HEB 1306

Wearable sensors: measuring activity, health, and performance

Fall 2023

When Wednesdays, 9:45 AM - 11:45 AM

Where MCZ 529, DeVore Conference Room

Instructor Ali Yawar : `aliyawar@g.harvard.edu`

Office hours Tuesdays 2-3 PM, over Zoom
https://harvard.zoom.us/j/93744078183?pwd=MFppMGJxZEZOdGxBeWRSS2tkdkZTdz09

Course summary and objectives

From heart rate and step count to blood glucose and oxygen saturation, we measure our health and activity metrics today with unprecedented resolution and accuracy. Given their massive potential to inform lifestyle choices, as responsible scholars we will ask: How do these sensors work, and what are the limitations to their use? This course is designed to introduce you to the field of wearable electronic sensors that have gained immense popularity in the last decade (think FitBits, Apple Watches). You will learn the operating principles of a range of biological sensors, how to build and debug simple electronic circuits, and how to implement them to collect data for your own experiments. The contents of this course should be specially relevant to anyone interested in experimental human biology research or device design and evaluation, both in the academic setting and in industry.

We will begin by learning experimental techniques that are broadly applicable to most biological experiments, and to wearable sensors in particular. In the first half of the semester, we will learn the basics of data acquisition (sampling, filtering, fourier transforms), fundamentals of electronic circuit design (Ohm's law, Kirchhoff's laws, prototyping), and the physical and biological operating principles of sensors that measure heart rate, ECG, body movements, temperature among others. Towards the second half of the semester, we will learn how to use the open-source Arduino programming platform. We will learn to write simple programs on the Arduino to record sensor data and generate human readable feedback based on these measurements. No prior programming experience is necessary. We will apply the principles learned up to this point in the semester towards designing a simple body mounted device using the Arduino. The goal of this device will be to measure locomotion metrics like step count and activity type. All necessary electronic equipment and supplies will be provided.

Grading

Your grade will be based on 6 equally weighted problem sets handed out through the semester approximately once every two weeks. Problem sets will cover simple mathematical analyses of bio sensors and circuits, followed by hands-on implementation of simple circuits on the Arduino platform in small bite-sized pieces in order to accomplish the final task of building a step counting device. **Each homework will contain several advanced "starred" questions which are required for graduate students to receive full credit.** Undergraduate students may attempt these questions for intellectual stimulation, but **not for extra credit**. There will be no final project or final exam.

Prerequisites

There are no prerequisites for this course.

Textbooks and other resources

While not required, these textbooks serve as good references when debugging programs and circuits. They cover a wider range of Arduino and Electronics applications that what is covered in the course, so they can also serve as good springboards to expand into general purpose electronics.

1. Margolis, M., Jepson, B. and Weldin, N.R., 2020. *Arduino cookbook: recipes to begin, expand, and enhance your projects.* O'Reilly Media, Inc. Harvard Library access.

2. Monk, S., 2017. *Electronics Cookbook: Practical Electronic Recipes with Arduino and Raspberry Pi.* O'Reilly Media, Inc.. Harvard Library access.

Comprehensive tutorials on electronics are maintained by Adafruit and Sparkfun. The Arduino programming platform has comprehensive online documentation maintained by an active community of volunteers. The scope of Arduino based wearable devices is vast, but a small sample of devices are available here.

Collaboration

Collaboration is highly encouraged. However, each student must submit their own homework solutions and project reports. With every submission, please maintain academic intergrity by clearly citing any sources you consulted including people, books and the internet. For your reference, The Harvard College Honor Code is reproduced here:

Members of the Harvard College community commit themselves to producing academic work of integrity - that is, work that adheres to the scholarly and intellectual standards of accurate attribution of sources, appropriate collection and use of data, and transparent acknowledgement of the contribution of others to their ideas, discoveries, interpretations, and conclusions. Cheating on exams or problem sets, plagiarizing or misrepresenting the ideas or language of someone else as one's own, falsifying data, or any other instance of academic dishonesty violates the standards of our community, as well as the standards of the wider world of learning and affairs.

Lecture plan and due dates

No.	Date	Topic	Due dates
Lec 1	Sept 6	Course Introduction. Fundamentals of experimentation: Digital and analog electronic signal acquisition, sampling, signal analysis methods, Fast Fourier Transform (FFT), filtering	
Lec 2	Sept 13	Electronic circuit basics: Ohm's law, Kirchhoff's circuit laws, electronic components, prototyping, breadboards	HW1 due
Lec 3	Sept 20	Measuring heart rate: Photoplethysmography sensors	
Lec 4	Sept 27	Measuring body electricity: Biopotential Sensors for ECG, EMG, EEG	HW2 due
Lec 5	Oct 4	Measuring human movement: Gyroscopes, Accelerometers and IMUs, seismo- and gyro- cardiography.	HW3 due
Lec 6	Oct 11	Introduction to Arduino: microcontrollers, example applications, specifications, peripheral devices, setting up the Arduino IDE	
Lec 7	Oct 18	Essential hardware and software, basic functions and programming, using libraries, building an LED blinker, analog output and LED dimming	
Lec 8	Oct 25	Reading and interpreting optical signals with an LDR	HW4 due
Lec 9	Nov 1	Fundamentals of sensor input-output (I/O) with an accelerometer, analog to digital converter, timing, digital outputs	
Lec 10	Nov 8	Building an accelerometer based "spirit" level	
Lec 11	Nov 15	Plotting accelerometer data, implementing filters: moving window average, butterworth, frequency response	HW5 due
	Nov 22	**Thanksgiving Break: No Lecture**	
Lec 12	Nov 29	Step count measurement using a wrist mounted accelerometer	
	Dec 6		HW6 due