Principles of Safe Autonomy ECE 484 Spring 2025 Lecture 1: Course Overview

Professor: Sayan Mitra

Jan 21, 2025

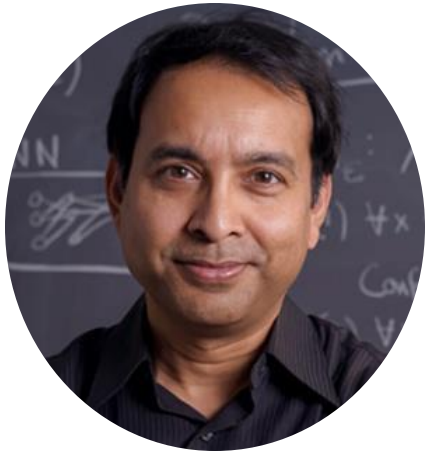
https://publish.illinois.edu/safe-autonomy/

https://mitras.ece.illinois.edu/

mitras@Illinois.edu

@Mitrasayn

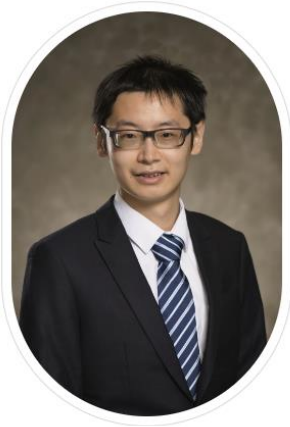
Welcome from Safe Autonomy Spring 2025 team!



Prof. Sayan Mitra (mitras)

Prof. Ali Belabbas (belabbas)

Daniel



Haonan

Guang Yin

John

Will

Jai

Ritvik

Gautam

Praveen

Hanna

Hyongju

Tanvi

Sidharth

Plan for today

- What is this course about?
- How will this course work?
- What is safety and how to check it?

Significant accomplishments in autonomy

- NASA's Perseverance rover performed autonomous science operations on Mars, the Ingenuity helicopter performed the first powered, controlled flights on another planet (2021-22).
- Waymo now has 22% market share of taxi journeys in San Francisco, and now exceeds human-driver taxi company Lyft.
- Zipline, Wing, Amazon Prime Air have launched commercial deliveries. Air taxis are on the horizon

Autonomy *could* improve society provided safety risks are mitigated

Driverless cars will improve productivity

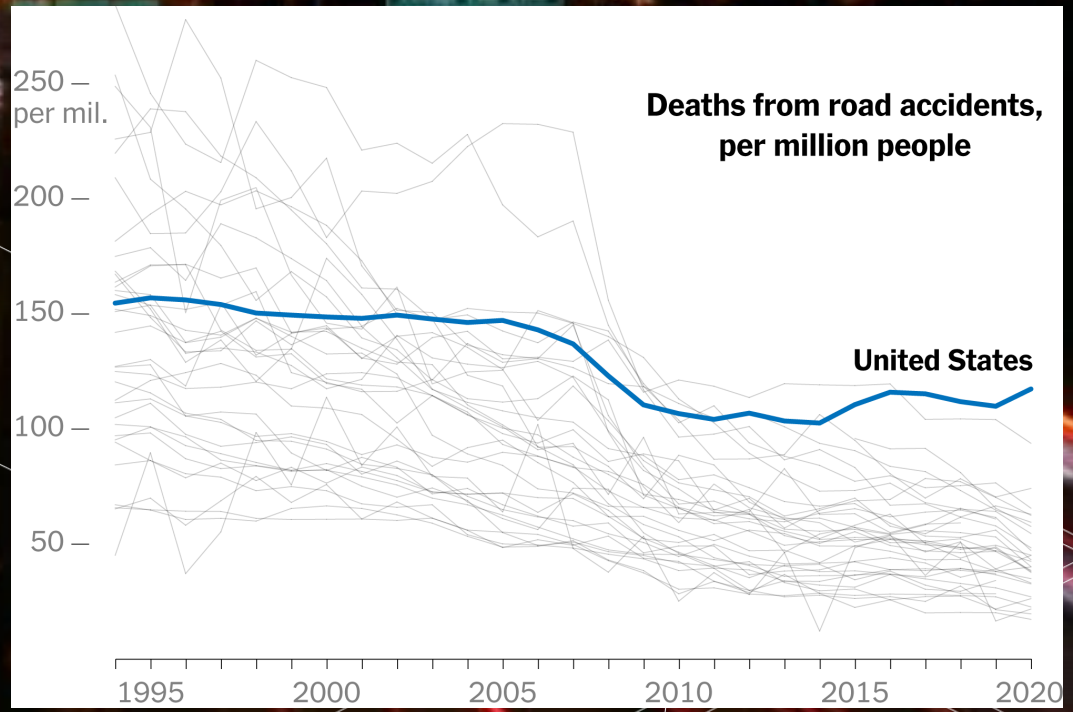
- Americans drives 13,474 miles (300 hrs) per year

Cities will be greener

- 40% of city surface is parking

Will autonomous cars be safer?

- Still 32K+ fatalities and 3M+ injuries every year in the USA



Challenges and opportunities in autonomy

- Cost
- Reliability
- Energy

New products

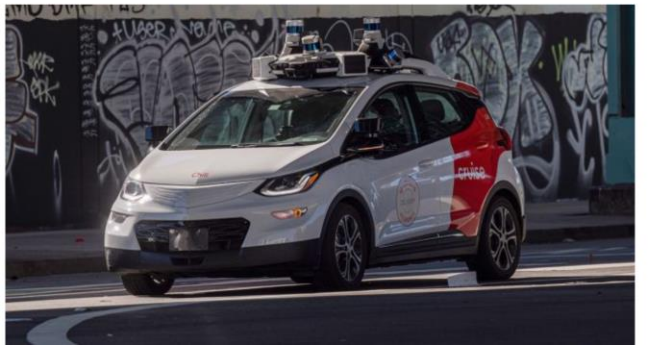
- Hospital and elderly care
- Home robot assistant

Autonomy is a ***frontier*** of engineering

You will build, found, join the coming autonomy transformation!

San Francisco Wants Halt to Cruise, Waymo Expansion Ruling

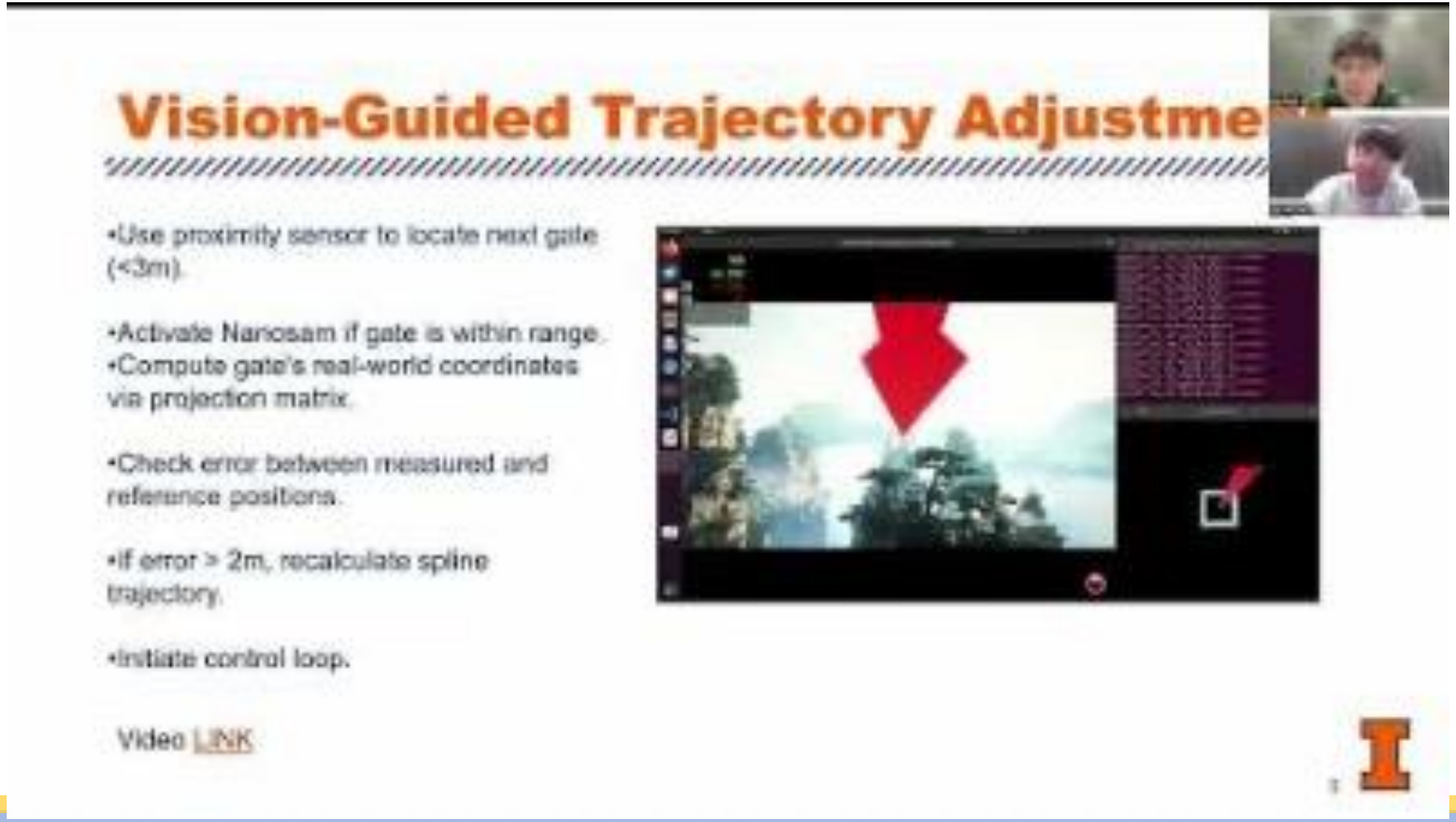
City Says Expanded Service for Robotaxis Can Cause 'Serious Harm'



Aug. 19, 2023, at 12:32 p.m. General Motors' Cruise autonomous vehicle unit has agreed to cut its fleet of San Francisco robotaxis in half as authorities investigate two recent crashes in the city.

Example of what you will build in 484

Another example: Drone racing project (Fall 2024)



Plan for today

- What is this course about?
- How will this course work?
- What is the safety verification problem?

Course Objectives

Learn

- Algorithms and math concepts for perception, planning, control, filtering, verification
- Software tools like ROS, Yolo, OpenCV, Z3, Verse

Build

- modules for lane detection, localization, planning, verification
- an autonomous system

Understand

- models for capturing uncertainty: automata, ODEs, Markov chains
- algorithms---assumptions and guarantees and limits

Get inspired to build the future of autonomy and uncover the scientific principles

Course Details

Learn

- Algorithms and math concepts for perception, planning, control, filtering, verification [HW, midterms]
- Software tools like ROS, Yolo, OpenCV, Z3, Verse [MPs, project]

Build

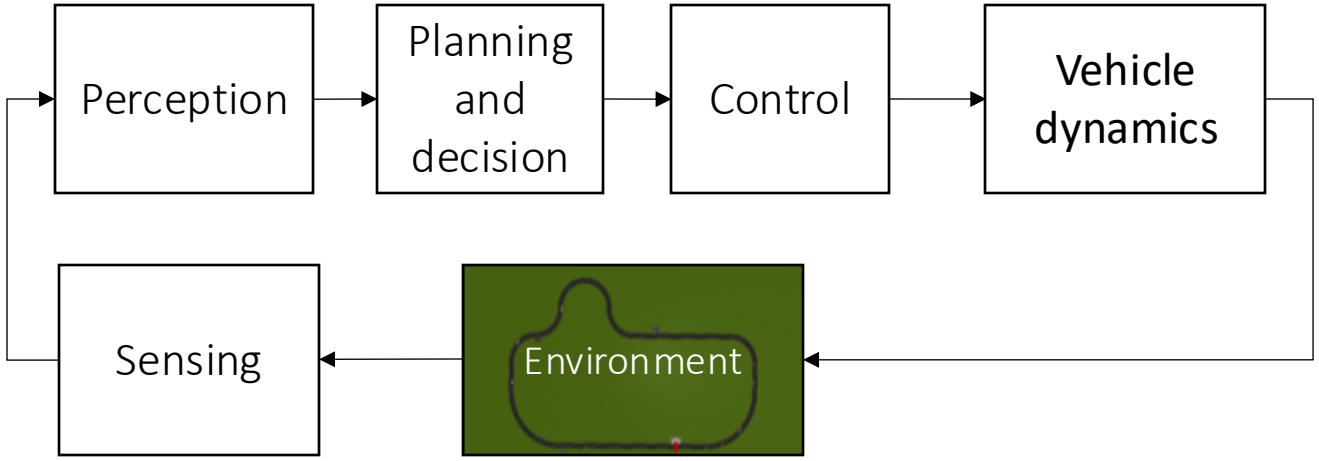
- modules for lane detection, localization, planning, verification [MPs]
- an autonomous system [project]

Understand

- models for capturing uncertainty: automata, ODEs, Markov chains [HW, midterms]
- algorithms---assumptions and guarantees and limits [HW, midterms]

Get inspired to build the future of autonomy and uncover the scientific principles [project]

Autonomous GEM vehicle



env: Lidar / vision

Sensing	Perception	Decisions and planning	Control
Physics-based models of cameras, LIDAR, radar, GPS, and so on.	Programs for object tracking, scene understanding, and so on.	Programs and multi-agent models of pedestrians, cars, and so on.	Dynamical models of vehicle engine, powertrain, steering, tires, and so on.

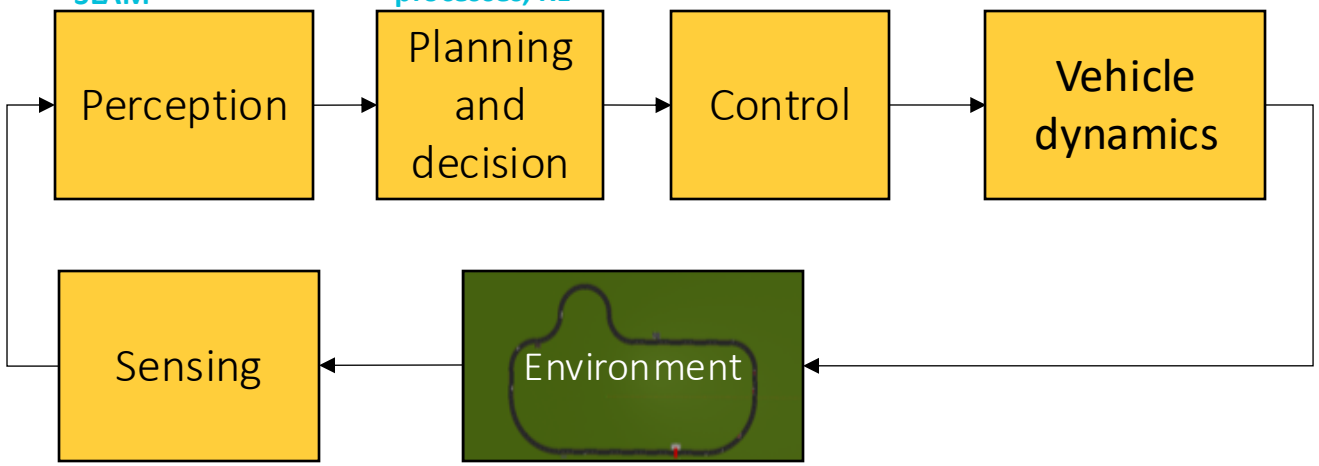
Course structure

Safety, end-to-end testing, simulation, system integration
MP0, MP5, Project
State machines, model checking, hypothesis testing, ROS

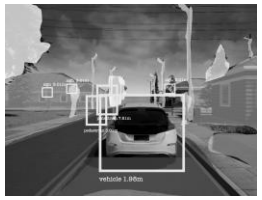
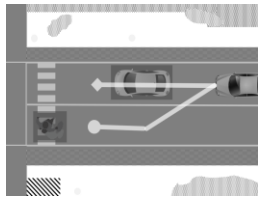
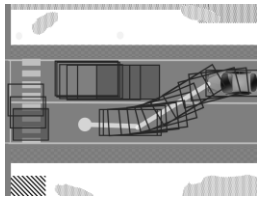
Convolution
Bayes filter
SLAM

RRT, Markov
decision
processes, RL

ODE, Stability, PID



env: Lidar / vision

Sensing	Perception	Decisions and planning	Control
MP3 **Project**	MP1 MP3 **Project**	MP4 **Project**	MP2 **Project**

Administrivia

Start here: https://publish.illinois.edu/safe-autonomy/

- Schedule, lab, resources, papers, homework, MP, code, project, gitlab links

Campuswire for announcements, but no SLA, best effort response delay ~2 days. https://campuswire.com/c/GECB976DF/feed/1

- Discussions, forming teams, occasional polls, feedback

Canvass for MP release and grades

Spring 2025 Calendar

Week	Tues Date	Topic 1	Thurs Date	Topic 2	Fri Date	Lab Topic / Notes	MP Notes
1	21-Jan	Overview / Safety 1	23-Jan	Safety 2	24-Jan	Intro, MP0 walkthrough	MP0 released
2	28-Jan	Safety 3	30-Jan	Perception 1	31-Jan	Team formation	—
3	4-Feb	Perception 2	6-Feb	Perception 3	7-Feb	MP0 Demo (MP0 due)	MP1 released
4	11-Feb	Perception 4	13-Feb	Control 1	14-Feb	MP2 walkthrough	MP2 released
5	18-Feb	GEM Field Trip	20-Feb	AirTrack, GRAIC, F1Tenth	21-Feb	MP1 Demo (MP1 due)	—
6	25-Feb	Control 2	27-Feb	Control 2 / Review	28-Feb	MP2 Demo (MP2 due)	—
7	4-Mar	Midterm 1	6-Mar	Filtering 1	7-Mar	MP3 Walkthrough	MP3 released
8	11-Mar	Pitch Presentation 1	13-Mar	Pitch Presentation 2	14-Mar	Open Lab	—
	17-Mar	Spring Break					
9	25-Mar	Filtering 2	27-Mar	Filtering 3	28-Mar	Open Lab	—
10	1-Apr	Filtering 4	3-Apr	Planning	4-Apr	MP3 Demo (MP3 due)	—
11	8-Apr	Planning 2	10-Apr	Planning 3	11-Apr	No more labs!	—
12	15-Apr	Planning 4	17-Apr	Review	18-Apr	Intermediate check-in	—
13	22-Apr	Guest Lecture	24-Apr	Midterm 2	25-Apr	—	—
14	29-Apr	TBD	1-May	Final Presentations 0	2-May	—	—
15	6-May	Final Presentations 1					
Finals	May9-15	Final Presentations 2					

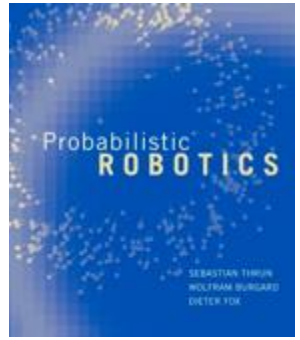
Course materials

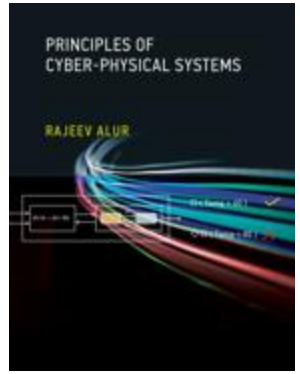
Lecture notes, slides, code, video lectures, lab manuals created and curated from recent research publications

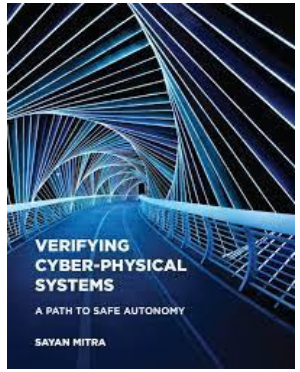
Course reader: Available from: https://publish.illinois.edu/safe-autonomy/files/2023/08/Safe_Autonomy_Course_Reader.pdf

References:

- *Probabilistic robotics, By Sebastian Thrun, Wolfram Burgard, and Dieter Fox, 2005*
- *Principles of Cyber-Physical Systems, Rajeev Alur, MIT Press, 2015*
- *Verifying Cyber-physical Systems, Sayan Mitra, MIT Press 2021*







Course: components and (tentative) weights

- 3-4 programming assignments or MPs 45% (group)
  - ROS + Python, Ubuntu, VM BYOD or use lab workstations
  - labs (Friday 9am-8 pm starting this Friday)
  - Office hours
- Homework assignments 10% (individual)
  - math, analysis, critical reasoning; preparation for midterms
- Midterms x2 20% (individual)
- Mini project 25% (group): more on this later, 4 tracks:
  - A. Dev and test concepts on GEM
  - B. GRAIC autonomous racing competition / testing
  - C. F1tenth small racing car
  - D. Drone racing

Tentative grade boundaries	
A	>90
B	>80
C	>65
D	>55

Teamwork: MP, labs, and mini project

- In groups: Form your group of 3-4 now! Create groups by this Friday (more details on Campuswire)
- Each MP will build a significant component of an autonomous system over **2 weeks**
- Use your computer with Ubuntu 20.04 or ECEB5072 lab computers
- TAs and LAs will run live labs in ECEB 5072
- MP walkthough, setup, bridge the lecture and the assignments
- MP0+HW0 will be released this Friday (1/24), labs starts this Friday
  - Your entire group has to attend 1 lab for the MP walkthrough
  - And 1 lab after the MP is due (to demo your work).

Mini projects: explore, inspire, and impress

- GEM Track. Build on existing SW, e.g., parallel parking, lane following, and pedestrian avoidance
- GRAIC Track. Participate in an open simulation-based autonomous racing competition
- Outcomes: Write research papers, jumpstart grad research, career in autonomy, incubate startup ideas, sharpen presentation skills
- We provide: Polaris GEM vehicle (camera, LIDAR, RADAR, IMU, GPS, and drive-by-wire system) modules for pedestrian detection, lane tracking, and vehicle control, a vehicle simulator, and testing facility (highbay) with indoor positioning system. GRAIC autonomy software stack
- Expertise (TA, lab and office hours, TBD)
- Timeline: Get started, be a member of IRL from this link
  - High-bay virtual site visit and training (in next 2 weeks)
  - Project pitch
  - Public presentation, demo, awards (End of Semester)

Spring 2022 projects
Spring 2020 projects
Fall 2020 projects