



HARVARD

John A. Paulson
School of Engineering
and Applied Sciences

Course Offering: Fall 2019
Instructor: Prof. Vijay Janapa Reddi
Teaching Fellow: Brian Plancher
Office: Maxwell Dworkin 147
Email: vj@eecs.harvard.edu

CS249r: Special Topics in Edge Computing

Topic: Autonomous Machines

Special Topics: Broadly, the course covers a range of hardware and software topics in the context of smart/intelligent embedded systems. Traditional embedded systems are passive electronic devices that perform a single task and operate in isolation. In contrast, modern embedded systems are intelligent devices that involve complex hardware and software to perform a multitude of cognitive functions collaboratively. Designing such systems requires us to have a deep understanding of the target application domains, as well as an appreciation for the coupling between the hardware and the software subsystems. To this end, the course is designed to help students come up to speed on various aspects of edge computing hardware and software, including interactions with remote cloud computing systems and microcontroller edge endpoints. Each year the course focuses on one or more emerging areas, including but not limited to autonomous vehicles, robotics, mobile, etc. It is a **seminar-style course** so students are expected to present, discuss, and interact with assigned research papers. At the end of the semester, students will present their work based on a **class research project**.

The **Fall 2019 edition** focuses on **Autonomous Machines** (cars, drones, ground robots, manipulators, etc.). The course is primarily structured around building “systems” for autonomous machines. For example, we will discuss what are all the hardware and software components that are involved in developing the intelligence required for an autonomous car?

Teaching Fellow

Brian Plancher (brian_plancher@g.harvard.edu)

Course Meeting Times

Mondays and Wednesdays from 10:30am-11:45am in Maxwell Dworkin (MD) Room 123

Office Hours

TBD

Webpage

<https://canvas.harvard.edu/courses/61276>



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Prerequisites

1. CS 141 and/or basic computer architecture and digital design
2. CS 61/161 and/or a basic systems programming experience
3. CS 124 and/or a basic algorithms experience

We hope to have a diverse class and assume few students will have full exposure to the full breadth of topics we will cover. As such, we intend to provide some background on all of the topics. That said, students may find it helpful if they also have some background in some of the algorithms employed in autonomous systems from classes such as CS 181/182 or AM 121. Please contact the instructor or teaching fellow if you are interested in taking the course but are unsure about whether the background you have is suitable.

Topics

The course will cover a range of topics that include but are not limited to the following:

- System design, architecture and implementation for autonomous machines/systems (simulators, physics engines, robot model, hardware, etc.)
- Runtime systems for multi-agent intelligence, and power and performance efficiency
- Algorithms for decision making (machine learning, optimization, etc.)

The course will require students to read a variety of different papers from top conferences. A detailed list of potential papers can be found at the end of this document.

Grade Formula

- Paper Reviews – 20%
 - Students will be expected to read the assigned papers before each class and submit a short response highlighting the key positives/negatives in the papers both in terms of content and writing style
- Paper Presentation – 20%
 - Students will each be expected to present at least one paper (chosen from the provided list) to the class and lead the class through an in-class discussion
- Class Participation – 10%
 - Students will be expected to attend class and participate in discussions about the assigned paper for that class
- Project (including final project presentation) – 50%
 - Students will undertake an in-depth course project on a topic of their choosing. The project will introduce students to research in the field of computer architecture and robotics. Project proposals will be due about midway through the class and regular meetings with the teaching staff will help refine the goals and milestones. Final output of the project is a presentation to the class and a project write up in the form of a research style paper.



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Diversity and Inclusion

In an ideal world, science would be objective. However, much of science is subjective and is historically built on a small subset of privileged voices. We acknowledge that it is possible that there may be both overt and covert biases in the material due to the lens with which it was written, even though the material is primarily of a scientific nature. Since integrating a diverse set of experiences is important for a more comprehensive understanding of science please contact the course staff (in person or electronically) or submit anonymous feedback if you have any suggestions to improve the quality of the course materials.

We would like to create a learning environment that supports diversity of thoughts, perspectives, and experiences, and honors your identities. If you have a name and/or set of pronouns that differ from those that appear in your official records, please let us know! If you feel like your performance in the class is being impacted by your experiences outside of class, please don't hesitate to contact us. If you prefer to speak with someone outside of the course, the SEAS Director of Diversity, Inclusion and Belonging is an excellent resource.

So that the course staff has enough time to implement accommodations, students needing academic adjustments or accommodations because of a documented disability must present their Faculty Letter from the [Accessible Education Office \(AEO\)](#) and speak with the course staff by the end of the second week of the term. All discussions will remain confidential, although the course staff may contact the AEO to discuss appropriate implementation.

Academic Integrity

This course's policy on academic honesty is best stated as "be reasonable." We recognize that interactions with classmates and others can facilitate mastery of the course's material. However, there remains a line between asking for help and submitting someone else's work.

For Paper Reviews and Paper Presentations students are permitted to ask classmates and others for conceptual help so long as that help does not reduce to another doing your work for you (e.g., writing your response or making your slides). Collaboration on the course's final project is permitted to the extent prescribed by its specification.

If in doubt as to whether some act is reasonable, do not commit it until you solicit and receive approval in writing from the course staff. Acts considered not reasonable are handled harshly. If the course refers some matter to the Administrative Board and the outcome is Admonish, Probation, Requirement to Withdraw, or Recommendation to Dismiss, the course reserves the right to impose local sanctions on top of that outcome. If you commit some act that is not reasonable but bring it to the attention of the course staff within 48 hours, the course may impose local sanctions, but the course will not refer the matter to the Administrative Board except in cases of repeated acts.



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Course Schedule

- The course schedule will be ~6 classes of Introduction/Background/Motivation (Lecture) and ~15 classes of research paper presentations.
- We will also have a simulated conference paper review session in the middle of the term and may add additional guest lectures later in the term.
- Note that the project proposal is also due in the middle of the term and the project report and presentation will be due/presented on the last day of reading period.
- The most up-to-date schedule will be posted to the course website
- A tentative schedule can be found below:

Date	Module	Class Type	Topic	Notes
Wed, Sep 4	Introduction	Lecture	Course Introduction, Overview, and Nuts and Bolts	
Mon, Sep 9	Motivation	Lecture	Intro to Robotics (Perception and Mapping)	
Wed, Sep 11		Lecture	Intro to Robotics (Planning and Control)	
Mon, Sep 16		Lecture	Intro to Domain Specific Architectures	
Wed, Sep 18	Sample Presentations	Research Paper(s)	Example Research Paper Presentations	
Mon, Sep 23	Domain Specific Accelerators	Research Paper(s)	Domain Specific Accelerators	
Wed, Sep 25		Research Paper(s)	Domain Specific Accelerators	
Mon, Sep 30	ML Motivation	Guest Lecture	Reinforcement Learning 101	Tentative
Wed, Oct 2		Guest Lecture	Deep Reinforcement Learning 101	Tentative
Mon, Oct 7		No Class	Columbus Day	
Wed, Oct 9	E2E Control	Research Paper(s)	E2E Control	
Mon, Oct 14		Research Paper(s)	E2E Control	
Wed, Oct 16		Research Paper(s)	E2E Control	
Mon, Oct 21		Research Paper(s)	E2E Control	
Wed, Oct 23	Conference Paper Review	Conference Paper Review	Simulated Conference Paper Review Meeting	
Mon, Oct 28	Perception / Mapping	Research Paper(s)	Perception / Mapping	Project Proposals Due
Wed, Oct 30		Research Paper(s)	Perception / Mapping	
Mon, Nov 4		Research Paper(s)	Perception / Mapping	
Wed, Nov 6		Research Paper(s)	Perception / Mapping	
Mon, Nov 11	Planning / Control	Research Paper(s)	Planning / Control	
Wed, Nov 13		Research Paper(s)	Planning / Control	
Mon, Nov 18		Research Paper(s)	Planning / Control	
Wed, Nov 20		Research Paper(s)	Planning / Control	
Mon, Nov 25	Final Project	No Class	Thanksgiving	
Wed, Nov 27		No Class	Thanksgiving	
Mon, Dec 2		Final Class	Wrap Up / Project Check-Ins / Office Hours in Class	
Wed, Dec 4		No Class	Reading period	
Mon, Dec 9		Project Presentations	Project presentations	Project Reports Due



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Assignment Descriptions

Paper Reviews – 20%

Purpose:

- Develop the skill of reading papers (especially those outside of one's main discipline) through practice. There is no one correct way to read a paper but [here is a helpful guide](#).
- Develop the skill of quickly taking away the big picture ideas from a paper to decide whether to invest time in reading and understanding it in detail.
- Crowdsource a best practices guide on writing papers for use in the final project

To that end students are required to:

1. Log onto the course HOTCRP and submit a "review" for all of the pre-reads and assigned papers being presented in each class **36 HOURS BEFORE THE CLASS**. These "reviews" will ask students to submit a couple of sentences on what they thought the key takeaways were from the paper and any questions/comments they have on the content AS WELL AS one thing they liked and disliked about the writing style.

Paper Presentation – 20%

Purpose:

- Develop the skill of understanding a paper in detail
- Develop the skill of presenting a (conference) paper to an audience
- Develop the skills of teaching a concept to a class
- Get feedback on presentation skills both in terms of delivery and slides

To that end students are required to:

1. Give at least one (depending on class size) [18 minute presentation](#) on one of the papers at the end of this document (organized by topic -- see schedule for dates for each topic)
 - a. ~5 minutes of setup (What is the problem? Why is it important? What are the key challenges in solving it?)
 - b. ~5 minutes of contribution (What did the author(s) do? Why was it novel?)
 - c. ~8 minutes of context (How did it compare to other work? What work did this build on? What are the relative strengths and weaknesses?)
2. The presentation should be supported by slides. Two guides for good slide design [can be found here](#) and [also here](#) (and the course staff will upload some templates to the course website). Also, [here is a guide](#) on effective presentations. Finally, international students who want additional help can contact [Sarah Emory](#) or [Pamela Pollock](#)
3. Each presentation will be followed by **10 minutes of Q&A / Discussion**
4. To help students develop their presentation, students are required to **meet with the course staff for 15 minutes one week prior** (ideally right before or after class) to their presentation to discuss their approach and the key ideas they want to get across. Ideally with ideas / outlines for slides. *The farther along the presentation is, the better the feedback the course staff can give (we do not expect finished presentations).*



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Class Participation – 10%

Purpose:

- Ensure that all students are able to end each paper presentation understanding the high level takeaways from a given paper
- To give feedback to presenters

To that end, students are required to:

1. Submit anonymous feedback on the provided forms on the presentation
2. Ask questions of the presenter both about their presentation and about things they chose not to present that they either found confusing or interesting

Final Paper – 50%

Purpose:

- Provide an opportunity for students to apply, extend, and integrate the foundational concepts learned in the course toward a topic of interest in the fields of computer architecture and/or robotics
- Practice conducting a formal (conference) research paper.
- Practice collaborating with others on research.
- Practice writing conference papers in appropriate Latex templates
- Practice getting feedback from advisers on research ideas

To that end, students are required to:

1. Work in teams of 2-3 students. Note that we expect all students to demonstrate a ~equal amount of work, so teams of 3 should be sure to tackle appropriately sized problems.
2. Submit a Project Proposal midway through the semester (**due 10/28 before class**):
 - a. A brief discussion of the problem and algorithms you intend to investigate and the system you intend to build in doing so.
 - b. Examples of expected behavior of the system or the types of problems the algorithms you investigate are intended to handle.
 - c. A list of papers or other resources you intend to use inform your project effort. This list will form the core of your project report reference list. If your project includes anything unusual (such as having significant systems demands), please state this as well.
3. Submit a 6-8 page two column Project Report in Latex (**due 12/9 by midnight**). The course staff suggests using the [overleaf online editor](#) which is free when students sign up with a Harvard email and the course staff will provide the required Latex template for the project. Your paper should contain (at a minimum): an abstract, introduction, related work, algorithm/system description, experiments, conclusion, and references. Strong papers will have descriptive figures that reveal good experiment design and execution.
4. Present their project in a simulated conference environment (**12/9 in class -- last day of reading period**). That is, teams are given **12 minutes** (subject to change based on class size) to present their paper in the style of the paper presentations.