CE 186: Design of Cyber Physical Systems

LEC 00 : Course Introduction

Professor Scott Moura
GSI Eric Burger
University of California, Berkeley

Fall 2016

Why take CE 186?

Why take CE 186?

Learn to ideate, design, and prototype

cyber physical systems.

Prerequisites

- Math 1A, 1B, 53, 54
- Physics 7A, 7B
- E7 -or- CS 61A -or- CS/STAT 8
- You are comfortable with programming
- You are comfortable with circuits/breadboards
- You can learn independently
- You can work in a team

- CE 191 is not required, but it’s recommended you take it concurrently

Why to drop CE 186?

Why to drop CE 186?

- I dislike math
- I dislike programming
- I dislike hardware, and creating things with my hands
- I dislike hard sciences, e.g. physics, chemistry, thermo
- I am solely interested in policy and economics, not technology
- I am looking for a filler class, something easy with readings I can ignore
- I am taking 20+ units, am president of the basket weaving club, captain of the rugby team, and work part-time on a start-up I launched with friends from high school.
- Homework on Day 1!? Nope.

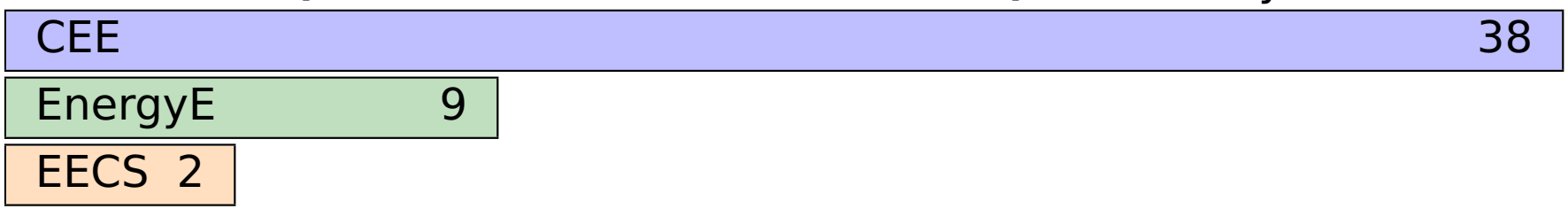
Who takes CE 186?

S14 Cohort (12 students): Mostly CEE majors

F15 Cohort (34 students): Where are they now?

- Grad student at MIT
- Grad student at Stanford
- Grad student at UC Berkeley
- Navigant
- New Sun Road
- XL Construction
- Cahill Contractors
- San Francisco PUC
- Toyota Technical Center (Ann Arbor, MI)

F16 Cohort (35 students + 15 on waitlist): Who are you?



Enrollment Priority Policy

Interest in CE186 is unprecedented...

“CE186... is already the largest of our design electives”
- CEE VCA Prof. Stacey
“I have never seen a waitlist for a design course that we could not clear”
- CEE Staff Member with ≈30 years experience

Priority categories

1. You are an undergraduate, and graduate in Fall 2016 or Spring 2017 (last chance to take CE186) [We check the degree list!]
2. You are a graduate student, and graduate in Fall 2016 or Spring 2017
3. You an undergraduate, and graduate in Fall 2017 or later (i.e. you have at least one more chance to take CE186).
4. You are a concurrent enrollment student

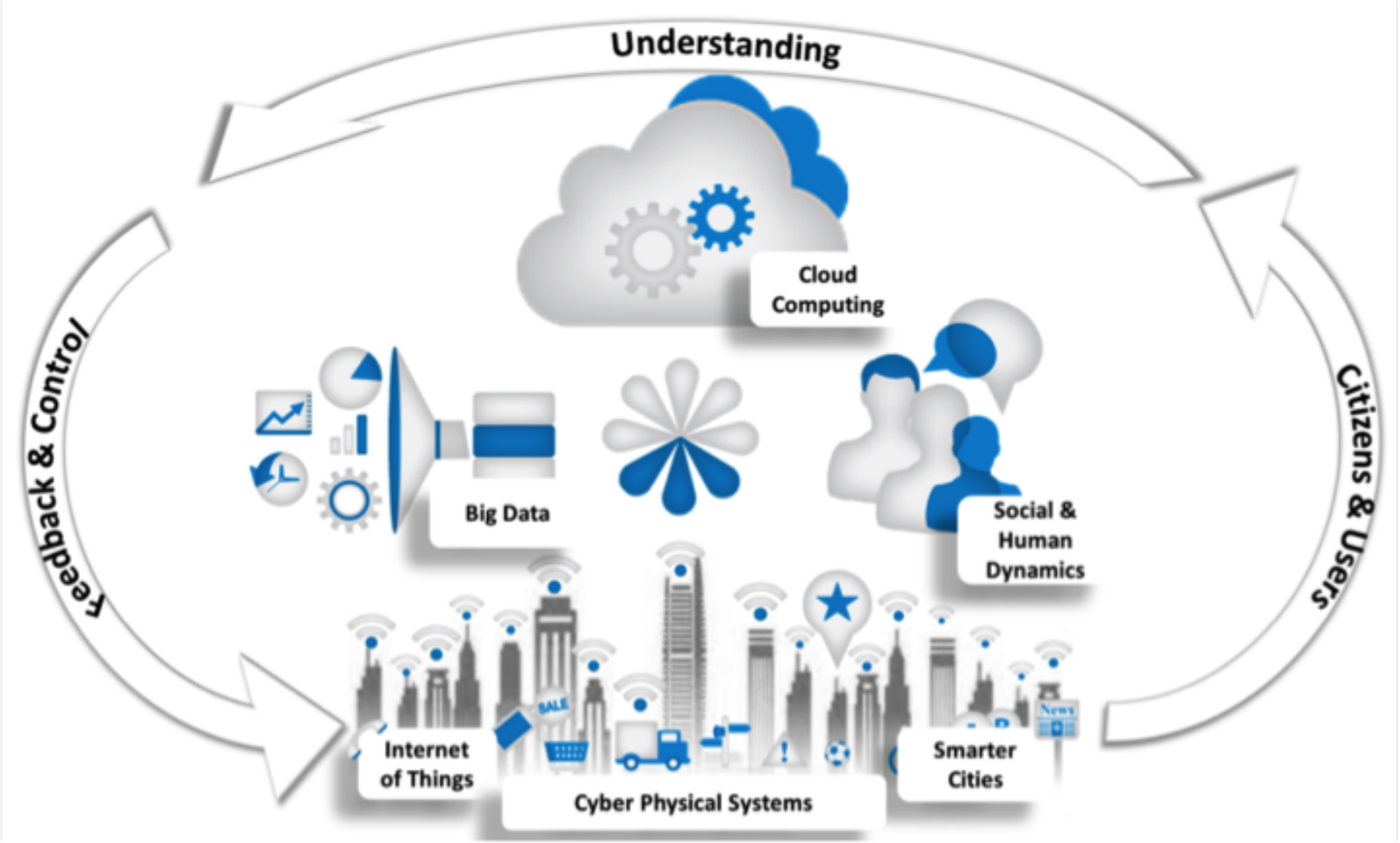
What is a Cyber Physical System (CPS)?

What is a Cyber Physical System (CPS)?

Integration of physical processes with networked computing

What is a Cyber Physical System (CPS)?

Sensing $\rightarrow$ *Understanding* $\rightarrow$ *Managing*



What is a Cyber Physical System (CPS)?

Relevant Industrial Sectors (hint: All of them!)

What is a Cyber Physical System (CPS)?

Five Elements of CPS

1. infrastructure;
2. hardware sensing/actuation;
3. data analysis;
4. connectivity;
5. visualization.

Class Format

Lectures/Workshop: MW 2-4pm, 210 Jacobs Hall

Website: `http://bcourses.berkeley.edu`

Professor Scott Moura
`smoura@berkeley.edu`
OH: M 4p-5:30p, Th 10:30a-12n
@ 625 Davis Hall

GSI Eric Burger
`ericburger@berkeley.edu`
Office Hours: Tu 4p-5p @ 220 Jacobs
& Th 2p-3p 210 Jacobs

Attendance is required to perform well!

Objectives

1. To provide students hands-on experience in prototyping cyber-physical systems. The five pillars of CE 186 are:
   1. infrastructure;
   2. hardware sensing/actuation;
   3. data analysis;
   4. connectivity;
   5. visualization.
2. To provide students with a “systems” perspective for designing, monitoring, and managing large-scale civil infrastructure.
3. To strengthen students’ programming, prototyping, and mathematical analysis skills.

Contents

This course is centered around three projects:

- Smart Energy & Environment
- Smart Mobility
- Smart Water

Laboratory assignments facilitate the essential skills for the projects:

Lab	Cyber Physical System Tool
1	Arduino Microcontroller & Communication
2	Analog vs. Digital I/O & Sensors
3	Python for Computing & Communication
4	Internet-based Services
5	Web Design & Visualization

Textbooks

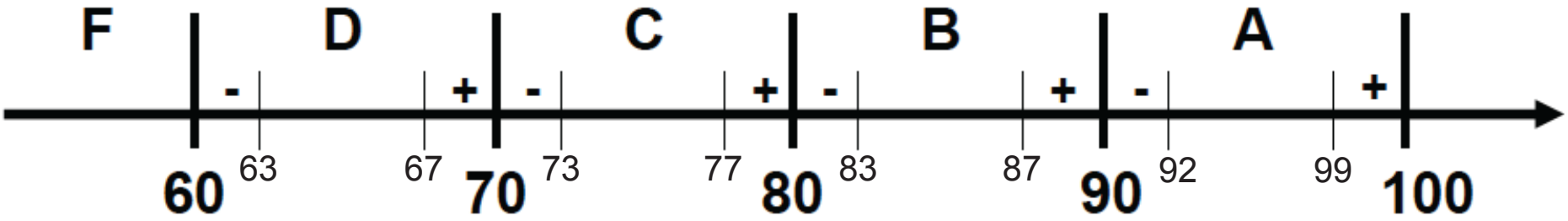
there is none

No textbooks are required. Required and supplemental reading materials have been collected specifically for CE 186, and will be distributed throughout the semester via bCourses.

Lecture format:

- 1 hour lecture with slides, 1 hour workshop
- Slides will be available online
- Supplemental reading materials will be available online

Grading



Labs	40pts	Five assignments (8pts each)
Training	4 pts	Jacobs Hall General Workshop Safety (2 pts); Complete one Specialized Equipment Training e.g. Type A 3D printer, Laser cutter, Electronics Lab (2 pts)
Project	56pts	Declaration (1pt); Proposal (8pts); Four In-class oral updates (4pts each); Symposium (10pts) Final Report (20pt); Self/Team Evaluation (1pt)

A total of 100pts are possible.

Lab assignments, the project declaration, proposal, final report, and self/team eval will be submitted via bCourses, with Friday 5pm PT deadlines.

Philosophy: Consistency and transparency

Q: *What letter grade is 89.9%?*

Projects - I

Students will engage in four member, semester-long course projects. The philosophy is to stimulate students' individual creativity and interests in cyber physical systems, grounded in the five CE 186 pillars. Teams may select amongst three projects:

- **Smart Energy & Environment:** Students will monitor and/or control an environment, e.g. Tiny House (THIMBY), a refrigerator, desk space, or snake terrarium! You are provided a wireless radio (ZigBee), and various environmental sensors, e.g. temperature, humidity, CO_2, photodetector.
- **Smart Mobility:** Students have access to a 1000W electric scooter, mountain bike + e-wheel, e-bike computer, Arduino microcontroller, and a power supply relay. They should use a mapping service.
- **Smart Water:** Students use Arduino microcontrollers, soil moisture sensors, temperature sensors, water flow meters, and pumps.

Q: *I have my own project idea. Can I do a one-person project?*
Q: *We want to make a system that mutes the TV whenever "Kim Kardashian" is mentioned. Is that OK?*

Projects - II

Each team is required to complete:

- a declaration statement, indicating the team members and project topic (1 sentence on bCourses)
- a project proposal (2 pgs max on bCourses)
- four in-class oral updates to the course instructors (see schedule)
- a poster/demo presentation in the Jacobs Winter Showcase
- a final report (8 pgs max, double column IEEE format on bCourses)
- a self and team evaluation (on bCourses)

Software - I

This course will use a variety of software and programming languages. All software is FREE and previous experience is NOT required. We teach the essentials, and all software is EASY to learn. Part of your education is to learn HOW to learn, and not get intimidated.

Arduino: The Integrated Development Environmental (IDE) Software and documentation is available at https://www.arduino.cc/en/Main/Software

Python: This course utilizes the Python programming language. Matlab users will find Python easy to learn. The following specific packages are utilized

- Python 2.7 | https://www.python.org/downloads/
- Anaconda scientific computing package w/ Spyder IDE | https://store.continuum.io/cshop/anaconda/

Q: *I am rusty with programming. Will you provide me materials to refresh?*

Software - II

Web Design: This course involves some web design, including HTML/CSS. Depending on the project, students may also use WAMP, PHP, Javascript, MySQL, or D3.js. There are literally thousands of decent, free HTML editors. Recommended editors include Notepad++, Brackets, Atom, Netbeans.

Computer Access: Students must bring a personal laptop with USB & AirBears2 access to class.

Hardware

All necessary hardware will be available to students in Jacobs Hall, e.g.

- Arduino Uno microcontrollers
- various sensors/actuators
- tools, cables, power supplies, etc.

Nominally, no hardware may leave Jacobs Hall with two exceptions.

1. Arduino “inventor kits” will be checked-out to students to take home for laboratory assignments.
2. Expensive equipment (e.g. eScooters & CO_2 sensors) will be checked-out to students for their projects.

For each checked-out item that is NOT returned/replaced, a grade penalty of 5 pts will be applied to the lab assignment category.

Students are welcome and encouraged to purchase their own hardware (e.g. Arduino Unos) and tools (e.g. wire strippers, screwdrivers, cutters), for the course. This is not required, however.

Jacobs Institute Facilities

Go to: http://jacobsinstitute.berkeley.edu/our-space/labs-and-equipment/

Most popular equipment for CE186:

- Laser cutter
- Type A 3D printer
- Electronics Lab

Materials Store: https://store.jacobshall.org/
Tab accumulates over the semester. Pay at end of semester.

Jacobs Institute Equipment & Safety Training

Go to: https://bcourses.berkeley.edu/courses/1353091

- **Required:** General Workshop Safety (GWS) - It is on bCourses only
- Maker Pass: Access Jacobs Hall workspace, equipment use, get support from design staff. Semester access fee is 75 USD.
- **Required:** Training on at least one specialized equipment, e.g. laser cutter, Type A 3D printers, electronics lab. On bCourses + in-person/hands-on training.

Course Sponsors

BECI
BERKELEY ENERGY & CLIMATE INSTITUTE
LBNL & UC BERKELEY

JACOBS INSTITUTE FOR DESIGN INNOVATION
COLLEGE OF ENGINEERING, UC BERKELEY

Dept. of Civil and Environmental Engineering

Professor Raja Sengupta
Professor Steve Glaser

Undergrad Justin Luke

NOTE: Comparable courses at UC Berkeley and elsewhere have a lab fee. For Fall 2016, your mandatory lab fee is 0 USD.

Policies - I

Late Submissions: One point is subtracted for each 24 hours submitted late (rounded up to nearest integer). Two free late days are allowed on any *lab* of your choice. Late submissions are not accepted after 96 hrs following a Friday due date (i.e. the following Tuesday).

Q: *Do I lose points if I submit at 5:02pm PT on Friday?*

Regrade Policy: If you feel a problem was graded incorrectly, you may submit a regrade request to Prof. Moura. This request MUST be submitted within one week of receiving the graded assignment, with a short paragraph justifying the regrade. Any regrade request is subject to a full regrade, i.e. points may be lost.

Q: *May I request a LAB1 regrade in December, before final grades are submitted?*

Extra Credit: One point of extra credit for completing the course questionnaire by Friday @ 5pm PT.

Policies - II

Planned Absences: You may request to submit assignments early or late. E-mail me your request two weeks prior to the assignment due date. Requests due to extended holidays will not be granted. Requests due to emergencies or personal reasons will be handled case-by-case.

Q: *I bought tickets for Cancun, Mexico on the Symposium date. Can I present early?*

Late Enrollment: Students require instructor permission to enroll after the first week of classes. However, given the large waitlist and limited lab/project materials, this request will almost certainly be declined.

Q: *I just learned about this class. It seems interesting. Can I enroll?*

Auditing or Satisfactory/Not-Satisfactory: Due to the nature of a group project-based class, auditing or enrolling with a satisfactory/not-satisfactory credit option is NOT permitted in CE 186.

Q: *I find this class super-interesting, but I am too busy to complete the labs and project. Can I audit?*

E-mail Correspondence: Use [CE 186] in your message subject. We typically respond within one day, however our ability to help declines as e-mail volume increases. Please be considerate and concise. Do not wait until the due-date to ask questions, otherwise they may not be answered.

How to Succeed (in a UC Berkeley Engineering Course)

- Ask questions in class
- Work with your project team
- Find online resources
- Start lab assignments early
- See instructor during OH
- See GSI during OH
- Send us an e-mail. Use `[CE 186]` in subject.

Project 1: Smart Energy & Environment

THIMBY - Tiny Home in my Backyard

Goal: Generate innovation in sustainable design and education

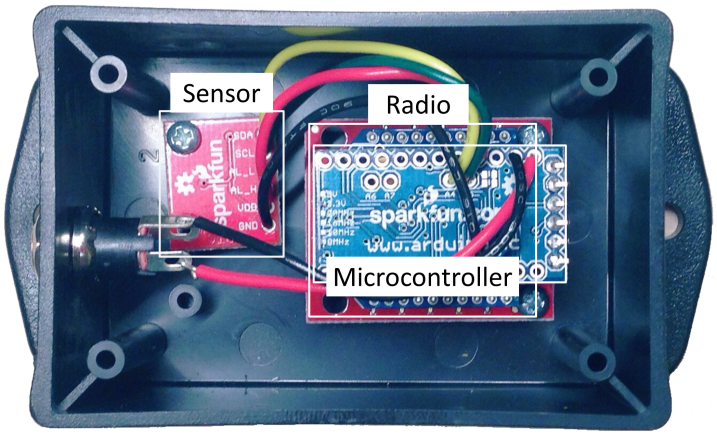
- Develop an affordable, sustainable housing option suitable for Richmond, CA residents
- Provide hands-on sustainability education to the campus and local communities
- Provide a living lab for residential sustainability and green building tech research
- Win the competition!

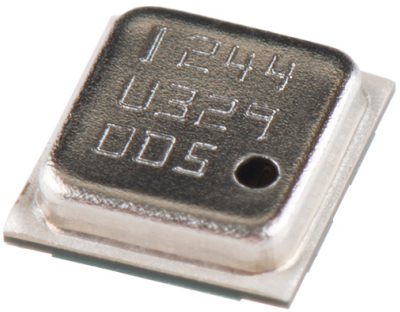
Need for Cyber-Physical Systems

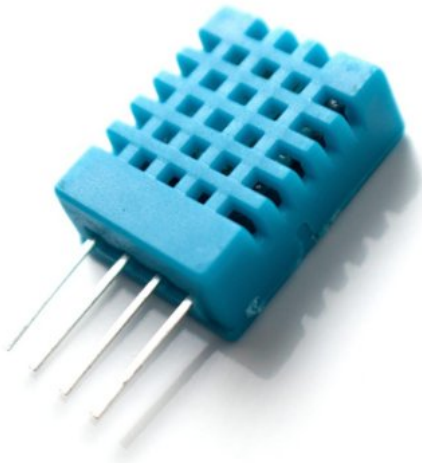
- Minimal roof-space for PV + weight restrictions limits energy production and storage
- Hot water tank + Tesla Powerwall battery allows for thermal & electric storage
- Prototype for Model Predictive Control (MPC) system to automate heat pump + radiant floor system operation already developed in CE295
- Need for further development of software + implementation in sensing and actuating hardware

Project 1: Smart Energy & Environment

Smart Personal Environment Regulator

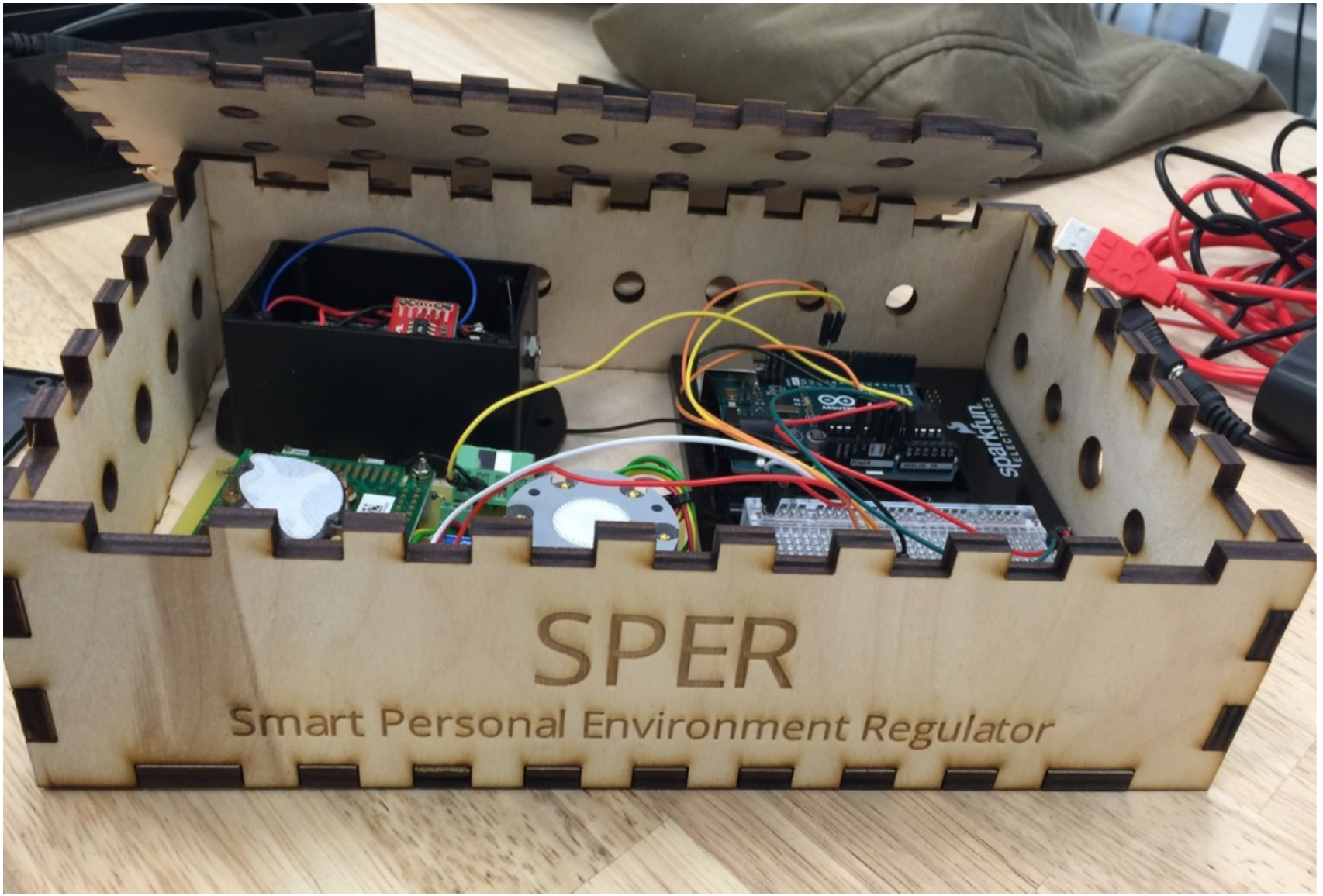






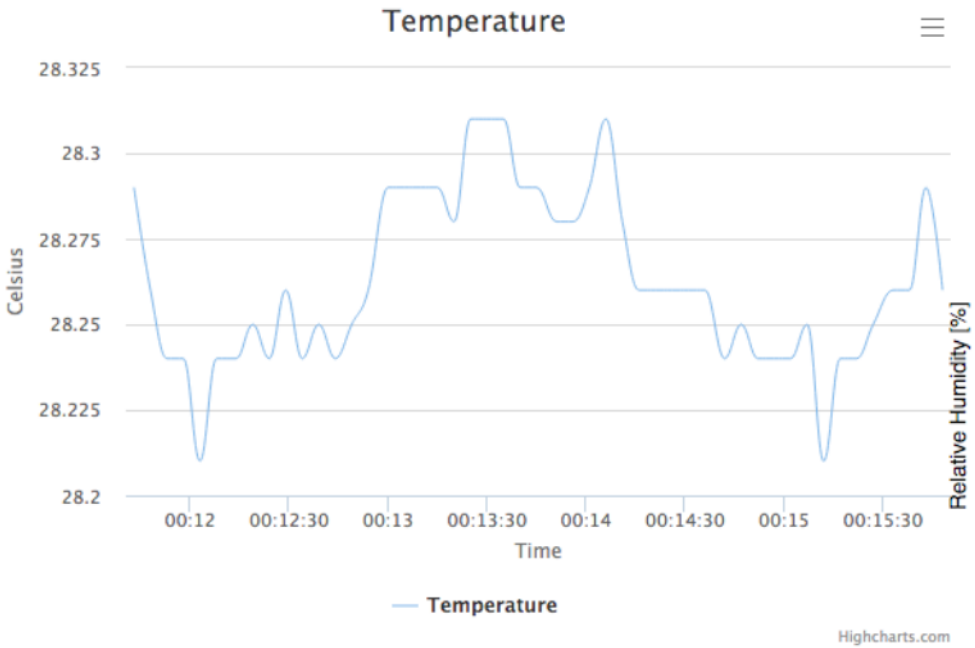
Project 1: Smart Energy & Environment

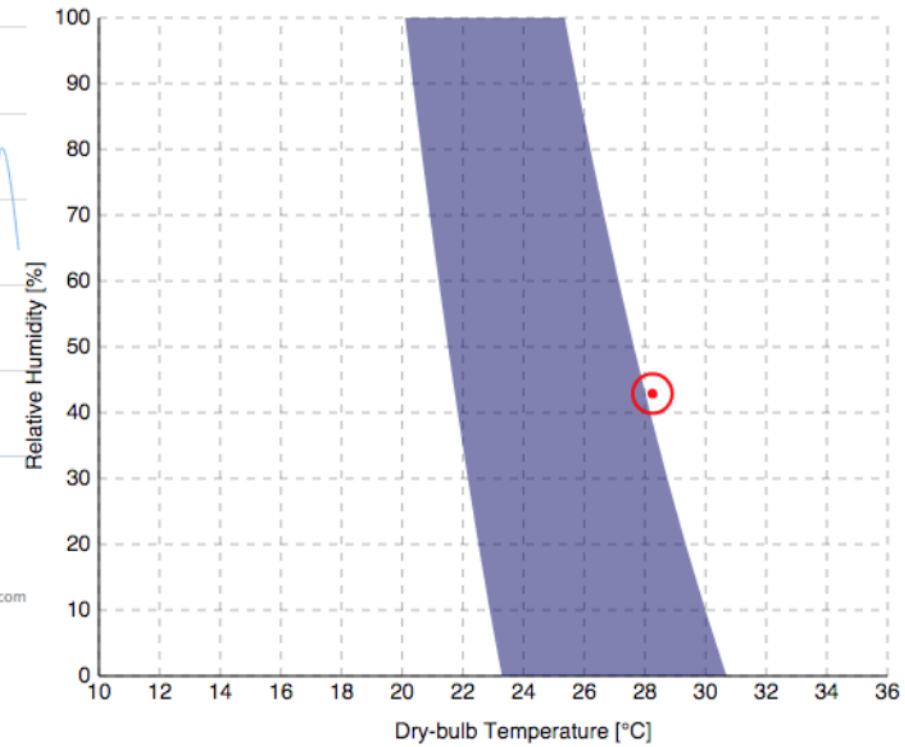
Smart Personal Environment Regulator



Live Data and Plots

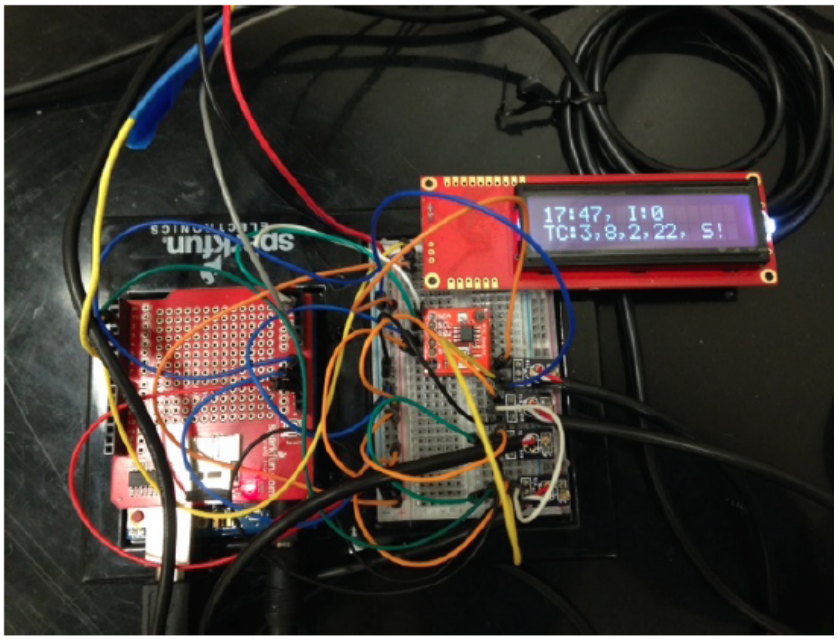
Ventilate! Please Turn the Fan Knob to Fan Mode





Project 1: Smart Energy & Environment

Smart Fridge



Project 1: Smart Energy & Environment

Smart Fridge

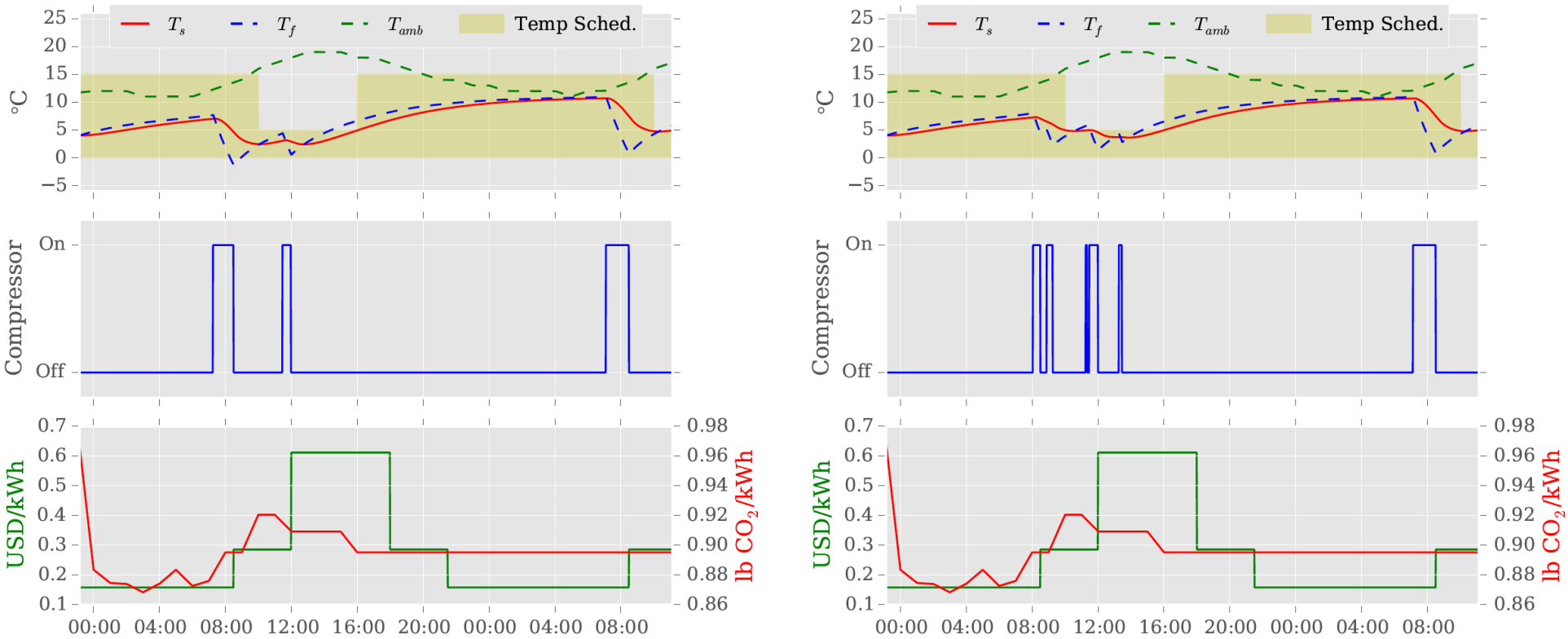


Figure 6: *Optimal Control Results: Left* $\lambda = 0.2$, *Right* $\lambda = 0.8$

Project 2: Smart Mobility

e-Bike

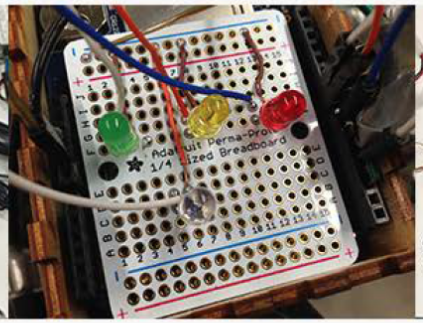
Project 2: Smart Mobility

e-Bike

HARDWARE

Battery Controller

Battery Components



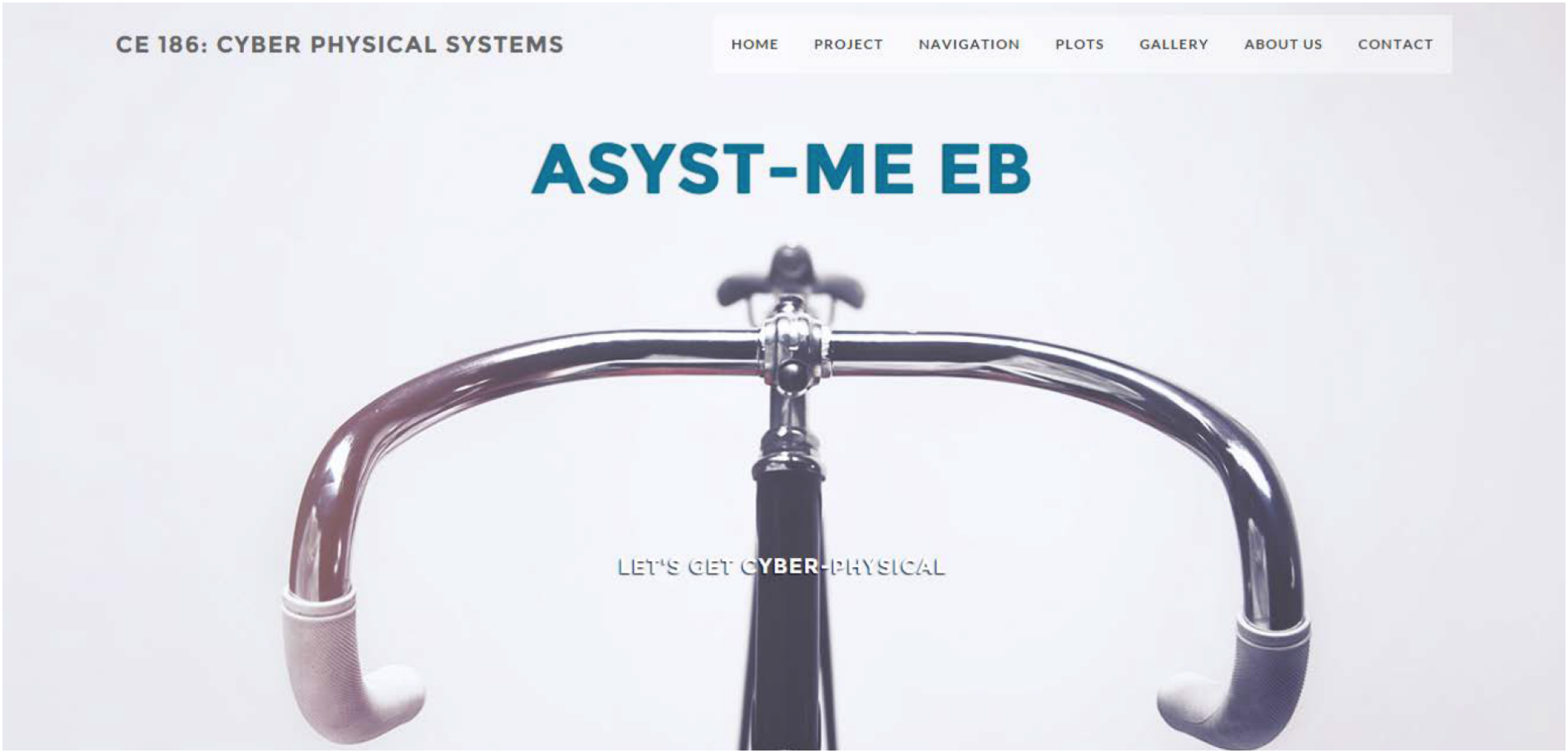
LED Actuation

Bike Components

BIKE

Project 2: Smart Mobility

e-Bike

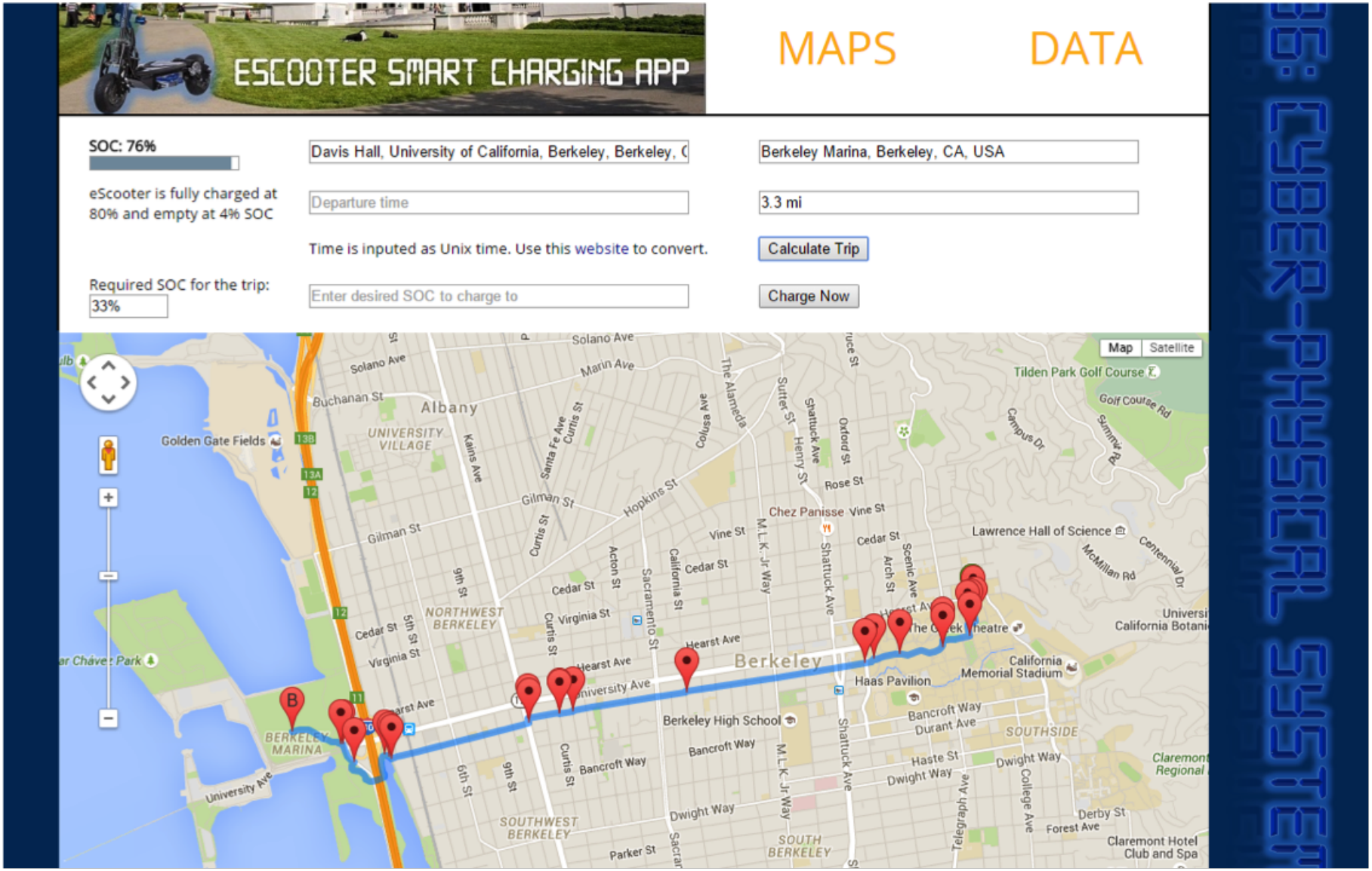


Project 2: Smart Mobility

e-Scooter

Project 2: Smart Mobility

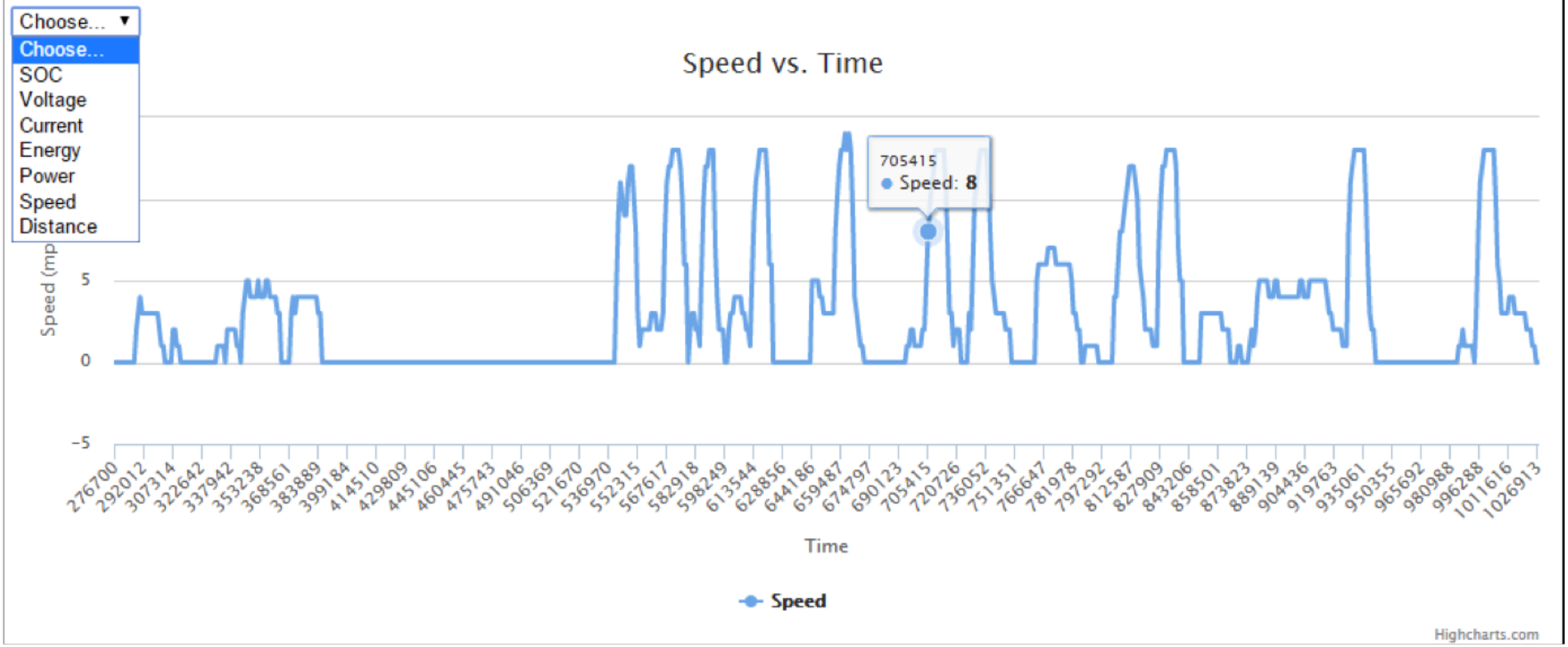
e-Scooter



Project 2: Smart Mobility

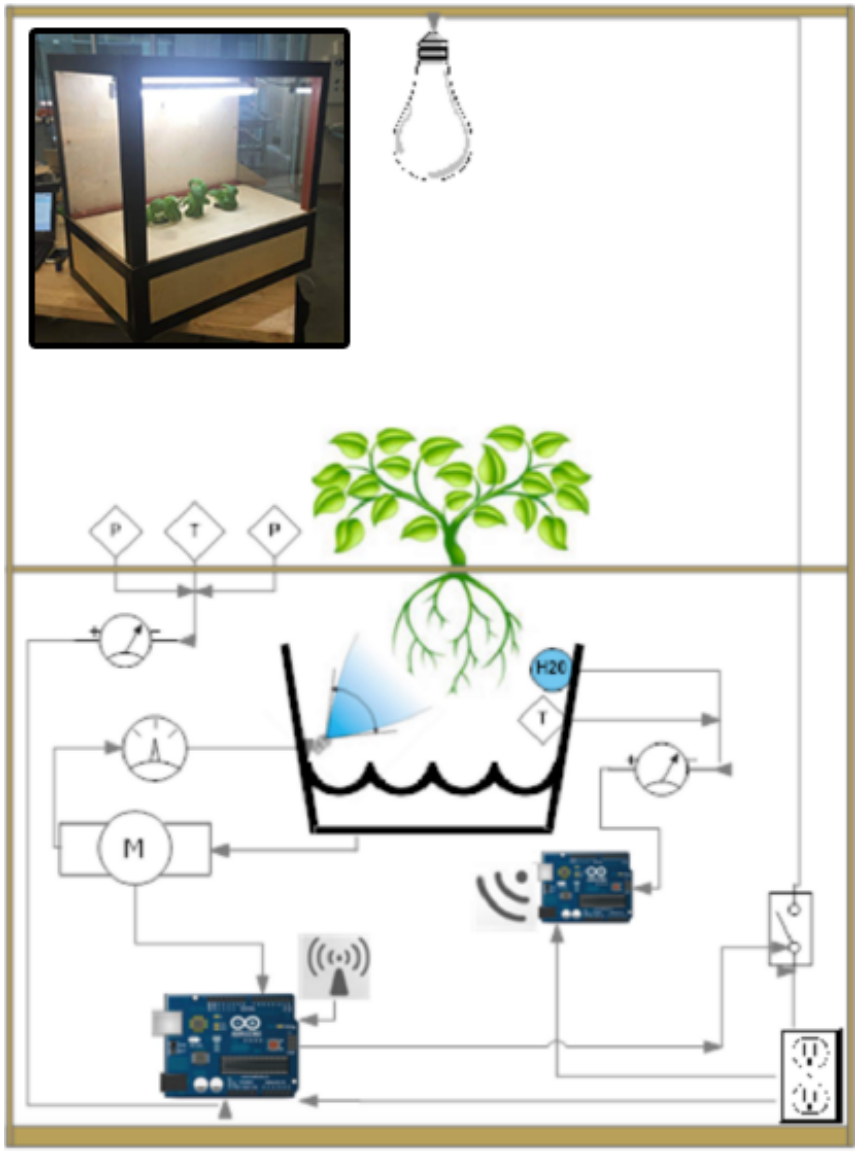
e-Scooter

MAPS DATA



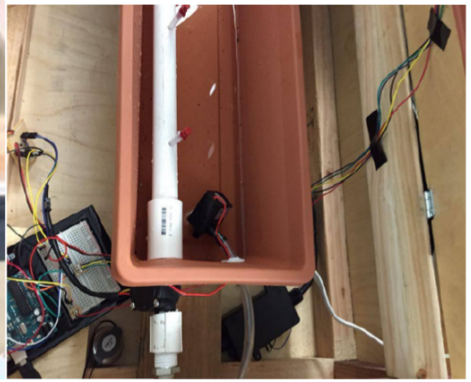
Project 3: Smart Water

Garduino



Project 3: Smart Water

Garduino



Project 3: Smart Water

Shower Thoughts

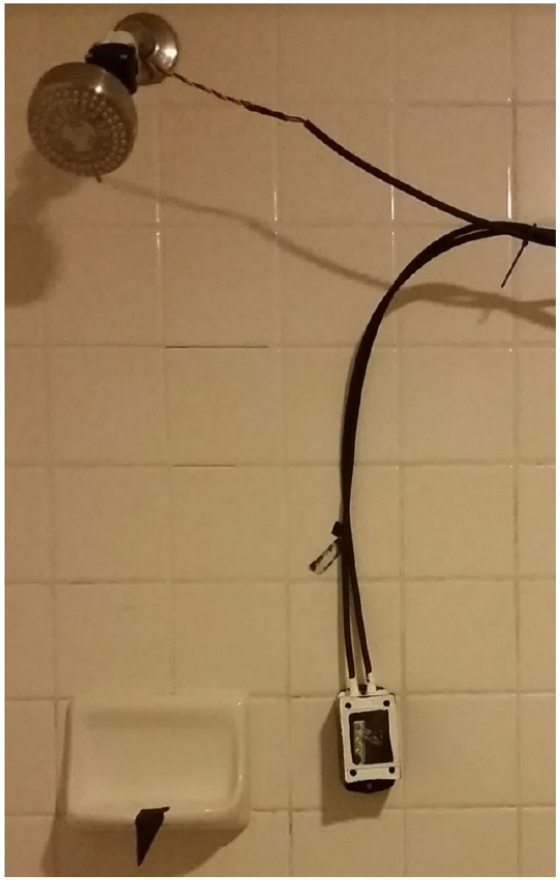


Figure 2: Flowmeter installed on showerhead

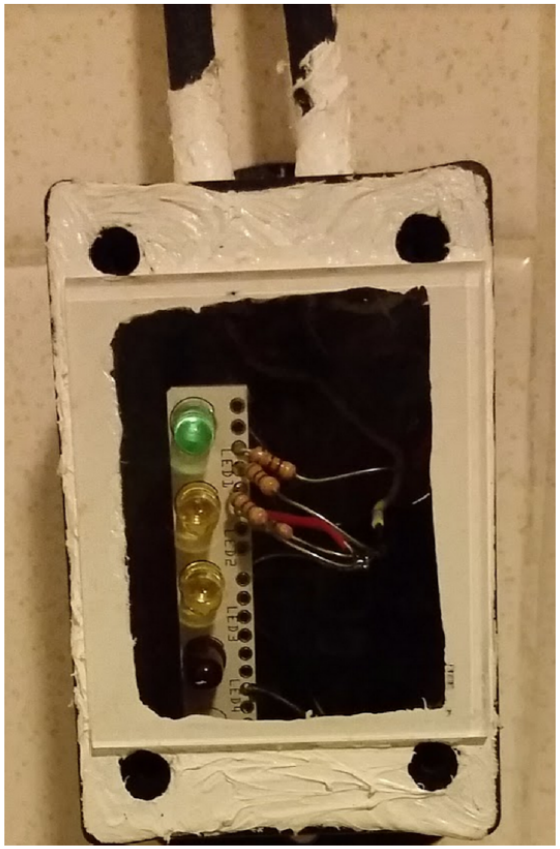


Figure 3: LED board

Figure 7: Water flow chart

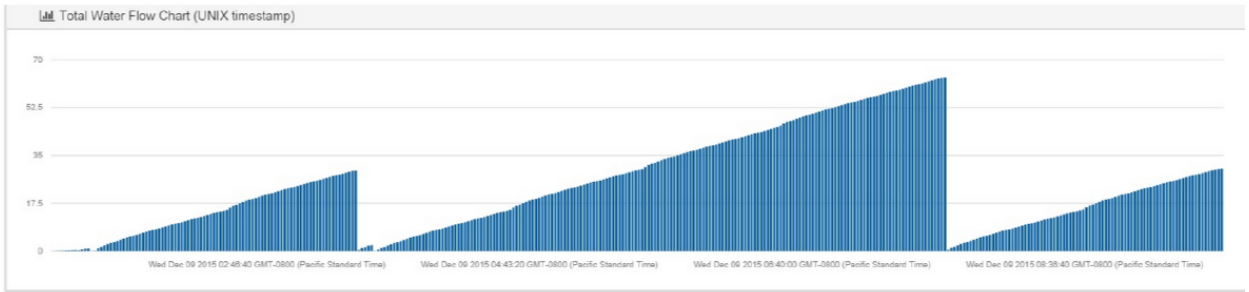
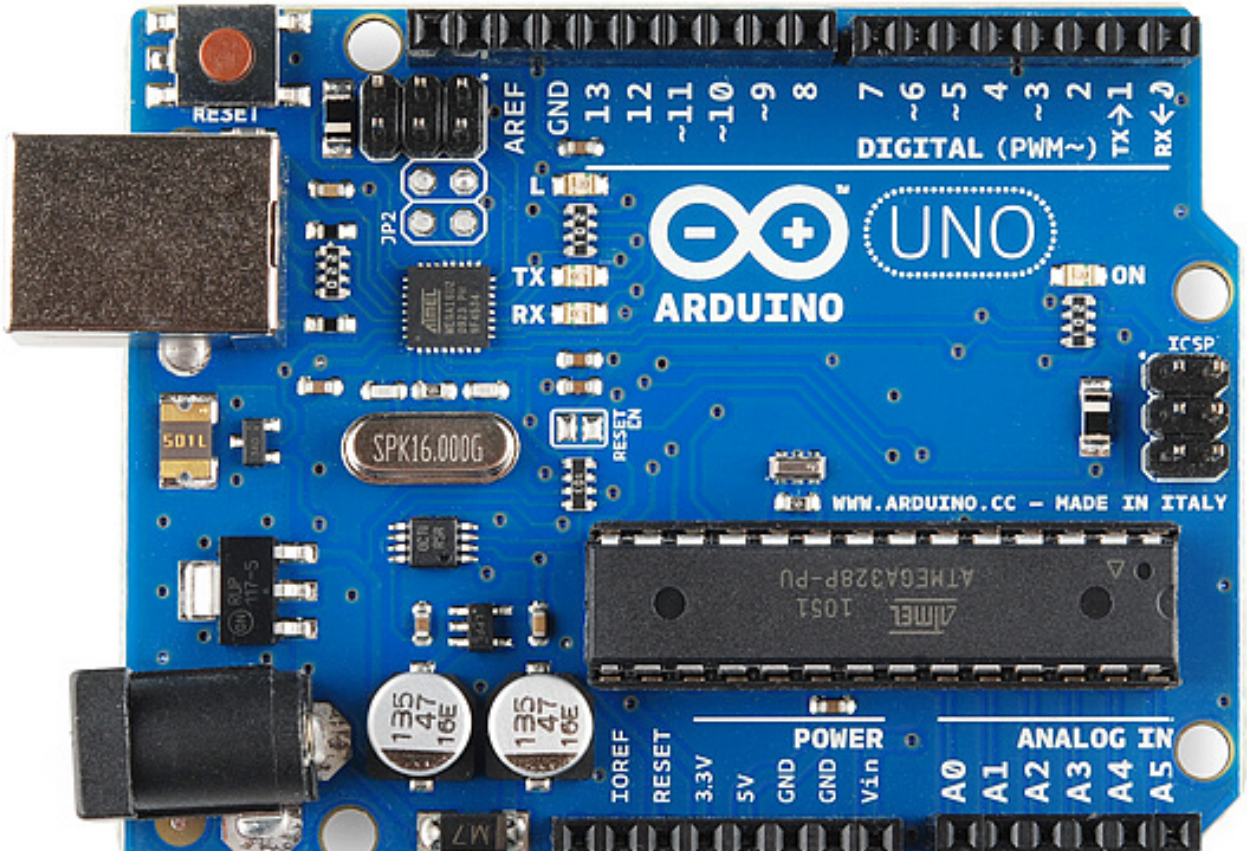


Figure 8: Total water used chart

Introduction to Arduino



Make Mag Intro: https://www.youtube.com/watch?v=CqrQmQqpHXc

Massimo Banzi TED Talk: https://www.youtube.com/watch?v=UoBUXOOdLXY

Cool! Can I buy my own to use beyond CE 186?

This is HIGHLY recommended. Some purchasing options, depending on your budget and interests:

SparkFun.com

- ($25) Arduino Uno R3 + ($7) USB cable + ($5) Breadboard + ($4) Arduino & Breadboard Holder = (≈$40) Total
- (≈$50) SparkFun Tinker Kit
- (≈$100) SparkFun Inventor's Kit - V3.2

Adafruit.com

- (≈$35) Budget Pack for Arduino
- (≈$65) Starter Pack for Arduino
- (≈$85) Adafruit ARDX - v1.3 Experimentation Kit for Arduino Uno R3

What now?

1) Complete course questionnaire (Due F Aug 26 @ 5pm PT)
https://goo.gl/forms/2wyih8bcaXiWDr4C2

2) Complete Jacobs Hall General Workshop Safety (Due F Sep 16 @ 5pm PT)
https://bcourses.berkeley.edu/courses/1353091

3) Check-out your Arduino Kit
front of studio

4) Start Lab 1 Exercises (Due F Sep 2 @ 5pm PT)
on bCourses