# Today's agenda

# 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
- Other interests:
  - Ultimate frisbee, roller skating
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# The Laboratory for Embedded Machines and Ubiquitous Robotics

https://uclalemur.com

- Overarching research interests:
  - How do we enable robots everywhere?
  - What can we do once we have that?
- Projects:
  - Democratization of engineering
  - Accessible printable robots
  - Mechanical intelligence
  - Distributed state estimation, localization, mapping
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# TA: Ruochen Hou

# About you

Tell us who you are! Due **this Thursday** 1/11 at **11am**:

- Online questionnaire form for us to better tailor the course to your needs
- Public introduction slides
  - One slide about you personally
  - Three possible final project ideas
  - Will be presented live at Thursday's class

# Today's agenda

1. About us
2. About this course
3. Project design
4. Robots and robotics

# ECE183: Design of Robotic Systems

- This class is about **design**:
  - Planning
  - Execution
  - Validation
  - Communication

- This class is (mostly) **not**:
  - Book problems
  - Product development
  - Hardware hacking

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# Goals of this class

In decreasing order of impact:

- Learn how to successfully plan, execute, and present an engineering design project
- Reinforce engineering skills learned from your past classes
- Learn new tools and technical skills relevant to robotics

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# Schedule and structure

- 4 unit class = 12 hrs commitment per week
- Winter term
  - In-class lab activities and project presentations: 6 hrs
  - Recorded lectures: ~2 hrs
  - Additional commitments: ~4 hrs
    - Lab work, project research & planning
- Spring term
  - Final project execution: ~10 hr
  - Meeting with staff: ~1 hr
    - Both scheduled and ad-hoc board meetings
    - Weekly progress reports also posted to the class
  - Peer assessment: ~1 hr

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# Lectures

- Pre-recorded lecture videos
  - Design
    - Front loaded to cover project process, deliverables
  - Robotics
    - Some will be mandatory, most will be optional.
  - Additional topics
- Lecture material will be relevant for both lab and project assignments

All lectures are available right now on our course website:

- https://capstone.uclalemur.com

All project assignments are available right now on our course git server:

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Suggested pacing given there, feel free to peek ahead

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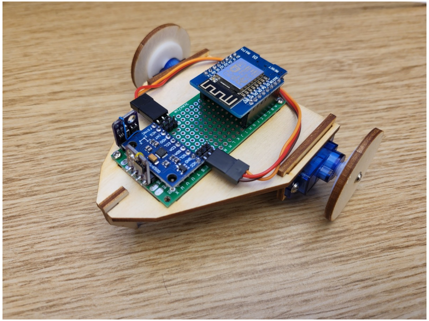
# Labs / Mini-project

- Toy problems based on Woodbot
  - Explore variety of modeling / prototyping tools
  - Develop experiments to support design process
- Observe design process examples
- Establish good project management habits
- Better estimate future plans



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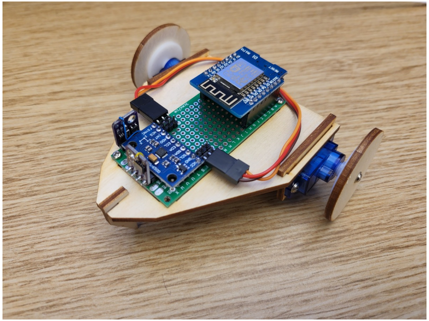

# Final project

- Formulate, design, justify, evaluate, and present a robotic solution to a problem
- Open-ended definition but must include:
    - Electromechanical mechanisms
    - Computation for processing / intelligence
    - System integration to address application needs
    - Evaluations and justification
    - Novelty

# 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 (Python3)
- Algorithms
- Rigid body mechanics
- Signal processing
- Feedback control

# Course communication

Three main sites to keep in mind:

- Class website: https://capstone.uclalemur.com
- Bruinlearn: https://bruinlearn.ucla.edu/courses/176994
- Gitlab repository: https://git.capstone.uclalemur.edu

Everything official from us will be handled via these websites:

- Announcements
- Handouts
- Assignments

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

# One final note

- This class is a bridge between student life and an engineering career
- We want your experience to be valuable and enjoyable
- Feedback is encouraged and always welcome
- This class is likely to evolve over the course of the year

# Questions?

Any questions on the administrivia?

# Today's agenda

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# Coursework vs Design

- Problem set
  - **Given**: tool, problem
  - **Do**: apply tool to problem
  - **Goal**: answer to problem
- Exam
  - **Given**: collection of tools, problem
  - **Do**: choose appropriate tool, apply to problem
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- Design
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  - **Given**: tools, plan
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- Hacking
  - **Given**: tools
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# Design process

Project: **technologies** → **solution** → **application**

The design process ensures that the right technologies are engineered in the right way to address the right problem.

If you don't attempt to **discover and validate** your choice of technologies, solution, and application, you're going to have a bad time.

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# Why design?

Potential **failure**

- Inappropriate application
  - Google glass: Pervasive (wearable) vision-based computing
- Inappropriate tool / technology
  - Nintendo Virtual Boy: Monochrome stereo-vision display
- Single technology for single application
  - Kodak: Light sensitive film for personal photography
- Single project pathway
  - Blackberry: pocket computer for personal computing via keypad

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# Validation

- What constitutes support that a problem is “optimal”?
  - Market research
  - User interviews
  - Experimentation / analysis
- What constitutes support that tools are “optimal”?
  - Industrial / academic research
  - Modeling / simulation
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  - Extrapolation
  - Comparison

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# The process

**Single solutions are not enough**

- Identify candidates and alternatives
- Select an evaluation method
  - Literature search
  - Analysis
  - Prototyping
- Execute the method to **justify** your choice
- **Process** is more important than product

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# Theme: Tech startup

- Build a **company**, not just a demo / device
- Plan extensively to justify ongoing investment
- Results are generated to validate **methods**

- Final deliverables
  - Artifacts, demonstration, presentation, writeup
- **Periodic deliverables**
  - Scoping, plan, design reviews, milestones

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# Top-down project definition

- **Application** pull, e.g.:
    - Netflix: Application = on-demand movies
        - Technology option 1: DVDs by mail
        - Technology option 2: streaming downloads
    - Early Uber: Application = app-driven taxi
        - Technology option 1: employed drivers
        - Technology option 2: ridesharing

# Bottom-up project definition

- **Technology** push, e.g.:
  - Amazon: Technology = scaleable computation
    - Application option 1: product recommendations
    - Application option 2: cloud compute services
  - Recent Uber: Technology = gig workers
    - Application option 1: ridesharing
    - Application option 2: food delivery

# Project deliverables: Pre-planning

Goal: Choose **and justify** a specific project, in stages

- Initial ideas:
  - One top-down application with multiple technology options
  - One bottom-up technology with multiple application options
  - A third idea of either type
- **P1**: Individual: build team of like interest, complementary skills
  - Due Thursday in your introduction presentation
- **P2**: Team: get feedback to minimize unexpected challenges and maximize success
  - Starts next week

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# Project deliverables: Pre-planning

Goal: Define **and justify** a specific project scope

- **P3**: One technology and application, with multiple pathways, e.g.:
  - Uber: gig workers for ridesharing
    - Build app to connect to connect passengers to drivers
    - Learn models of passenger distribution to command driver patrol routes
- **P4**: Requirements Review (RR) / System Design Review (SDR)
  - Identify all necessary subsystems
  - Explore and understand interactions between subsystems
  - Characterize unknowns, action items, and risk

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# Project milestone: Shark tank VC pitch

**P5** Goal: Externally **validate** your preliminary justifications

- Explain to potential investors:
  - Project scope (technology, application, and pathways)
  - Resource allocation
    - Time
    - Personnel
  - Expected deliverables
  - Risk/reward analysis

- Initial investments reflect:
  - potential value of solution
  - thoroughness of pre-planning process

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# Project deliverables: Planning

**P6** Goal: Ensure successful project completion

- Preliminary Design Review (PDR) / Test Readiness Review (TRR)
  - Resolve most impactful unknowns
  - Mitigate most significant risks
  - Decompose project (hierarchically) into individual atomic tasks
  - Allocate / schedule all tasks and all resources
  - Ensure that dependencies are identified and accomodated
  - Manage internal and external uncertainty
  - Define incremental success criteria

# Project deliverables: Weekly execution

Goal: Ensure regular progress and allow course correction

- Progress update
  - Comparison of current status to PDR plan
    - Mitigation strategy for shortfalls
  - Refinement of future tasks
  - Clear action plan for upcoming week

- Investment change (stock trading) reflects confidence in plan and execution

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# Project planning goals – q1

- Achievable
  - Meet weekly deliverables and final goals
  - Culminate in interactive integrated demo
  - Justify final design
- Ambitious
  - Exercise all your engineering skills
  - Prepare scaleable stretch goals
  - Build a project you can show off
- Impactful
  - Add value beyond just this class
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# Final milestones – q2

- Presentations
  - Sales pitch for product / results
  - Final Design Review (FDR) for process / methods
- Live demos
- Writeups
  - FDR documentation
- Company exit (details to come)

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# Engineering philosophy

- Engineering is a combination of technology and communication. The grading policy reflects that.
- The important contribution is the **process**; generating and analyzing results is necessary to **validate** the process
- Answer the What, How, Why of the results:
  - **What** did you accomplish?
  - **How** did you do it?
  - **Why** that way?
- . . . and again for the process:
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# Questions

Any questions on course and project expectations?

# Today's agenda

1. About us
2. About this course
3. Project design
4. Robots and robotics

# What is a robot?

# What is a robot?


From WPI: Robotics Engineering

# What is a robot?

Ask 10 roboticists, you'll get 12 different answers

Approximate consensus:

"A machine that can sense, think, and act."

# Defining characteristics of a robot

- **Machine**: a physical artifact built by humans

- **Sense**: gather data from the environment
- **Think**: compute, reason, process, plan
- **Act**: effect a change in the enviroment

- Are any of these optional?

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# Robots today

- Industry
  - Automobile manufacturing
  - Silicon processing
  - Pharma testing
  - Warehousing
- Military
  - Manned vehicles
  - Smart weapons
  - Unmanned surveillance
  - Bomb disposal
- Field and Service
  - Space exploration
  - Agriculture automation
  - Environmental monitoring
  - Homeland security
- Consumer
  - Home automation
  - Toys
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  - Integrated circuits
  - Power systems
  - Communications
- Mechanical engineering
  - Structures
  - Kinematics and dynamics
  - Fluids and thermodynamics
- Computer science
  - Algorithms
  - AI and machine learning
  - Human-robot interaction
- And more. . .
  - Civil and environmental engineering
  - Material science
  - Bioengineering
  - Statistics
  - Sociology/Psychology
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- And more. . .
  - Civil and environmental engineering
  - Material science
  - Bioengineering
  - Statistics
  - Sociology/Psychology
  - Urban studies
  - . . .

# Interdisciplinary subjects

- Electromechanical transducers and devices
- Embedded systems programming
- Controllers and control systems
- Manufacturing processes
- Design optimization
- Security, privacy, fairness, equity and inclusion
- . . .

# Robotics is hard

- Inherently tightly integrated interdisciplinary engineering
- Devices must operate in the real world
  - Analog, continuous, nonlinear, coupled, and dynamic
  - Full of uncertainty
  - Models are necessarily limited in accuracy
- Devices must interact with humans
  - Humans are even more fiddly
  - Two way communication with unknown assumptions
  - Safety regardless of usage
- We are all a part of society

# Robotics research

Parallel Sessions—Tuesday, Nov 5

| Tr# | 11:00-12:30 | 14:45-16:15 | 16:45-18:15 |
|---|---|---|---|
| | | TuSF1 (L3-RA) Industrial Forum I | |
| | | 14:45-16:30 TuSF2 (L3-RB) CEO Forum | |
| | | | 16:00-18:00 TuSF3 (L3-RC) Government Forum |
| 1 | TuAT1 (L1-R1) Calibration and Identification | TuBT1 (L1-R1) 3D Vision and Pose Estimation | TuCT1 (L1-R1) RGB-D Perception |
| 2 | TuAT2 (L1-R2) Deep Learning for Aerial System | TuBT2 (L1-R2) Deep Learning for Computer Vision | TuCT2 (L1-R2) Deep Learning for Grasping |
| 3 | TuAT3 (L1-R3) Learning and Adaptive System I | TuBT3 (L1-R3) Learning and Adaptive System II | TuCT3 (L1-R3) Learning and Adaptive System III |
| 4 | TuAT4 (L1-R4) Award Session I | TuBT4 (L1-R4) Award Session II | TuCT4 (L1-R4) Award Session IV |
| 5 | TuAT5 (L1-R5) Robot Safety | TuBT5 (L1-R5) Award Session III | TuCT5 (L1-R5) Award Session V |
| 6 | TuAT6 (L1-R6) Aerial Robotics I | TuBT6 (L1-R6) Aerial Robotics II | TuCT6 (L1-R6) Aerial Robotics III |
| 7 | TuAT7 (L1-R7) Computer Vision and Application I | TuBT7 (L1-R7) Computer Vision and Application II | TuCT7 (L1-R7) Computer Vision for Automation I |
| 8 | TuAT8 (LG-R8) Cutting Edge Forum: Autonomous Driving: Contributions from Intelligent Robotics, AI and ITS | TuBT8 (LG-R8) Autonomous Agents and Robots | TuCT8 (LG-R8) Autonomous Vehicle Navigation I |

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Technical Sessions—Wednesday, Nov 6

| Tr# | 10:30-12:00 | 13:00-14:30 | 14:45-16:15 | 16:45-18:15 |
|---|---|---|---|---|
| | WeSF1 (L3-RA) Industrial Forum II | | | |
| | WeAPT (L3-RB) Pioneer's Talks | | | |
| 1 | WeAT1 (L1-R1) Object Detection and Segmentation I | WeBT1 (L1-R1) Object Detection and Segmentation II | WeCT1 (L1-R1) Semantic Scene Understanding I | WeDT1 (L1-R1) Semantic Scene Understanding II |
| 2 | WeAT2 (L1-R2) Deep Learning from Demonstration | WeBT2 (L1-R2) Deep Learning in Robotics and Automation I | WeCT2 (L1-R2) Deep Learning in Robotics and Automation II | WeDT2 (L1-R2) Deep Learning of Autonomous Agents |
| 3 | WeAT3 (L1-R3) Learning from Motion and Path Planning I | WeBT3 (L1-R3) Learning from Motion and Path Planning II | WeCT3 (L1-R3) Learning from Demonstration | WeDT3 (L1-R3) Learning from Human-Robot Interaction |
| 4 | WeAT4 (L1-R4) Mechanism Design I | WeBT4 (L1-R4) Mechanism Design II | WeCT4 (L1-R4) Mechanism Design III | WeDT4 (L1-R4) Mechanism Design IV |
| 5 | WeAT5 (L1-R5) Telerobotics and Teleoperation I | WeBT5 (L1-R5) Telerobotics and Teleoperation II | WeCT5 (L1-R5) Robot Control I | WeDT5 (L1-R5) Robot Control II |
| 6 | WeAT6 (L1-R6) Aerial Robotics IV | WeBT6 (L1-R6) Aerial Robotics V | WeCT6 (L1-R6) Aerial Robotics VI | WeDT6 (L1-R6) Aerial Robotics VII |
| 7 | WeAT7 (L1-R7) Computer Vision for Automation II | WeBT7 (L1-R7) Computer Vision and Visual Servoing I | WeCT7 (L1-R7) Computer Vision and Visual Servoing II | WeDT7 (L1-R7) Performance Evaluation and Benchmarking |
| 8 | WeAT8 (LG-R8) Autonomous Vehicle Navigation II | WeBT8 (LG-R8) Autonomous Vehicle Navigation III | WeCT8 (LG-R8) Autonomous Vehicle Navigation IV | WeDT8 (LG-R8) Autonomous Vehicle Navigation V |
| 9 | WeAT9 (LG-R9) Social Human-Robot interaction IV | WeBT9 (LG-R9) Cutting Edge Forum: Human Interaction with Multi-Robot Systems | WeCT9 (LG-R9) Cutting Edge Forum: Cognitive Architectures for Humanoids | WeDT9 (LG-R9) Robot Audition |

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Technical Sessions—Thursday, Nov 7

| Tr# | 11:00-12:30 | 14:45-16:15 | 16:45-18:15 |
|---|---|---|---|
| 1 | ThAT1 (L1-R1) Sensor Fusion and Sensor-Based Control | ThBT1 (L1-R1) Sensor Fusion I | ThCT1 (L1-R1) Sensor Fusion II |
| 2 | ThAT2 (L1-R2) Deep Learning with Visual Methods | ThBT2 (L1-R2) Learning for Localization | ThCT2 (L1-R2) Learning for Mobile System |
| 3 | ThAT3 (L1-R3) Physical Human-Robot Interaction I | ThBT3 (L1-R3) Physical Human-Robot Interaction II | ThCT3 (L1-R3) Physical Human-Robot Interaction III |
| 4 | ThAT4 (L1-R4) Tendon/Wire Mechanism | ThBT4 (L1-R4) Parallel Robots | ThCT4 (L1-R4) Compliant Structures |
| 5 | ThAT5 (L1-R5) Compliance and Impedance Control | ThBT5 (L1-R5) Optimal Control I | ThCT5 (L1-R5) Optimal Control II |
| 6 | ThAT6 (L1-R6) Aerial Robotics VIII | ThBT6 (L1-R6) Model Learning for Control I | ThCT6 (L1-R6) Model Learning for Control II |
| 7 | ThAT7 (L1-R7) Visual Learning | ThBT7 (L1-R7) Vision-Based Navigation I | ThCT7 (L1-R7) Vision-Based Navigation II |
| 8 | ThAT8 (LG-R8) Intelligent Transportation Systems | ThBT8 (LG-R8) Simulation and Amination | ThCT8 (LG-R8) Control and Programming |
| 9 | ThAT9 (LG-R9) Cognitive Human-Robot interaction I | ThBT9 (LG-R9) Cognitive Human-Robot interaction II | ThCT9 (LG-R9) Cognitive Human-Robot Interaction III |
| 10 | ThAT10 (LG-R10) Visual SLAM II | ThBT10 (LG-R10) Mapping I | ThCT10 (LG-R10) Mapping II |
| 11 | ThAT11 (LG-R11) Medical Robot: Laparoscopic | ThBT11 (LG-R11) Medical Robot: Microsurgery | ThCT11 (LG-R11) Medical Robot: Vision |

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| Tr# | 11:00-12:30 | 14:45-16:15 | 16:45-18:15 |
|---|---|---|---|
| 9 | TuAT9 (LG-R9) Social Human-Robot Interaction I | TuBT9 (LG-R9) Social Human-Robot interaction II | TuCT9 (LG-R9) Social Human-Robot interaction III |
| 10 | TuAT10 (LG-R10) SLAM I | TuBT10 (LG-R10) SLAM II | TuCT10 (LG-R10) SLAM III |
| 11 | TuAT11 (LG-R11) Medical Robot: Design | TuBT11 (LG-R11) Medical Robot: Control | TuCT11 (LG-R11) Medical Robot: Continuum |
| 12 | TuAT12 (LG-R12) Human Detection and Tracking | TuBT12 (LG-R12) Gesture Posture and Facial Expressions | TuCT12 (LG-R12) Human Factor and Human-In-The-Loop I |
| 13 | TuAT13 (LG-R13) Humanoid and Bipedal Locomotion I | TuBT13 (LG-R13) Humanoid and Bipedal Locomotion II | TuCT13 (LG-R13) Humanoid and Bipedal Locomotion III |
| 14 | TuAT14 (LG-R14) Space Robotics | TuBT14 (LG-R14) Climbing Robots | TuCT14 (LG-R14) Robotics in Construction |
| 15 | TuAT15 (LG-R15) Motion and Path Planning I | TuBT15 (LG-R15) Motion and Path Planning II | TuCT15 (LG-R15) Motion and Path Planning III |
| 16 | TuAT16 (LG-R16) Grasping I | TuBT16 (LG-R16) Grasping II | TuCT16 (LG-R16) Grasping III |
| 17 | TuAT17 (LG-R17) Micro/ Nano Robots I | TuBT17 (LG-R17) Micro/ Nano Robots II | TuCT17 (LG-R17) Micro/ Nano Robots III |
| 18 | TuAT18 (LG-R18) Localization I | TuBT18 (LG-R18) Localization II | TuCT18 (LG-R18) Localization III |
| 19 | TuAT19 (LG-R19) AI-Based Methods for Robotics | TuBT19 (LG-R19) Planning, Scheduling, and Coordination I | TuCT19 (LG-R19) Planning, Scheduling, and Coordination II |
| 20 | TuAT20 (LG-R20) Biologically-Inspired Robots I | TuBT20 (LG-R20) Biologically-Inspired Robots II | TuCT20 (LG-R20) Biologically-Inspired Robots III |

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| Tr# | 10:30-12:00 | 13:00-14:30 | 14:45-16:15 | 16:45-18:15 |
|---|---|---|---|---|
| 10 | | WeBT10 (LG-R10) SLAM IV | WeCT10 (LG-R10) SLAM V | WeDT10 (LG-R10) Visual SLAM I |
| 11 | WeAT11 (LG-R11) Medical Robot: Endoscope | WeBT11 (LG-R11) Cutting Edge Forum: Surgical Robotics with AI | | WeDT11 (LG-R11) Medical Robot: Endovascular and Needle |
| 12 | WeAT12 (LG-R12) Human Factors and Human-In-The-Loop II | WeBT12 (LG-R12) Human-Centered Robotics I | WeCT12 (LG-R12) Human-Centered Robotics II | WeDT12 (LG-R12) Service Robots |
| 13 | WeAT13 (LG-R13) Humanoid Robots I | WeBT13 (LG-R13) Humanoid Robots II | WeCT13 (LG-R13) Legged Robots I | WeDT13 (LG-R13) Legged Robots II |
| 14 | WeAT14 (LG-R14) Field Robots I | WeBT14 (LG-R14) Field Robots II | WeCT14 (LG-R14) Field Robots III | WeDT14 (LG-R14) Agricultural Automation |
| 15 | WeAT15 (LG-R15) Motion and Path Planning: Aerial and Autonomous Vehicles | WeBT15 (LG-R15) Motion and Path Planning: Learning and Adaptive Systems | WeCT15 (LG-R15) Motion and Path Planning: Legged Robots | WeDT15 (LG-R15) Motion and Path Planning: Manipulators |
| 16 | WeAT16 (LG-R16) Grasping and Manipulation | WeBT16 (LG-R16) Perception for Grasping and Manipulation I | WeCT16 (LG-R16) Perception for Grasping and Manipulation II | WeDT16 (LG-R16) Grippers and Other End-Effectors |
| 17 | WeAT17 (LG-R17) Virtual Reality and Interfaces | WeBT17 (LG-R17) Wearable Robots | WeCT17 (LG-R17) Physically Assistive Devices | WeDT17 (LG-R17) Rehabilitation Robotics I |
| 18 | WeAT18 (LG-R18) Localization IV | WeBT18 (LG-R18) Swarm Robotics | WeCT18 (LG-R18) Cellular and Modular Robots | WeDT18 (LG-R18) Dynamics |
| 19 | WeAT19 (LG-R19) Path Planning for Multiple Robots I | WeBT19 (LG-R19) Path Planning for Multiple Robots II | WeCT19 (LG-R19) Reactive and Sensor-Based Planning | WeDT19 (LG-R19) Sensing and Planning |
| 20 | WeAT20 (LG-R20) Biologically-Inspired Robots IV | WeBT20 (LG-R20) Neurorobotics | WeCT20 (LG-R20) Soft Robot: Applications | WeDT20 (LG-R20) Soft Robot: Materials and Design |

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| Tr# | 11:00-12:30 | 14:45-16:15 | 16:45-18:15 |
|---|---|---|---|
| 12 | ThAT12 (LG-R12) Cutting Edge Forum: Human Movement Understanding for Intelligent Robots and Systems | ThBT12 (LG-R12) Force and Tactile Sensing I | ThCT12 (LG-R12) Force and Tactile Sensing II |
| 13 | ThAT13 (LG-R13) Legged Robots III | ThBT13 (LG-R13) Hydraulic/Pneumatic Actuators | ThCT13 (LG-R13) Industrial Robots & Actuators |
| 14 | ThAT14 (LG-R14) Marine Robots I | ThBT14 (LG-R14) Marine Robots II | ThCT14 (LG-R14) Marine Robots III |
| 15 | ThAT15 (LG-R15) Behavior-Based Systems | ThBT15 (LG-R15) Collision Avoidance I | ThCT15 (LG-R15) Collision Avoidance II |
| 16 | ThAT16 (LG-R16) Grasping and Object Tracking | ThBT16 (LG-R16) Haptics and Bio-Inspired | ThCT16 (LG-R16) Haptics and Haptic Interfaces |
| 17 | ThAT17 (LG-R17) Rehabilitation Robotics II | ThBT17 (LG-R17) Prosthetics and Exoskeletons I | ThCT17 (LG-R17) Prosthetics and Exoskeletons II |
| 18 | ThAT18 (LG-R18) Multi-Robot Systems I | ThBT18 (LG-R18) Multi-Robot Systems II | ThCT18 (LG-R18) Multi-Robot Systems III |
| 19 | ThAT19 (LG-R19) Manipulation Planning I | ThBT19 (LG-R19) Manipulation Planning II | ThCT19 (LG-R19) Dexterous Manipulation |
| 20 | ThAT20 (LG-R20) Soft Robot: Modelling, Control and Learning | ThBT20 (LG-R20) Soft Sensors and Actuators I | ThCT20 (LG-R20) Soft Sensors and Actuators II |

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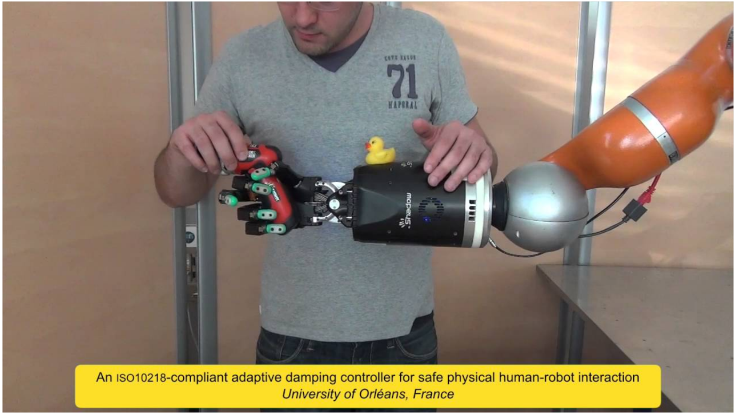
# Robotics topics

- Human-robot interaction
- Unmanned aerial systems
- Robot vision
- Sensor fusion
- Micro/nano robots
- Surgical robotics
- Manipulation planning and control
- Swarm robotics
- Learning from demonstration
- Grasping
- Marine robots
- Soft-bodied robots
- Haptic interfaces
- Humanoid and bipedal locomotion
- Joint / mechanism design
- Networked robots
- Cooperative manipulators
- Localization
- Formal methods
- ...

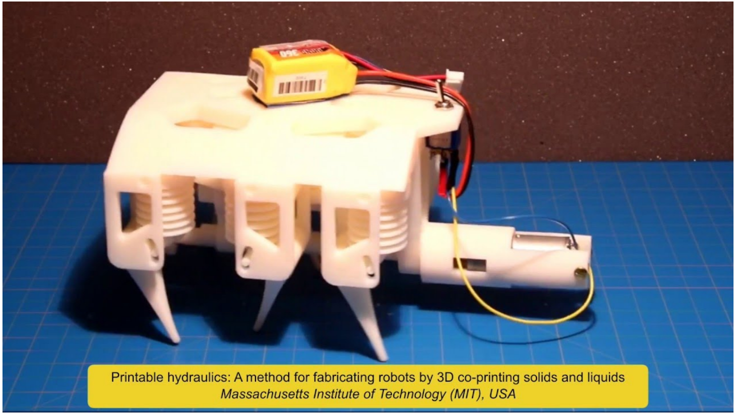
# Recent robotics projects

# Recent research results

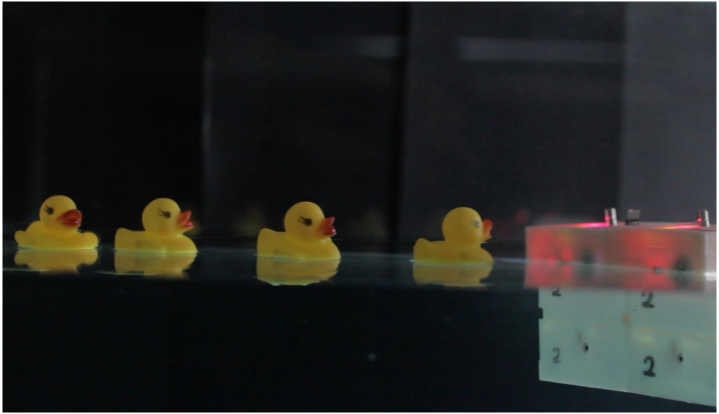
# Recent research results



# Recent research results



# Recent research results



# Next up

- Due before the start of this Thursday's class:
  - Online questionnaire
  - Introduction slides
- Thursday classes:
  - Introductions, meet-and-greet, lab + project team forming
- Due before the start of next Monday's class:
  - Prereq's homework
  - 2 lectures