EECS 507: Introduction to Embedded Systems Research
Course Goals, Organization, and Logistics

Robert Dick

University of Michigan

Outline

Embedded system definition

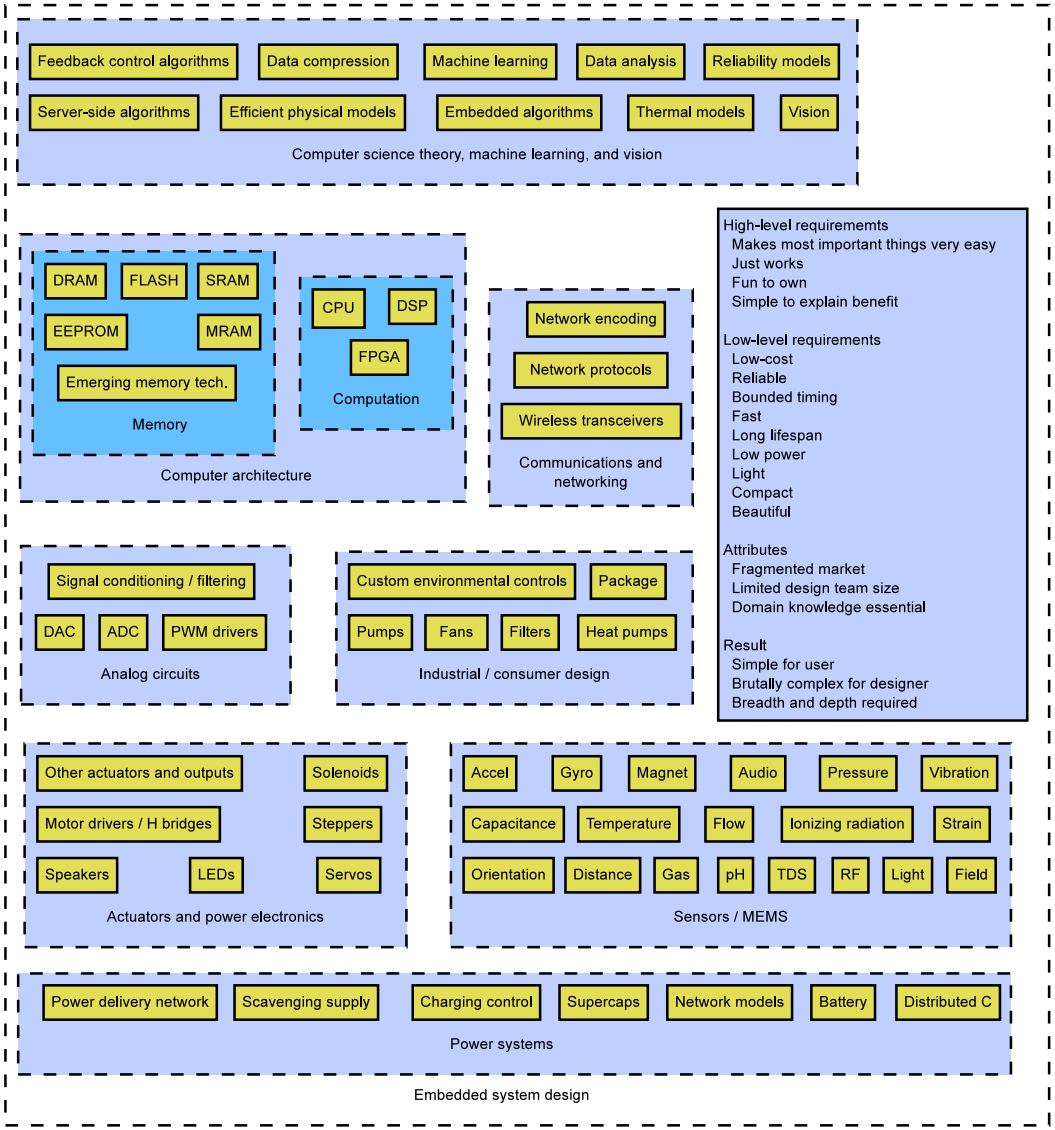
An (application-specific) computer
within something else
that is not generally regarded
as a computer.

Significance: if it's working as intended, it may be unnoticed.

Common embedded system requirements

- **Mobile:** limits PCB and power supply size.
- **Wireless:** power and reliability implications.
- **Reliable:** consider cars.
- **First time correct:** field repairs difficult.
- **Rapidly implemented:** IP reuse, automation, corner cutting.
- **Low price:** competition between many companies.
- **High-performance:** massively parallel, using ASICs.
- **Low power:** battery life and cooling costs.
- **Secure:** complicates design analysis.
- **Integrated w. physical world:** noise / security / control / other implications.
- **Hard real-time:** deadlines must not be violated.

Embedded system structure



Embedded systems market

- Dominates general-purpose computing market in volume.
- Projected to be ∼$120-billion/year in 2025, 7% CAGR.
- Desktop computing market is ∼$3-billion/year, -1% CAGR.
- High-performance computing market is ∼$40-billion/year, 7% CAGR.
- Car example: over half of value from embedded systems, zero a few decades ago.

Waves in computing

- ∼1980: personal computers.
- ∼1995: the internet.
- ∼2010: smartphones.

What now, and next?

- Wearables.
- Internet-of-Things.
- New forms of communication.
- Ambient intelligence.
- Others?
- When?

Prediction

Law of Toys

Every new class of computer systems will initially be seen as a toy by most.

As it becomes socially and commercially important, nearly everybody will act as if it was always obvious . . .

. . . even those who claimed it would always be a toy.

Advice

If logic dictates change, ignore the naysayers.

However, measure customer demand.

Embedded systems market fragmentation

- Application-specific.
- Divergent hardware and software.
- Limited market size for each class.
- Many small–moderate size companies.
- Limited engineering staff.

Implication

Embedded systems engineers must have deep knowledge of many levels of the design process.

Course goals

My goals

1. Prepare you for independent research on embedded systems.
2. Understanding of the history and current state of embedded systems research and practice.
3. Familiarity with embedded system commercialization.

What are your goals?

Examples

Distinguish between objectives and design.

Understand design as an optimization problem.

Estimate energy and thermal characteristics of an embedded system.

Understand energy consumption, performance, and reliability characteristics of many wireless communication standards.

Explain the architectural and algorithmic implications of focusing on particular embedded domains, e.g., automotive, wearable, or mobile.

Identify main security vulnerabilities of a given embedded architecture.

Implement several algorithms appropriate for ultra low power machine learning on resource-constrained platforms.

Etc.

Course structure (mainly for undergraduates)

Most undergraduate courses	**This course**
Highly structured	Less structured, topics change based on student interest
Material on which all agree	New and therefore contentious material
Everything important in a book	Substantial material based on personal experience and research papers
Closed-ended labs/project	Open-ended project
Structure prods students to do what is required	Students must be responsible and interested for the course to succeed

Main expectations

Time per week

- 10–15 hours/week for those without projects.
- 20–30 hours/week for those with projects.

Behave honorably.

Do the assignments.

Actively participate in the search for good ideas during paper discussions.

For project version: develop and evaluate a novel idea related to embedded systems.

This course is optional

- Relatively unstructured.
- A lot of reading, and the papers may not be written in a style that makes your life easy.
- Read/understand the papers you don't present.
- Give several presentations.
- Projects will take time, more time than one credit would suggest.
- Nobody requires this course to graduate.
- If it looks interesting and worth the effort and chaos, welcome!
- If it looks too burdensome or unstructured, drop it.

Commitment

Will do my best to

- structure the course to help you toward the goals,
- revise structure based on my observations and your feedback,
- treat you fairly, and
- share my experience.

Your teacher: Robert Dick

History

- Brief CE Bachelor's degree while working as an electronics technician and television station business manager.
- Graduate studies at Princeton University.
- Visiting Researcher at NEC Labs, America; technology went into their smartphones.
- Mandarin course at Peking Normal University.
- Visiting Professor at Tsinghua University.
- Professor at Northwestern University.
- Founding CEO of direct-to-consumer Stryd athletic wearable electronics company.
- Professor at University of Michigan.
- $>$100 research papers on embedded system design and machine learning cited 12,000 times. Several patents.

Interaction style

"You are a good professor and I like you, but you're scary."

— Project advisee at graduation, after requesting a photo with me.

Something about my demeanor (serious, high-energy, very blunt) makes some students uncomfortable approaching me.

... but I do my best to help students

Come to office hours if you want to talk about the class, embedded systems related career, entrepreneurship, etc.

$$\text{Serious} + \text{blunt} \neq \text{annoyed} + \text{grumpy}.$$

Everybody schedules 20-minute meetings with me, in groups of four.

- I'll ask you about your goals for the course and career, and about your background.
- Ask me anything.
- I'll make in-person and Zoom slots available.
- These aren't supposed to be project teams. They are just to make the schedule manageable and encourage discussion.

Outline

Justification for course structure

Your participation and attention are essential to the success of the course.

Consider paper discussion and project presentations.

Lectures

Your attendance is required.

Email me if you need to miss due to illness or travel.

Tell me before class if you need to leave early due to an unavoidable conflict.

There will be a few guest lectures by experts on particular topics.

Initially, lectures will take the entire class period.

Later, much of the class period will be spent on research paper presentation and discussion.

Exams and quizzes

Midterm exam.

Final exam

Cumulative but focusing on material after midterm.

Some quizzes may be delivered

- Accounting for at most 15% of the exam portion of the course grade.
- Primary purpose: determine your current state of understanding so I can best allocate lecture and reading assignment time.

Reading

One research paper per class on average.

Paper summaries

- Summarize each paper using the template provided.
- TA and I grade a random subset.
- Other students also provide feedback, but not grades.

Paper summary critiques

- Critique randomly assigned summaries by other students.
- I will spot check these critiques and may penalize poor ones.
- Based on past experience, students almost always do well on these.
- They are surprisingly quick to complete, and often help fill in gaps in understanding.

Paper presentations

- Starts in in mid-September.
- You will be notified at least a week in advance.
- You will need to read the paper in detail and prepare slides.
- Summarize the paper briefly and indicate promising applications, areas of discussion, and connections with other work and concepts.
- You will have at least a week's notice of assigned presentation requirements.
- Others are expected to read the paper in full and come with questions and observations.
- I will also ask questions, and comment/summarize if necessary.

Projects

Required for four-credit version of course.

Extensions of research ideas introduced in the course or novel ideas.

Generally, theory or design concepts validated via prototypes.

Quality sufficient for a research conference publication.

Report should be at a level enabling submission to a conference if another 100 hours were spent on improved evaluation and revision.

Team or individual work are both permitted.

Project presentations

- Teams will present their projects to the entire class.
- The class provides feedback.

Competition and collaboration

Number of high and low grades depends on cohort performance. I use prior cohorts as reference points.

Don't hold back on hard questions of other students or me.

"I don't know but will follow up via Piazza" is a perfectly legitimate response...

...unless it is on a very basic concept from the paper you are leading.

Website

https://robertdick.org/iesr/.

Simple hand-written website to manage course handouts and assignments.

Grades will be shared through Canvas.

Piazza

- For administrative notification and discussion.
- Required: do not miss Piazza announcements.

Topics of interest thread

- Questions about embedded systems related topics that might not be related to items in the syllabus.
- May influence lectures and course topics.

Grading scheme

Without project

- Summaries of assigned reading and critiques: 35%
- Presentation and questions: 35%
- Exams and quizzes: 30%

With project

- Summaries of assigned reading and critiques: 30%
- Presentation and questions: 30%
- Exams: 20%
- Project: 20%

Outline

Homework

All due 28 Aug.

Estimated total time: <30 minutes.

Look at every link in the website menu. More will appear during the course.

Download and review the slides from the first lecture.

Make a post on Piazza under "topics" indicating your main areas of interest related to embedded systems.

Select a time for your meeting with me.

https://docs.google.com/spreadsheets/d/1OY6CPy3E3zjhSyf3oGoS9cTanZ9TILH0n7rJoyRdjG8.