CS391R: Robot Learning

Perception and Decision Making: Architectures, Algorithms, and Applications

Prof. Yuke Zhu

Fall 2021
Traditional form of **automation**
General-purpose robot autonomy
Today’s Agenda

- What is Robot Learning?
- Why studying Robot Learning now?
- Course content overview
- Logistics
- Student introduction
Special-Purpose Robot Automation

- custom-built robots
- human expert programming
- special-purpose behaviors

General-Purpose Robot Autonomy

- general-purpose robots
- ?
- general-purpose behaviors
Special-Purpose Robot Automation

custom-built robots → human expert programming → special-purpose behaviors

General-Purpose Robot Autonomy

general-purpose robots → Robot Learning → general-purpose behaviors
General-Purpose Robot Autonomy: Imaginations

Unimate - The First Industrial Robot
British TV (1968)
General-Purpose Robot Autonomy: Challenges

DARPA Robotics Challenge (2015)

“The Moravec's paradox”
General-Purpose Robot Autonomy: Progress

We will learn the algorithms and techniques behind the latest progress.

Grasping (DexNet 4.0; 2019)  
Locomotion (ANYmal; 2020)  
Manipulation (OpenAI; 2019)
What is **Robot Learning**?

**Definition #1**
The study of machine learning algorithms and principles with their applications to robotics problems

**Definition #2**
The study of methods and principles that make robots learn from data

**Definition #3**
The research field at the intersection of machine learning and robotics (copied from Wikipedia)
When **NOT** to Make Robots Learn?

Learning is not a solution to every problem in robotics.

Harnessing the priors and structures of a problem goes a long way…

Learning is most effective when used in conjunction with modeling.
When to Make Robots Learn?

Learning is critical for taking robots to the real world.

- object variation
- environment uncertainty
- adaptation
Now is the best time to study and work on Robot Learning.

Recent breakthroughs in machine learning and computer vision, e.g., deep learning (Turing awards 2018)

Your smartphone is millions of times more powerful than all of NASA’s combined computing in 1969.

More reliable and affordable cobot hardware that costs around annual salary of American workers
Now is the best time to study and work on Robot Learning.

Positive and negative **societal impacts** of robot learning research is an important part of our in-class discussions.

https://www.therobotreport.com/tag/coronavirus/
Robot Learning as a Growing Research Community

Conference on Robot Learning is 4 years old.

Growth of “Robot Learning” Publications
[Source: Google Scholar]
Course Content  We review the Robot Learning literature in these topics.

Part I: Robot Perception

Topic 1-10
seeing and understanding the physical world

Part II: Robot Decision Making

Topic 11-20
planning and control of robot behaviors

Prerequisite: coursework / experience in AI and Machine Learning
Course Content

We review the Robot Learning literature in these topics.

Part I: Robot Perception

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Part II: Robot Decision Making

Topic 11-20

planning and control of robot behaviors
Robot Perception

2D object detection

3D data processing

- synthetic data for robot perception
- self-supervised visual learning
- implicit neural representations

multimodal understanding

recursive state estimation

attention architectures

interactive perception
Course Content

We review the Robot Learning literature in these topics.

Part I: Perception

Topic 1-10
seeing and understanding
the physical world

Part II: Decision Making

Topic 11-20
planning and control of
robot behaviors

Prerequisite: coursework / experience in AI and Machine Learning
Robot Decision Making

- model-free RL
- inverse RL
- model-based RL
- adversarial IL
- imitation as supervised learning
- hierarchical policy & neural programming
- offline RL

Collecting demonstrations ➔ Training in simulation ➔ Running on real robot

3D motion controller

Robot Learning (Fall 2021)
Learning Objectives

● understand the potential and societal impact of general-purpose robot autonomy in the real world, the technical challenges arising from building it, and the role of machine learning and AI in addressing these challenges;

● get familiar with a variety of model-driven and data-driven principles and algorithms on robot perception and decision making;

● be able to evaluate, communicate, and apply advanced AI-based techniques to robotics problems.

... through literature reviews, research presentations, and course projects
Learning Objectives

Get a taste of Robot Learning research in the full circle
Logistics

Lectures
Time: 9:30-11:00am CT, Tuesdays and Thursdays
Location: Online or in-person (Zoom links on Canvas)

Office Hours
Instructor: 3-4pm Mondays (GDC 3.422) or by appointment
TA: 4-5pm Wednesdays (GDC 3.516)
Instruction Modality

**Now to September 17**

Online lectures + in-person office hours

**After September 17**

Adjusting plans based on university policy

**In-Person Experiences**

Office hours, instructor/TA meetings by appointment, GDC 4.302
## Logistics

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<th>Week 16</th>
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### Instructor Lectures
- overview of research topics

### Student Presentations
- presentation of research papers

### Final Project Spotlights
- spotlight talks of course projects

[https://www.cs.utexas.edu/~yukez/cs391r_fall2021/](https://www.cs.utexas.edu/~yukez/cs391r_fall2021/)
# Logistics

## Required Readings (No Review)
Overview or survey papers with lectures

## Required Readings
Key papers that will be discussed in class

## Optional Readings
Recommended papers for in-depth reviews

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| Week 16 | Fri, Dec 10 | No Class | Final Report Due |

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Logistics

Grading Policy

Student presentation (20%)

Paper reviews (30%)

Course project (40%)

In-class participation (10%)

20% each

• At least one presentation for each student (chances to do more)
• Length: 20min (± 2min) + 3min Q&A
• Format: problem formulation, technical approach, results, … (see slide template for more details)
• Followed by 5-10min in-class discussions
• Email the slides to the TA and the instructor seven days (EOD) prior to the presentation date
• Presentation recordings posted in Canvas (protected under FERPA)
• Breakout rooms and in-class discussions will NOT be recorded.
Logistics

Grading Policy

Student presentation (20%)

Paper reviews (30%)

Course project (40%)

In-class participation (10%)

2% each x 15 reviews

• Due by **9:59pm** the previous night of each student presentation

• Write a review for **one paper** from the required readings (2 choices for each class)

• Online review form in R:SS format

• **No late date** - but more than 15 presentation classes (feel free to skip some)

• Have energy to do more? **Top-scored 15** for grading

• **Class attendance and participation** is required for review grades
Logistics

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Logistics

Grading Policy

Student presentation (20%)

Paper reviews (30%)

Course project (40%)

In-class participation (10%)

40%

- Project Proposal (5%). Due Thu Sept 16.
- Project Milestone (5%). Due Thu Oct 21.
- Final Report (25%). Due Fri Dec 10.
- Spotlight Talk (5%). Week 15.

Hands-on experience of robot learning research
Logistics

Grading Policy

Student presentation (20%)

Paper reviews (30%)

Course project (40%)

In-class participation (10%)

project platform: robosuite (robosuite.ai)

Alternative projects require instructor approval.

Tutorials, computing resources, project instructions, …
Logistics

Grading Policy

Student presentation (20%)

Paper reviews (30%)

Course project (40%)

In-class participation (10%)
Tell Us About Yourself
Robotics beyond CS391R

Be part of the Robotics + AI revolution.

UT Robot Perception & Learning Lab

Mission: Building General-Purpose Robot Autonomy in the Wild

TEXAS Robotics

https://robotics.utexas.edu/