EE 193 / BME 193 / ME 193 Embedded Medical Devices
Fall 2023

Class meeting time: Tue/Thu 1:30-2:45
Instructor: Joel Grodstein. Office hours: by appointment.
Teaching assistant: TBD.

What is an embedded medical device, anyway?

Like many terms, this one does not have a precise definition. But here's how we meant when we named this course, at least 😉.

The term "embedded" usually refers to things that live inside of other things. So, for example, a pacemaker could be an embedded medical device because it lives inside of a human body. I.e., it's implanted surgically. By this token, though, not only is a pacemaker an embedded medical device, but so are the screws that a surgeon might use to hold bones together – and that's not what this course covers.

Not all embedded devices live inside of the human body. For example, the term "embedded computing" typically refers to a device that, while not perceived as a computer per se, depends for its functionality on substantial computation inside of it. By that token, the pacemaker is an embedded medical device for a second reason as well – it has substantial processing power inside, but we think of it as a cardiac device and not as a computer.

For the purposes of this course, "embedded medical device" will mean a device, used for medical purposes, that has substantial computing power in it. We'll focus on small devices, so think pacemakers and prosthetics rather than an MRI machine.

Why this course?

Engineering as a whole is becoming more interdisciplinary, and embedded medical devices are no exception. If this trend continues (and we expect it to), then the choice we face is to embrace it and learn to live in a multidisciplinary world or to fall behind.

Most students, though, live largely within the courses that their own department offers. After their basic introductory courses, they may not take a lot of courses with students from other departments. Working in the area of embedded medical devices, however, typically requires being part of an interdisciplinary team. You may need hardware and software skills to design the innards of the machine, as well as biomedical skills to design the sensors and understand the big picture of what the device is meant to accomplish. And understanding the algorithms often requires specific medical expertise.

Furthermore, depending on the particular device, mechanical expertise can be quite useful. Neural prosthetics, for example, are essentially mechanical devices.

***Course Objectives*:**

Upon completion of the course, students will be familiar with:

1. The basics of embedded systems; hardware and software

2. The basics of real-time software; how do you write software that has to respond in a specific amount of time.
3. Analyzing an ECG: filtering to remove background noise, and processing to recover the heart rate.
4. The pros and cons of various embedded-device environments (Arduino, Raspberry Pi, bare metal, FreeRTOS).
5. Special considerations for medical devices: safety and reliability.

What we will cover

- *The basics of embedded-system hardware and software*. What is an embedded system? How do we deal with no keyboard or screen or hard drive? What are the types of memory that an embedded system can use? What is a bare-metal system, a Linux system, and a real-time operating system, and when would we use each one?
- *Threading*. How do embedded systems use threads to seemingly do multiple things at the same time? Cooperative threading, preemptive threading, round-robin scheduling.
- *Filtering*. When would we use analog vs. digital filtering? Basics of digital-signal processing for embedded systems.
- *Applications*. Processing of ECG signals.

Lab work

- Build small real-time systems to prep us for the real thing.
- Build small systems with FreeRTOS.
- Build a basic ECG monitoring system.
- Potentially work with sEMG signals also.

Workload

- We will have roughly six labs. Each group should hand in only one official lab report.
- There is a final project (with presentations during the final-exam slot). There is no midterm or final exam.

Grading

The course grade will be computed roughly as follows:

- labs = 80% of the total grade
- final project = 20%

Late Assignments:

Late assignments will be penalized by 10% per day. Any extensions due to extenuating circumstances (illness or family emergencies) must be arranged ahead of time with the instructor before the original due date.

Prerequisites

- This is an intentionally interdisciplinary course, covering parts of biology, computing, electrical engineering and programming. It is expected that very few people will enter the course being competent in all of these areas, and we thus are not being strict about prerequisites. Obviously, the more areas you have to learn, the more work you will have. With that in mind…
- The labs will expose you to a fair amount of programming, especially real-time programming. We will use C, since it is by far the most common language used in the industry. Our code will not be complex; CS 11 or the equivalent is more than enough, and really all you need is the basics of C. On the other hand, neither CS 11 nor most CS courses at Tufts really prep you for

multi-threaded real-time programs, which is what many medical devices are. So you will hopefully learn a lot 😊.

- We will work with digital signal processing. Some background on working in the frequency domain (e.g., EE 20, BME 10 or ME 30) would be useful.

ABET

This course may help fulfill ABET objectives as follows:

1. *an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics*. Our labs do this. Especially, the final labs use a combination of software, hardware, DSP (which involves math) and algorithms.
2. *an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors*. Our guest lecturer will talk about medical-regulatory issues, which addresses public health and safety (but that's just one lecture). And certainly we talk about usefulness of medical devices, but the emphasis of the course is less on that and more on embedded engineering.
3. *an ability to communicate effectively with a range of audiences*. Not a lot.
4. *an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts*. Not a lot.
5. *an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives*. Essentially all of your work in this course will be as part of a roughly-three-person team.
6. *an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions*. You'll be doing lots of debugging for this course – which will require you to do all the above.
7. *an ability to acquire and apply new knowledge as needed, using appropriate learning strategies*. In your final project (if we do one), you'll be gathering lots of information yourselves. Otherwise, your path is fairly charted out for you.

Additional resources

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