Autonomous Robotics

Course Introduction

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About Me

- Assistant professor in CS since 2021.
- Research focus on AI and robotics with a focus on reinforcement learning.
- B.S. in CS and Math from the University of Kentucky.
- Ph.D. from the University of Texas at Austin.
- Post-doc at the University of Edinburgh.
- I enjoy: running, being outside, reading, and spending time with family (wife and kids, <1 and 3).

Robots and Me

- Ph.D. work focused on RL and robot learning.
- During post-doc, spent time at FiveAI working on autonomous driving.
- Currently my lab uses robot soccer as a testbed for RL research.

What is a robot?

- Physical artifact with the ability to sense, move, and affect change in its external environment.

What makes a robot autonomous?

- Able to act without human intervention.
- We will particularly focus on robots that act without human intervention while coping with uncertainty:
  - About what their senses tell them.
  - About the effects of their actions.
- And that do more than one simple task, again and again.

Pretend you are a robot

Key Concepts

- States: reality, a collection of variables specifying the state of the world.
- Observations: partial and potentially noisy information about the current state.
- Actions: what the robot can control
- Assumption:
  - Observation depends on the state.
  - State transitions depend on the state and action chosen.

Examples

- Autonomous vehicle
- Roomba
- Manufacturing robot

Robotics is hard!

- Moravec's paradox
- Variation in the world
  - Never see the exact situation twice
  - Non-determinism
- Uncertainty
  - Robot doesn't know what the real state is
- Long evaluation and iteration times

- Hardware limitations
  - Sensors
  - Actuators
  - Battery

Course Goals

After taking this course, you will be able to:

1. Explain and implement algorithms that enable a robot to recognize the state of the world using its onboard sensors.
2. Explain and implement algorithms that enable a robot to plan and enact movement in the world.
3. Understand the broader landscape of advanced robotics topics: learning, HRI, and societal impacts.

Not a hardware course! Other options in ME Dept, e.g., ME 439

10,000 Foot Preview

- Basics:
  - Control
  - State estimation and localization
  - Mapping and SLAM (simultaneous localization and mapping)
  - Planning
- Advanced: learning, human-robot interaction, society, and applications

Goal is to provide an overview of many topics in robotics.

Programming Assignments

- We will use the Webot's simulator for assignments and the final project.
  - https://cyberbotics.com/doc/guide/installation-procedure
- Implement algorithms introduced in the class.

Schedule Overview

- See course webpage: https://pages.cs.wisc.edu/~jphanna/teaching/25spring_cs639/schedule.html

Classroom Environment

- Complete reading assignments ahead of class sessions and come prepared to ask questions and discuss.
- Please commit to helping create a climate where we treat everyone with dignity and respect.
- Creating an environment where we are all comfortable learning is everyone’s job: offer support and seek help from others if you need it, not only in class but also outside class while working with classmates.

Pre-requisites

- Probability and Statistics
  - Random variables, probability distributions, Bayes rule, conditional, marginal, joint distribution, random sampling, Gaussian distribution
- Linear Algebra: dot-product, transpose, vector-matrix multiplication, matrix inverses.
- Calculus: basic differentiation and integration.
- Programming: maturity to pick up a new framework

Pre-requisites

- https://forms.gle/6qRjHnh6iMXtHJYm8

Class Periods

- **[Before class]** Required Weekly Readings
  - **Submit reactions and questions by Monday at 12pm US central time.**
  - Submitted via Gradescope
- Any questions?
- Lecture and discussion

Reading Responses

- Credit is based on evidence that the reading was completed.
- Responses and questions will be used to shape the week's lecture.
- Possible responses:
  - Questions
  - Critiques or suggestions for extensions.
  - What you want to learn about more.
  - Thoughts on what you find most important.

Attendance Policy

- Class attendance and participation are necessary for the participation component of the grade.
- Absences will most likely be approved if an email is sent before class starts.
- It is always fine to miss class if you are unwell
- Class will not be canceled if the university remains open and I can make it to campus and it is always fine to miss class if you have safety concerns.

Logistics

- Course Webpage: https://pages.cs.wisc.edu/~jphanna/teaching/25spring_cs639/
- Piazza: https://piazza.com/wisc/spring2025/cs639004
  - Access code: j1wihj7gfgm
- Canvas: https://canvas.wisc.edu/courses/448602
- Office Hours: Tuesday / Thursday @ 11am-12pm (after lecture) or by appointment.

Syllabus

- Spend 10 minutes reading the syllabus and skimming the course webpage.
- With 2-3 people sitting next to you, discuss potential confusion, questions, and concerns.
  - Prepare questions to ask after 10 minutes is up.
- https://pages.cs.wisc.edu/~jphanna/teaching/25spring_cs639/index.html

Action Items

- Join Piazza! https://piazza.com/wisc/spring2025/cs639004
  - Access code: j1wihj7gfgm
- Background survey: https://forms.gle/6qRjHnh6iMXtHJYm8
- Send a reading response by 12pm on Monday.