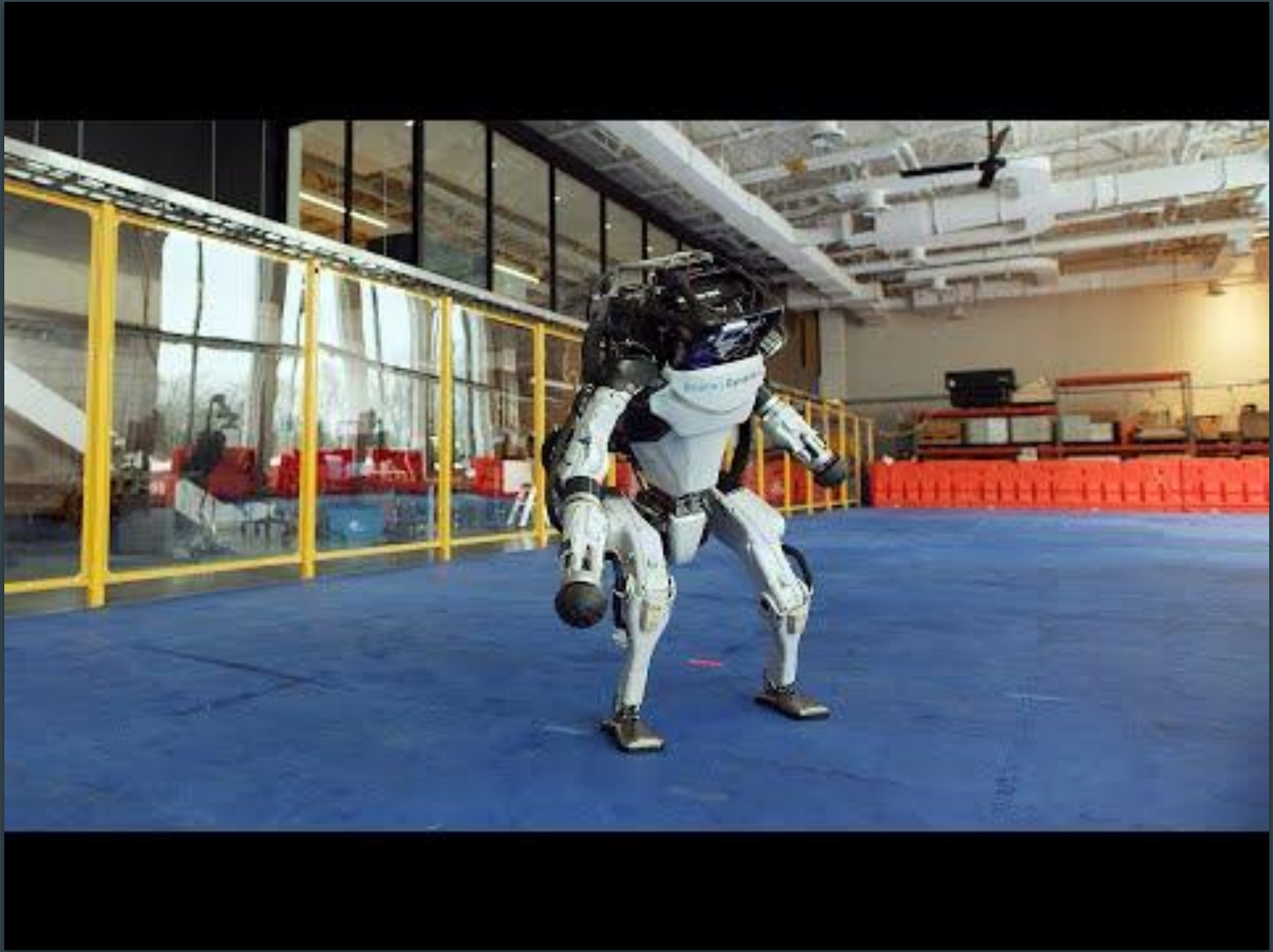


CS4501
Robotics for Soft Eng
•••

Sebastian Elbaum
Fall 2022

Is this Class for me? - Poll

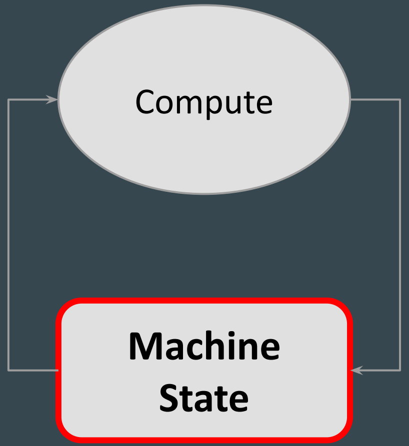
- You want to learn about unique aspects of software development for robots
  - Class is <u>not</u> about AI, Mechanics, or Electronics
- You have not taken a Robotics class at the University level that require progr.
- You are a very competent programmer in python or C++
- You are familiar with programming with threads
- You can handle systems’ issues on your own

If your answer was YES to ALL questions then this class is for you

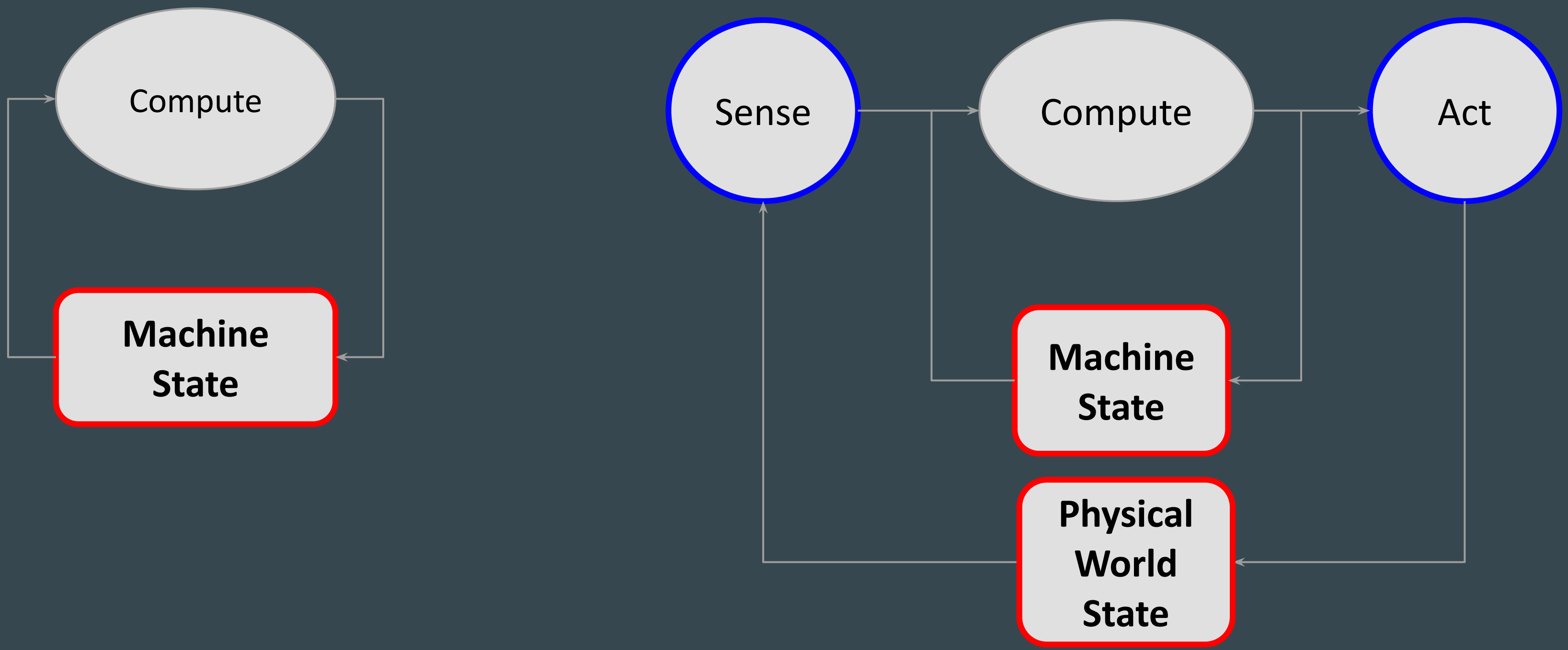
How do we build systems that can

physically operate safely in the world?

Operating in Cyber World



Operating in Cyber vs Physical World



Operating in Physical World - Exercise

- Teams of 3
- Task: lift chair on top of other chair
- Person 1: SENSE
  - Looking at chair
  - You are a camera+ that reports XYZ pincer and XYZ chairs in frame
  - Reports in writing to Compute
- Person 2: ACT
  - Eyes close
  - Takes command with 3 parameters:
    - open or close the pince
    - 1 DOF elbow (yaw angle)
    - 2 DOF shoulder (pitch angle, yaw angle}
- Person 3: COMPUTE
  - Looking away from chair
  - Based on written SENSE input, instruct ACT verbally

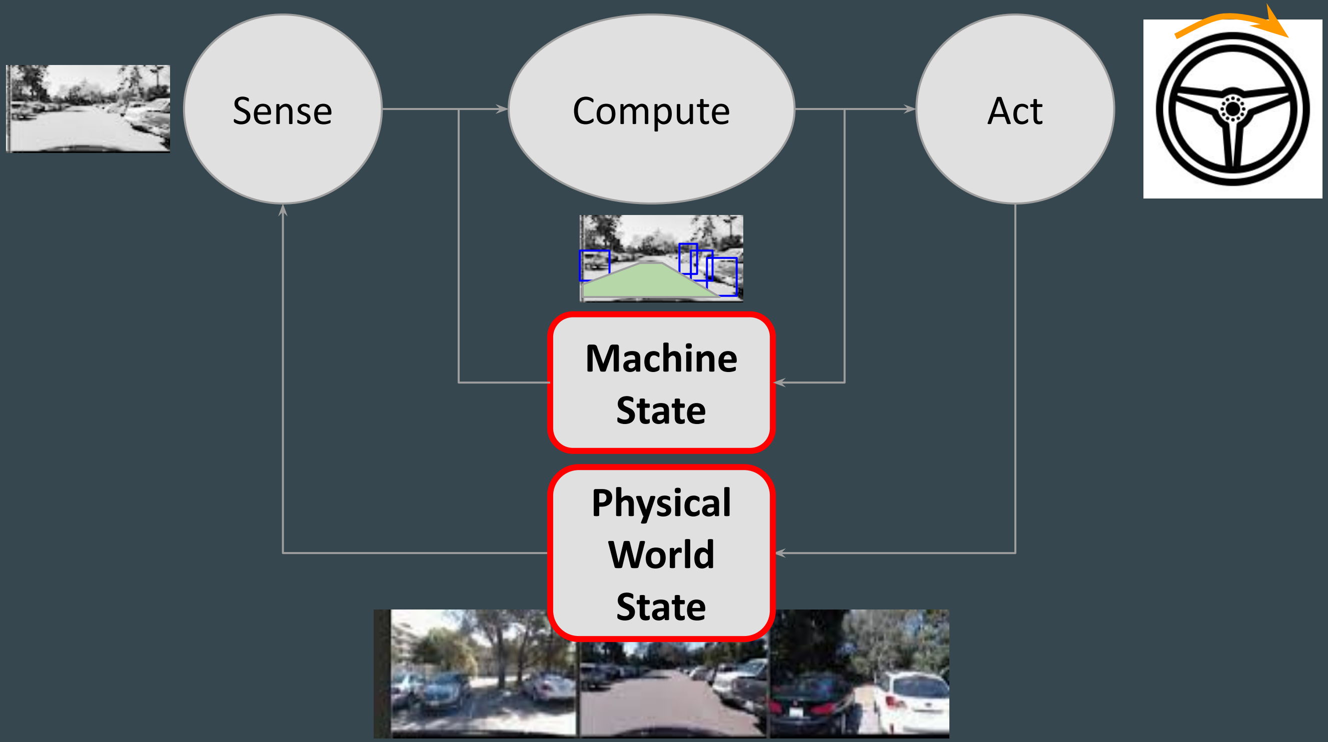
Operating in Physical World - Exercise

- Demo
- Challenges identified
  - *Poor quality / limited images*
  - *Pincer’s strength/grip, arm precision*
  - *Frames of reference*
  - *Incomplete model of world*
  - *Wrong interpretation of the world*
  - *...*

Operating in Physical World is Hard

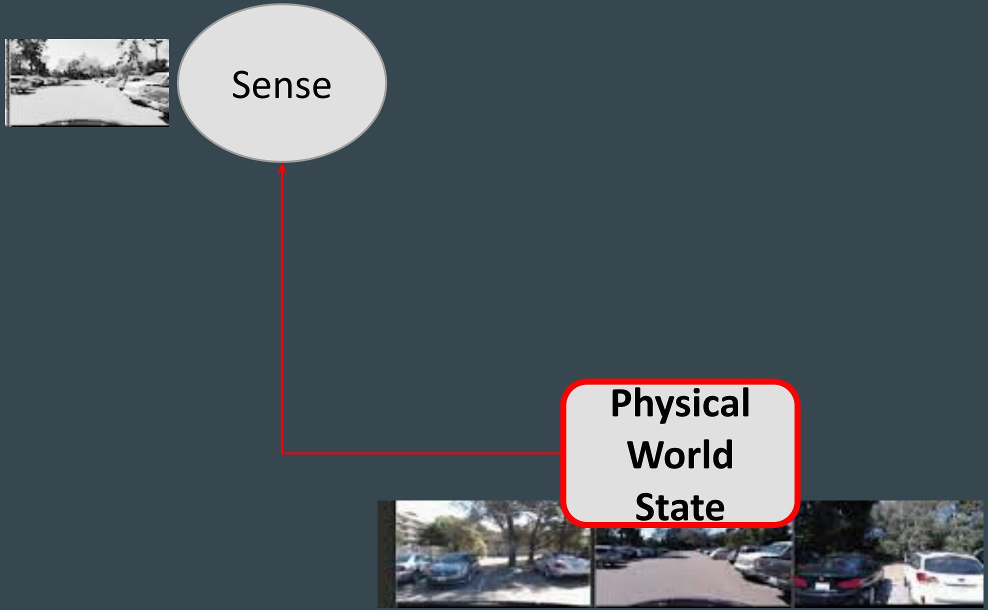
- World is messy
- Sensors are not perfect
- Interpreted world is an approximation at best
- Actuation effect is uncertain
- Timing is important
- Model of world matters

Operating in Physical World



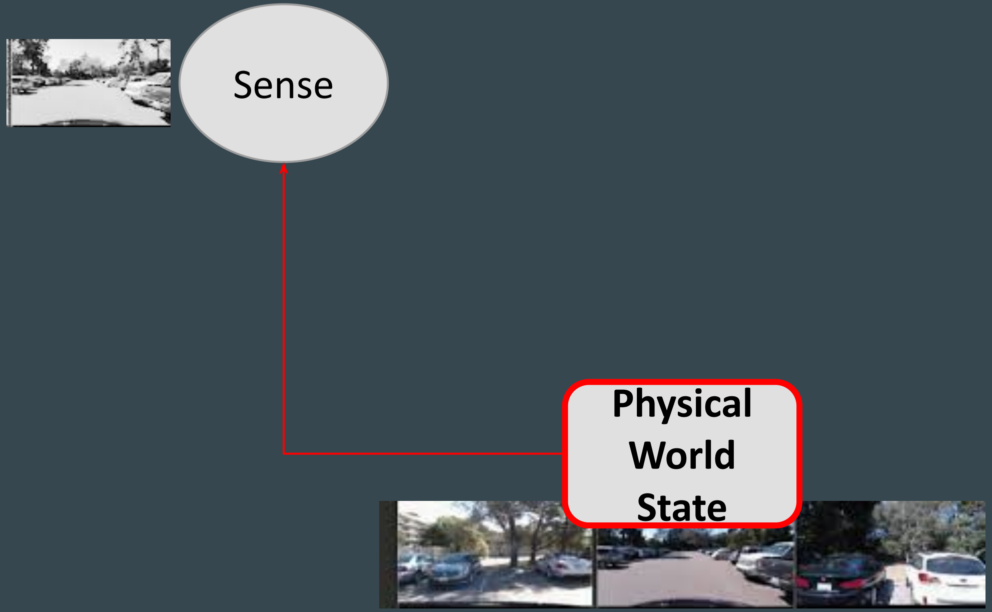
Sensing Physical World

- Physical world state is partially observable



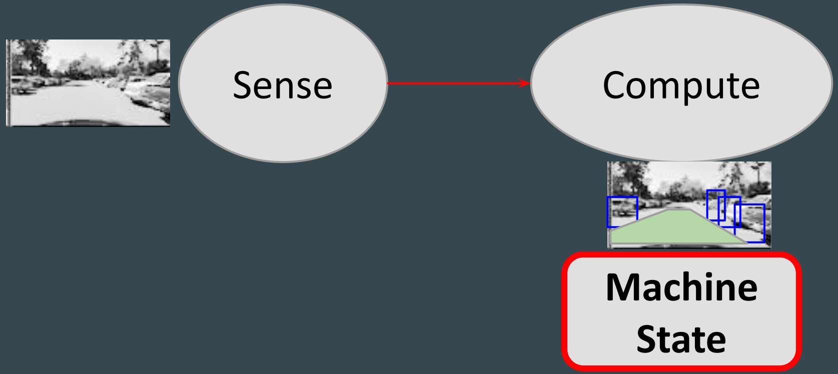
Sensing Physical World

- Physical world state is partially observable
- Sensors are noisy, inaccurate, and limited



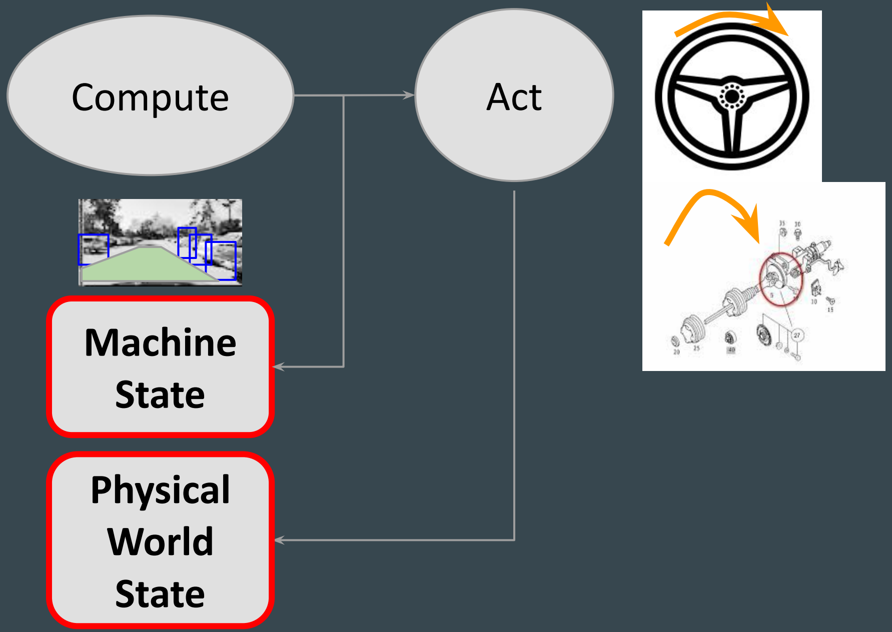
Sensing Physical World

- Physical world state is partially observable
- Sensors are noisy, inaccurate, and limited
- Inferring state from sensors’ data is another approximation



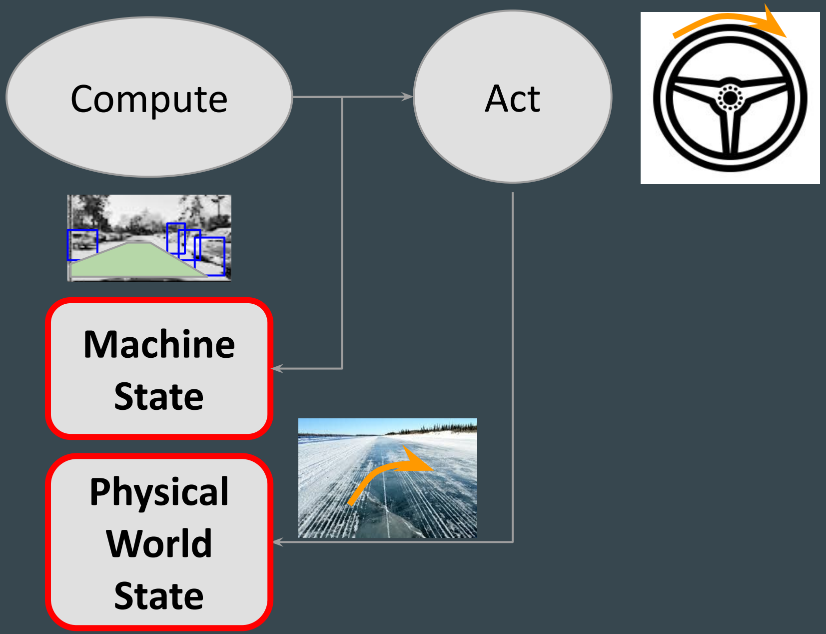
Actuating on Physical World

- Actuators inaccuracies when electro-mechanic assumptions break



Actuating on Physical World

- Actuators inaccuracies when electro-mechanic assumptions break
- Actuators inaccuracies when mismatch of physical and machine state



Compensation Strategies

- More and more powerful sensors
  - And cheaper and smaller
- Better models of the robot and the world
  - What to abstract?
- More and faster feedback loops
  - Can/Must Human be a part of it?
- Exposure to more scenarios
  - More deployed cars
  - More and better simulation

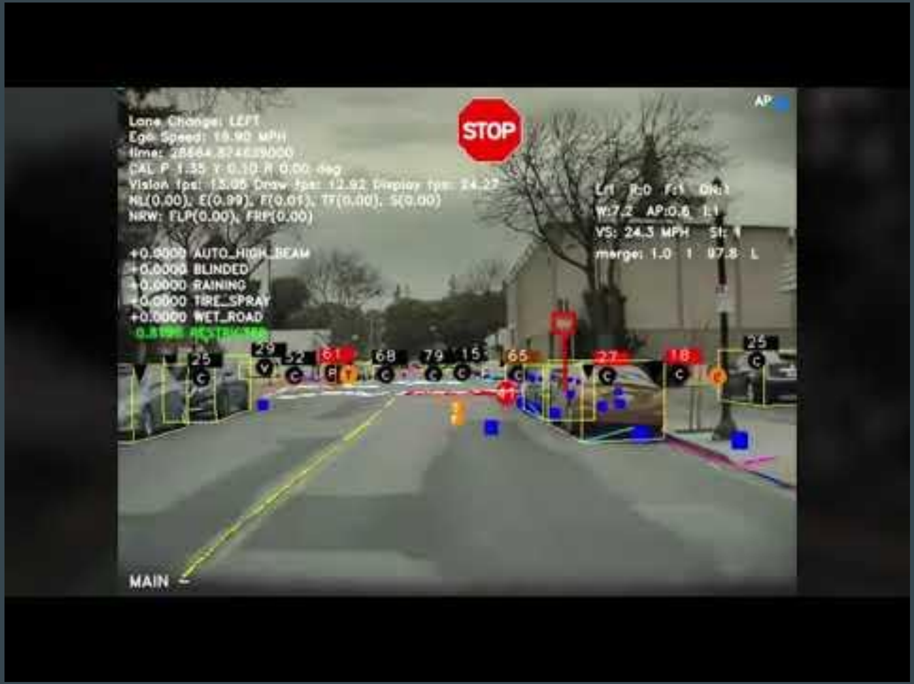
Single Camera

Wide Angle
Cameras + GPS

+ Cameras
+ Lidar

Night, Dirt

Are we there yet?



NATIONAL TRANSPORTATION SAFETY BOARD - 2020: *"The Tesla's Autopilot lane keeping assist system steered the vehicle to the left into the neutral area of the gore, without providing an alert to the driver, due to limitations of theAutopilot vision system's processing*

How do we ~~build~~ software engineer systems that can physically operate safely in the world?

Software Engineer

- Architectures and design patterns
- World representation in the machine
- Algorithms and data structures
- Simulation to bridge the testing gap with physical world
- Programming the deployment in the real world

How this class came about

How this class came about

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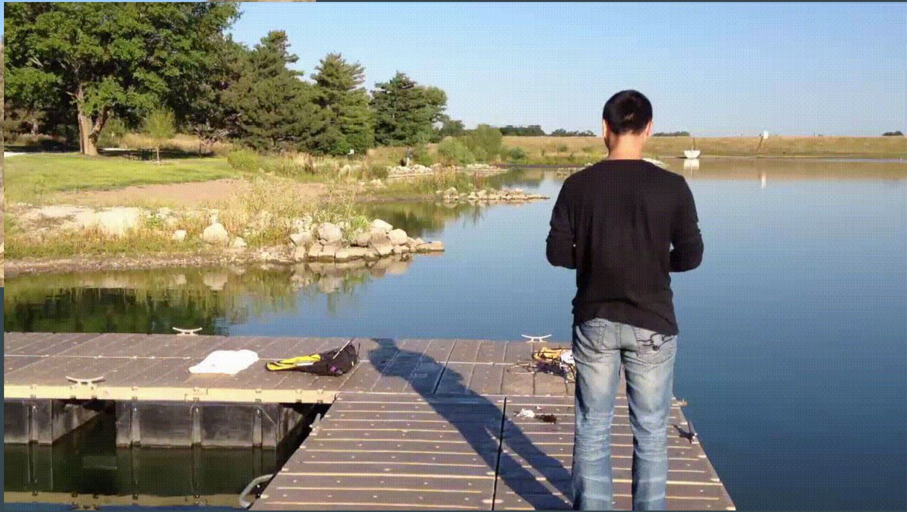

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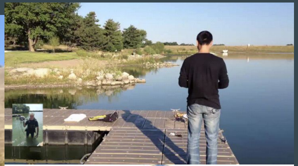

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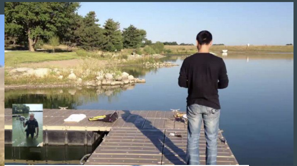
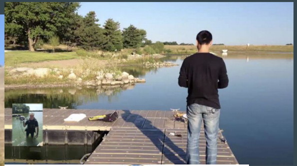


How this class came about



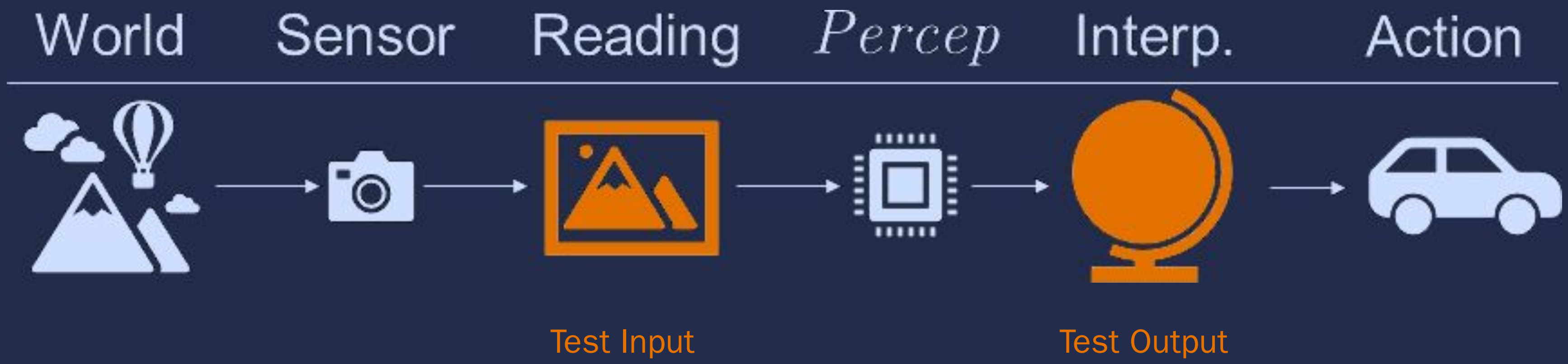
Ongoing Work - TA introduction

Semantic Image Fuzzing of AI Perception Systems

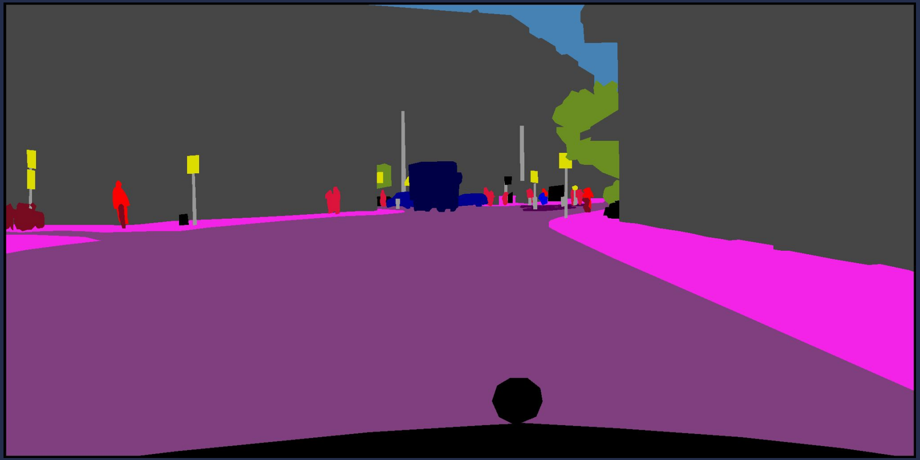
ICSE 2022

Trey Woodlief
adw8dm@virginia.edu
LESS Lab, University of Virginia

Robotics System Pipeline



Sensor Reading vs Perception

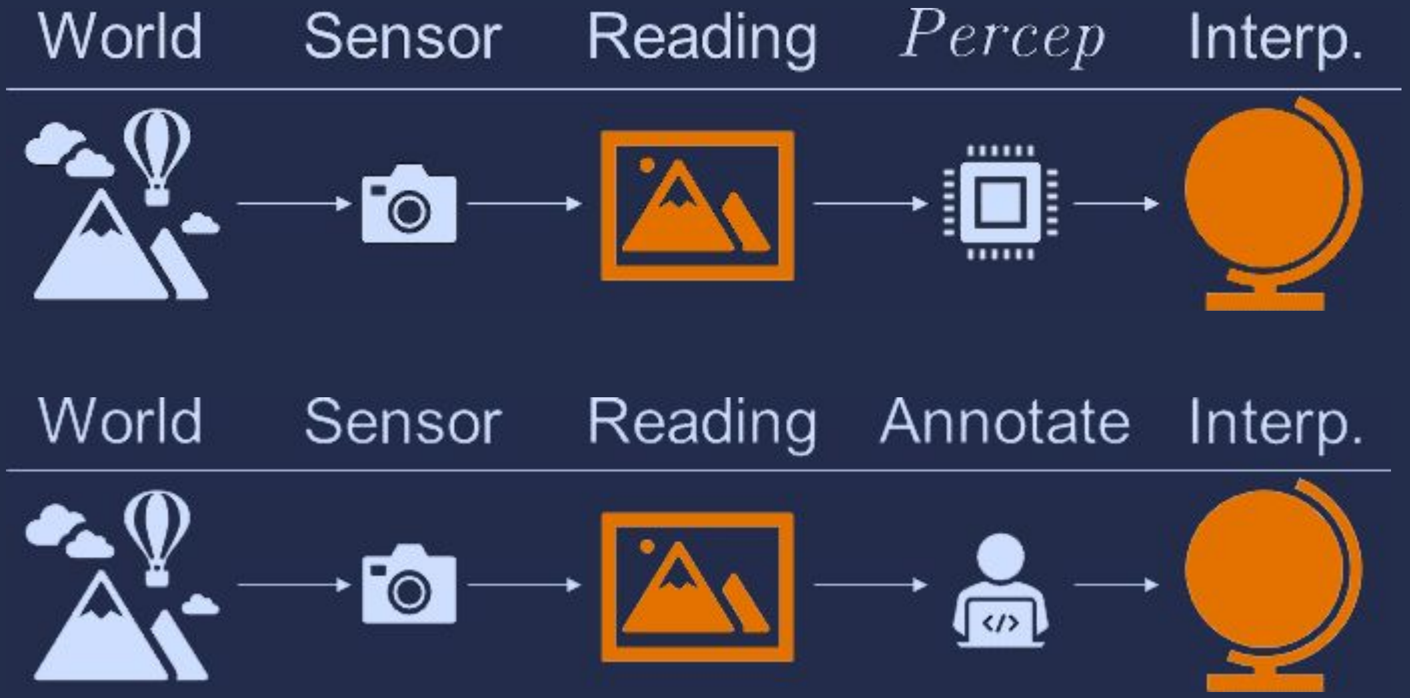


LESS LAB

Why is testing hard?

- Real data is expensive
  - Drive in the real world, pay someone to hand-label all tests
- Run in a simulator
  - The simulation-reality fidelity gap means revalidating results
- Mutate Prior Tests
  - Current techniques mutate without considering scene semantics

Testing the Perception: Human Oracle



Semantic Mutations

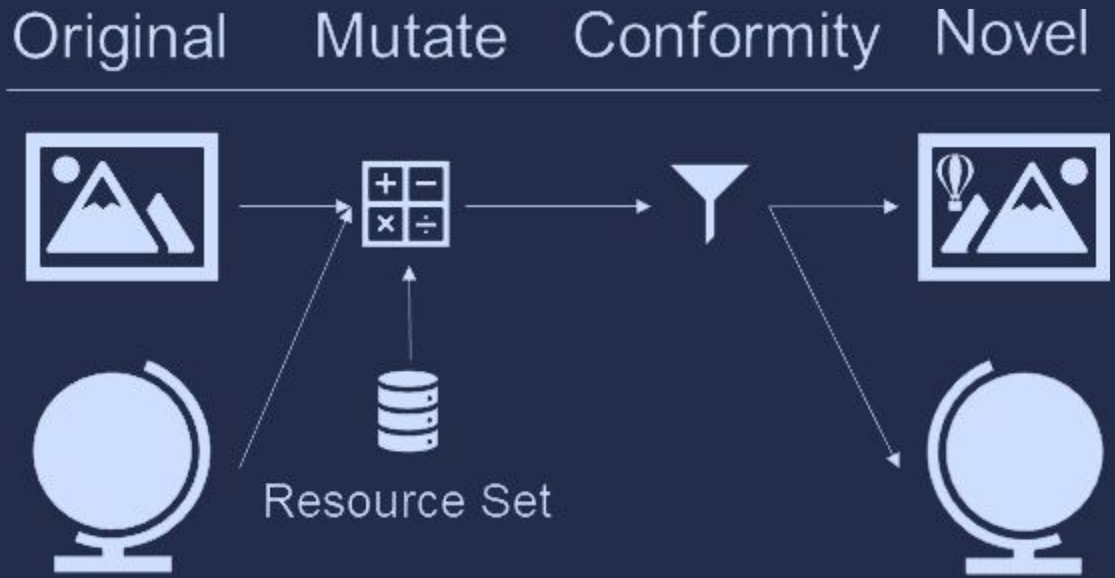
LESS LAB

Semantic Mutations

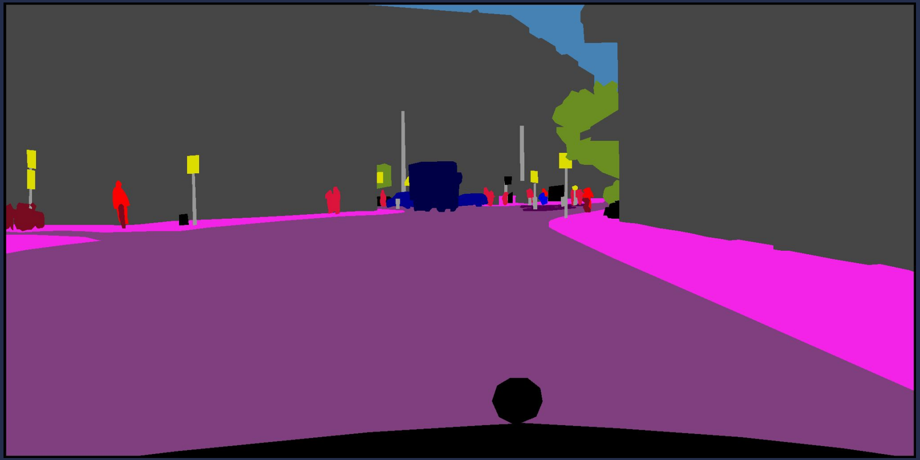
- Start with existing data
  - Cheap (already paid for)
- Existing real-world data
  - Bypass Simulation-Reality Gap
- Semantic Mutations
  - Find meaningfully different scenarios
  - Ensure scenarios are semantically valid

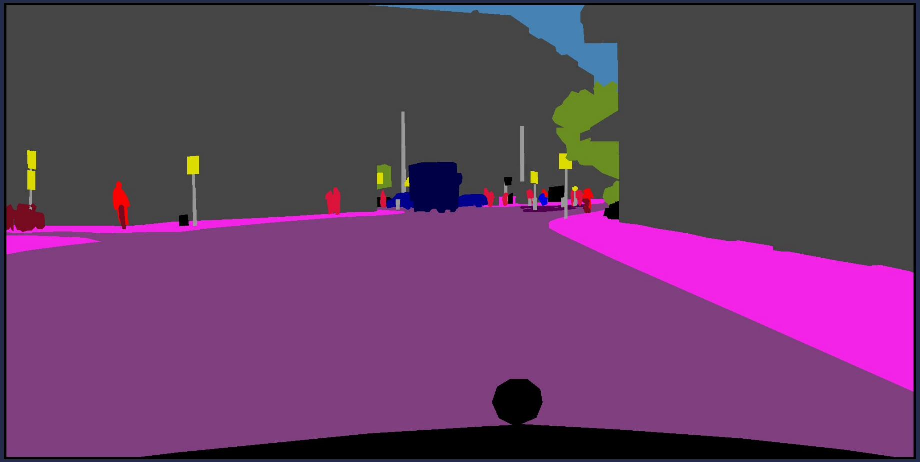
LESS LAB

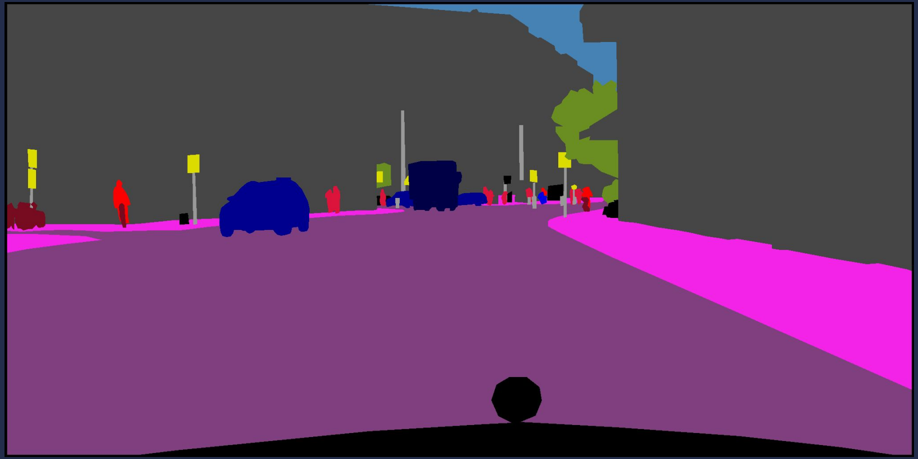
Semantic Mutations



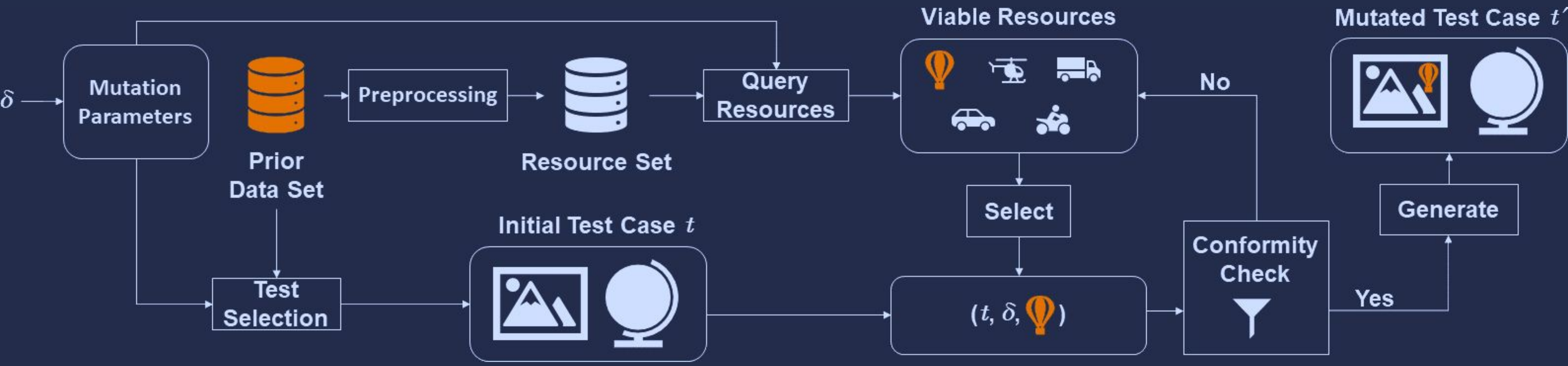
Semantic Mutations



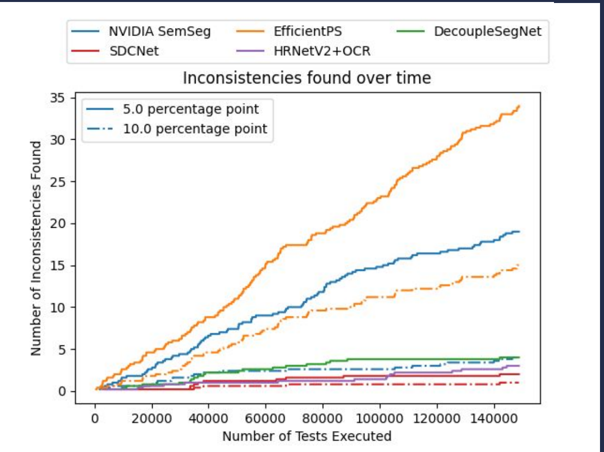


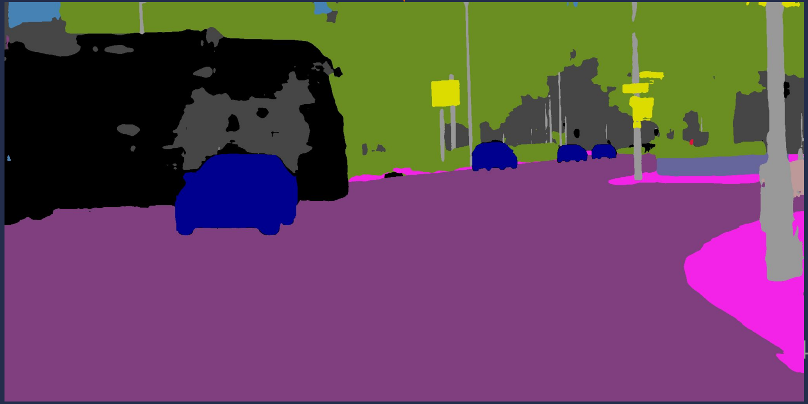


Semantic Mutations with Real Data



Real Results





False Positives

False Positives (Overlap)

False Positives (Lighting)

False Positives (Coloring)

False Positives (Incomplete Object)

False Positive? (Domain Constraints)

Example Images


GEOX
Jacques Bockel


Hund

What next?

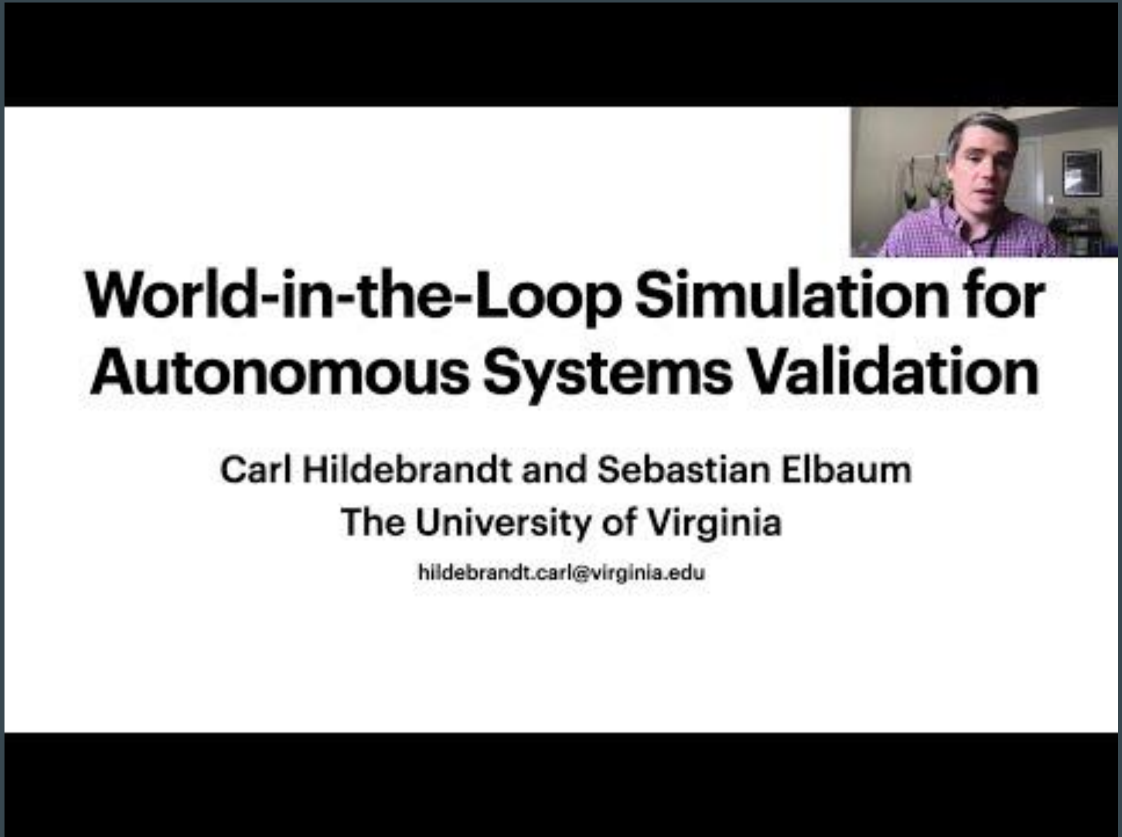
- More/Improved mutations!
  - Fixing lighting problems (add shadows, remove glares, etc.)
  - Covering up existing objects
  - Better understanding of spatial relationships
- Guided Mutations
  - Uncommon situations - car going wrong way on the street
  - Guiding by prior results
- More sensors!
  - LIDAR, radar, etc.

LESS LAB

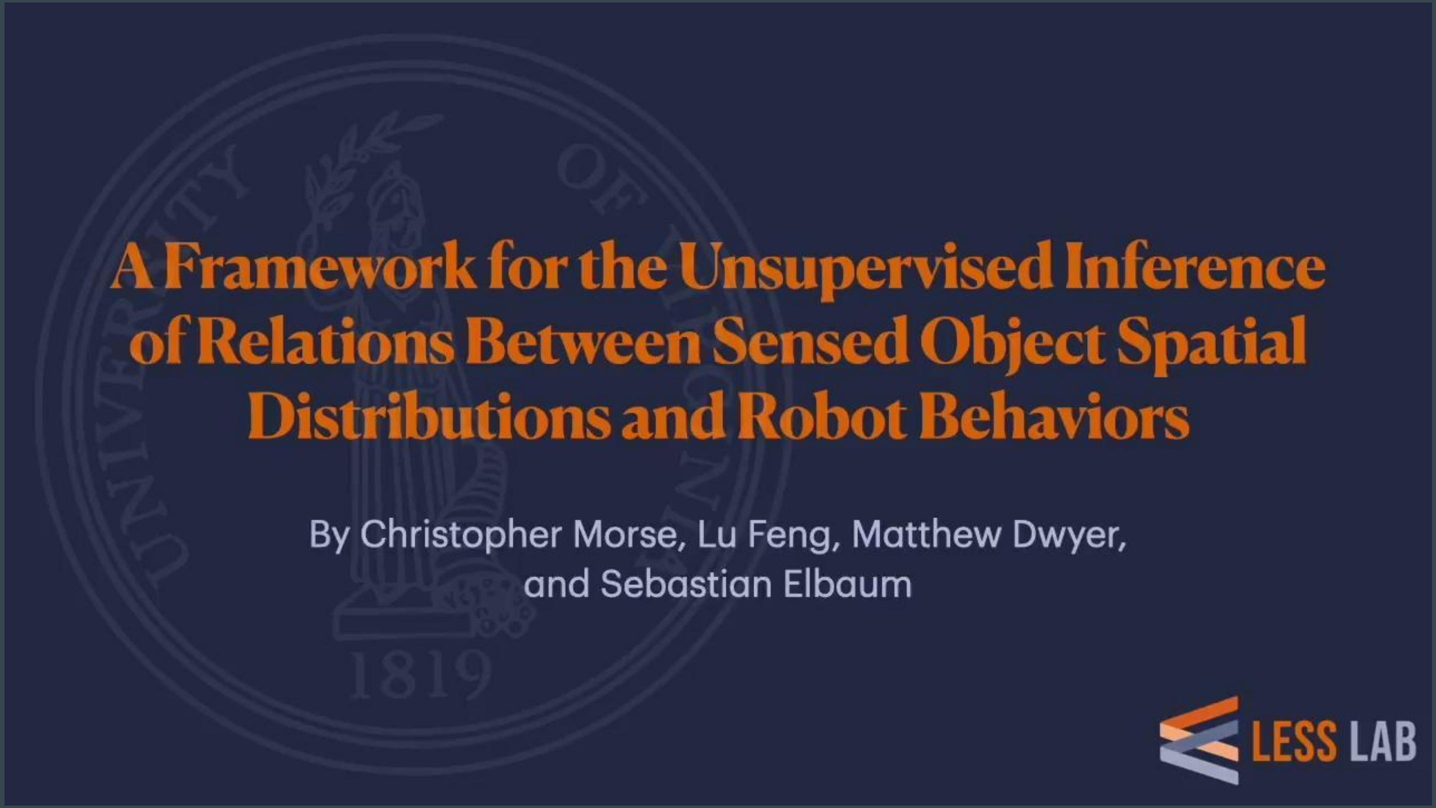
Ongoing Work - TA introduction

Ongoing Work - TA introduction

Ongoing Work - TA introduction



Ongoing Work - TA introduction



Course Structure

- Lectures on Mondays
- Labs on Wednesdays (70 points)
- 4/5 Quizzes on covered materials (8 points)
- 2-min Robotics Video (2 points)
- Project for the last couple of weeks (20 points)

Lab Structure

- Be laptop-ready on Wednesday to complete labs
- Work in mini-groups with rotating support
- Sign-up for Slack
- Lab Grading
  - “Life grading” during office hours or Lab time
    - “Life” means we get to chat a bit more, dig a bit deeper, answer questions
  - Grading Timelime
    - To get full grade: graded within a week of being assigned
    - To get 50%: within 2 weeks of being assigned
    - 0 otherwise

Course Materials Walkthrough

- Website for all materials and labs
  - https://less-lab-uva.github.io/CS4501-Fall2022/
- Collab for announcements and grades
- Office hours for lab support with sign up sheets

Course Policies - Doing your own work

- Students must fully comply with all the provisions of the University's Honor Code.
- Offering and accepting solutions from others (for labs, quizzes, etc) is a serious offense
  - All graded labs, quizzes, and project must be pledged
  - You can discuss strategies for labs and project with others, but you cannot share code
  - All suspected violations may be forwarded to the Honor Committee
  - You may, at the instructor discretion, receive an immediate zero on that assignment and fail the course regardless of any action taken by the Honor Committee
  - Do not exchange information during quizzes
- Labs can get full credit if returned within a week of the class when they were introduced. After a week, the labs get 50% credit. After two weeks the labs get 0 credit.

When in doubt, ask me.
When in need of a break, talk to me, the sooner the better.

Course Policies - Accommodations

- If you feel sick, let me know and stay home. We will work on a temporary solution.
- If you anticipate any issues related to the format, materials, or requirements of this course, please meet with me outside of class so we can explore potential options.
- If you are unsure if you require an accommodation, or to learn more about their services, you may contact the SDAC at the number above or by visiting their website at https://studenthealth.virginia.edu/sdac.
- If you are struggling with violence or discrimination, I am ready to provide support and guide you towards the many resources available at the University of Virginia.
- If you need academic accommodation for a religious observance, please submit an email request to me as far in advance as possible. Note that accommodations do not relieve you of the responsibility for completion of any part of the coursework missed as the result of a religious observance.

Tentative Schedule

Week	Monday	Wednesday
1	—	Introduction
2	Distinguishing Development Features	Lab-1: Set up and Basic ROS
3	—Labor Day—	Lab-2: ROS processes, Communication, and Simulation Environment
4	Software Machinery + Q1	Lab-3: Types and Machines
5	Robot and World Types	Lab-4: Sensor Types and Handling Uncertainty and Noise
6	Abstractions for Perception + Q2	Lab-5: Perception through Image Analysis
7	—UVA Break Day—	Invited Speaker
8	Controlling your Robot	Lab-E: Robotics and Ethics
9	Tradeoffs when Making Plans + Q3	Lab-6: Controlling and Testing Tobots
10	Localization and Navigation Stack	Lab-7: Mapping and Motion Planning Software Stack
11	Overloading and Transformations	Lab-8: Pose Transformations
12	Advanced Robotics + Q4	Lab 9: Swarms and Safety
13	Project parameters	Invited Speaker
14	Project check	Project consult
15	Project Presentations and Demos	Project Presentations and Demos
16	Taking stock	—

TODO by Monday

- Visit class website
- Sign up for Slack
- Get ready for next class:
  - Submit (before next class): URL for ‘2’ min video presentation with text answering posted question in Collab
- Get ready for first lab by learning about Docker:
  - https://docs.docker.com/get-started/