
- One final team project
  - Built on the outcomes of an open-ended research exploration
  - May be built on / interleaved through the challenge problems

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Self-pacing

- "Baseline schedule" may not allow appropriate time for specific final projects (e.g. those built upon material from later lectures)
- All the lectures, problem sets, and challenge problems are available from the start (now!) on
  - https://comprobo.uclalemur.com
- Only enforced deadlines are:
  - Regular (weekly) participation
  - Final project deliverables

Weekly schedules

$\forall n : n \in \mathbb{N}, 1 \leq n < 10$

- Tuesday of week n:
  - You should have watched the week n lecture by now
  - 9am: Weekly pset due
  - 10am: Presentation of new weekly challenge problems (by me)
  - Then: Collaborative work on challenge problems
- Tuesday-... of week n:
  - Asynchronously : Discussion of pset solutions via Coauthor
- Thursday of week n:
  - 10am: Progress updates on challenge problems (by you)
  - Then: Collaborative work on challenge problems

Online collaboration framework

- Coauthor
    - Real-time collaborative discussion forums—capture and preserve all meaningful live discussions for async collaboration
    - Check announcements / go to https://coauthor.csail.mit.edu and sign up.
        - Preferably use your UCLA email address; email me if not so I can give you access to our site.
- Github / Gitlab
    - Share code
- Overleaf
    - Formalize outcomes as academic documents
- Collaborative whiteboard / sketchpad?
- Collaborative coding?
- Other? Play around and let us know!

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Final project dates / deadlines

- Friday of week 9
  - 4pm: 2 minute teaser video
- Friday of week 10
  - 4pm: $8 + 2k$ minute project presentation (k = team size)
- Tuesday of week 11 (Finals week)
  - 11:30am-2:30pm: Interactive project demos
- Tuesday of week 11
  - 11pm: Comments / suggestions / feedback on other projects
- Friday of week 11
  - 11:59pm: Final project writeup(s)

Final project

- Formulate, analyze, solve, and present a robotic problem
- Built off of one of the weekly challenge problems
- Should push the boundaries of the state of the art
- **Discuss with me before committing to a project**
- Deliverables: Proposal, presentation, writeup, code repository

- Expect to submit papers to e.g. RSS or IROS (due early next year)
- Select projects may be eligible for long-term funded GSR positions / research opportunities

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Final project ideas

Control, perception, and planning

- Distributed multi-robot algorithms
- Mobility aware communication protocols
- Network aware motion planning
- Underactuated guidance and control
- Human-in-the-loop control

Design systems

- Formal programming language for functionality
- NLP for task specification
- Generative parametric design
- Meta-design systems

. . . more to come

Grading

- Homeworks and challenge problems (100pts) = 10 pts per week, divided as follows:
  - 1 pt attendance in class
  - 3 pts participation in interactive sessions
  - 3 pts contributions to challenge problem writeups
  - 3 pts pset
- Final project (50pts)
  - 25 pts oral presentation
  - 25 pts written paper
  - (up to) 10 pts extra credit for ACM/IEEE submission

Alternate grading

Submit 10 psets, get an automatic B

- No in-class challenge problems
  - No attendance or participation
- No final project

"Prerequisites"

- Linear algebra
  - Matrix math
  - Linear systems
- Differential equations
  - Multivariable systems
  - State space descriptions
  - Numerical methods
- Probability and Statistics
  - Discrete and continuous random variables
  - Bayesian inference
  - Simulation and modeling

Also

- Programming
- Algorithms
- Rigid body mechanics
- Signal processing
- Feedback control

There is an optional ungraded problem set 0 on the prereqs posted to the class website. Download and submit via Canvas if you'd like; solutions will be posted next week.

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Course communication

- Official announcements and assignments will be handled through the course Canvas site:
  - https://bruinlearn.ucla.edu/courses/214371
- Handouts, assignments, lecture videos, and all other media are on our official course webpage:
  - https://comprobo.uclalemur.com
- All other interactions will happen on Coauthor
  - https://coauthor.csail.mit.edu

Make sure your email address is correct, and check email regularly.

One final note

- This course is designed to enable different learning objectives
  - . . . so think about what you want to achieve, and how best I can help you get there
- What's important is that you learn and have fun
- Feedback is always welcome

Recent feedback: flipped classroom

- “This course uses flipped class room, which I am not a big fan of.”
- “The flipped classroom format really did not work for me”
- “I did not enjoy the flipped classroom style . . . I could see the appeal of the flipped classroom given the amount of lecture material, but I think it’s worth having these lectures in person where specfic concepts can be directly questioned in the moment rather than after the fact.”

Recent feedback: pacing and self-determination

- “I think that can be overwhelming at times due to the level of mastery you can achieve in each weeks lectures can go much deeper than just one class period”
- “to be able to do all of this in 10 weeks with two other courses and/or other commitments is impossible”
- “We were not able to solve many challenge problems properly given the time constraint. And the challenge problems felt critical in grasping the concepts.”
- “week 7 and 8 topics are very vast and covering them in two weeks does not give them justice I think”

Recent feedback: driven interaction

- “He just has us watch low quality lecture recordings from years ago, and then has us work in groups during class, so we have to teach ourselves. . . . What a disappointment. I might as well have just watched some youtube videos and I would’ve learned all this just fine.”
- “the problems formulation inside it is confusing to be honest and I found it does not enhances my understanding of the material. If you are confused about one of the question, there aren’t much places or resources to help you, which is also not ideal.”
- “Only after going to the discussion did I finally feel like I understood the content for the week, and even then I wished we went over the problems more so that I knew if I was on the right track.”
- “I would often try and just sit back and try to get my own understanding of the problem and ask questions. This allowed me to learn, but gave the feeling of being behind my peers.”

Recent feedback: collaborative problem solving

- “Most of these group exercises just end in the same person doing everything and everyone else just sitting around”
- “It was too easy to be disengaged in class, there was never a sense of urgency to solve the challenge problems. I would’ve preferred to do these outside of class on my own, so I could understand the problem myself instead of spending so much time trying to understand someone else’s code or just using an LLM to generate a base code.”
- “In class, the challenge problems were structured well, but the dynamic of the work group I was in sometimes went like this: one student would understand the solution and work on challenge problems prior to class or a student would use an LLM tool in order to create a simulation and the rest of the team tried to catch up in understanding. This happened for many weeks and I would often try and just sit back and try to get my own understanding of the problem and ask questions. This allowed me to learn, but gave the feeling of being behind my peers.”
- “In class challenge problems sometimes felt like busy work because of group size.”

Next steps

- Introductions / teaming: posted on Coauthor
  - What do you want to get out of this class?
  - What are interests / skills / passions / background relevant to a potential final project?
  - Who could complement you in a project team?
- Optional PSet 0 (prereqs)
- Watch Lecture 1: Mathematical abstraction and computational framework for robot systems
  - PSet 1 due Tuesday
  - First set of challenge problems will begin in class Tuesday

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