Creative Embedded Systems

COMS 3930
Spring 2022

Instructor Info

Mark Santolucito

Office Hrs: TBA

505 Milstein

msantolu@barnard.edu

Course Info —

Prereq: COMS 3157, alternatively, 5 semesters of COMS courses

Tuesday, Thursday

2x 75 min lecture (TuTh)

516 Milstein

24 enrollment cap

Overview

Ubiquitous computing is creating new canvases and opportunities for creative ideas. This class explores the use of microprocessors, distributed sensor networks, IoT, and intermedia systems for the purposes of creative expression. The course is delivered in a mixed lecture and lab format that introduces the fundamental concepts and theory behind embedded systems as well as issues particular to their creative employment. The key objective of the course is for students to conceive of and implement creative uses of computation.

Grading Scheme

55%	Module Assignments
10%	Participation
10%	Quizzes and Tests
25%	Final Project

Learning Outcomes

- Appreciate the current efforts and motivation to push the limitations of computation for creative expression, both in new application and new foundational research.
- Weigh factors such as cost, power, processing, memory, I/O, and networking capabilities when choosing a set of embedded devices and sensors.
- Produce documentation for code and systems, while considering the difference in doc style required for reproduction vs presentation.
- Contextualize unfamiliar hardware and languages through examples, documentation, and familiar design patterns.
- Manage communication between multiple languages, devices, and protocols.

Additionally, students will finish the course with :

- A digital portfolio of their work in the form of writing, code, video, audio, and physical artifacts.

Material

All required hardware materials will be provided by the instructor. Students may choose to use their own hardware, or to purchase hardware to supplement their projects. Any additional hardware used in any project will have no impact on grades.

Required Texts

The course text is open-source and may be found at http://TBA

Late Policy

The late policy of this classes follows a policy found in many Barnard/Columbia CS courses. Each day (24-hour period) or partial day late incurs a 20% penalty on the assignment. However, you are allowed a total of 4 “flex” days, to be used as you wish throughout the semester (on written homeworks and/or projects). Late hours round up the nearest day. To use a “flex” day, simply submit your work late and add a note indicating how many “flex” days your late submission has incurred, and how many remaining “flex” days you have remaining. When possible, advance notice is appreciated.

If there is a situation that you feel should be exempt from this policy, you must reach out over email at least 48-hours prior to the due date of the assignment.

This policy does not apply to the final project, which cannot be accepted after the due date except in exceptional circumstances.

Class Attendance Policy

Beyond the 10% of your grade that is allocated to participation as stated above, you are expected to attend every class period. Excessive absences will require consultation. See the next page for further notes on the class attendance policy for when this class is taught in a remote learning mode.

FAQs

Do I need to know Electrical Engineering for this course?

Not at all - we will spend time working through the basics of EE that you need as a computer scientist. If you already have background, that is fine too - please be a class leader and help others.

I am worried that this isn't the course for me.

Please don't be worried! As long as you have met the prerequisite courses, you have the appropriate background.

Is the Maker Movement dead?

Admittedly, a little, especially with the low cost of imported electronics. But the need for basic awareness of hardware is still well-motivated by exploratory, ecological, and equal-access perspectives.

How does this course compare to other electronics focused courses?

This course is a middle ground between MUSI GR6249 and CSEE4840. The goal is to give you the confidence to build and deploy creative embedded systems, with focus on both the software and hardware issues that arise in real-world application.

Honor Code

You are expected to hold yourself to the highest standard of academic integrity and honesty, as reflected in the Barnard Honor Code. Approved by the student body in 1912 and updated in 2016, the Code states:

We, the students of Barnard College, resolve to uphold the honor of the College by engaging with integrity in all of our academic pursuits. We affirm that academic integrity is the honorable creation and presentation of our own work. We acknowledge that it is our responsibility to seek clarification of proper forms of collaboration and use of academic resources in all assignments or exams. We consider academic integrity to include the proper use and care for all print, electronic, or other academic resources. We will respect the rights of others to engage in pursuit of learning in order to uphold our commitment to honor. We pledge to do all that is in our power to create a spirit of honesty and honor for its own sake.

Wellness Statement

It is important for undergraduates to recognize and identify the different pressures, burdens, and stressors you may be facing, whether personal, emotional, physical, financial, mental, or academic. We as a community urge you to make yourself–your own health, sanity, and wellness–your priority throughout this term and your career here. Sleep, exercise, and eating well can all be a part of a healthy regimen to cope with stress. Resources exist to support you in several sectors of your life, and we encourage you to make use of them. Should you have any questions about navigating these resources, please visit these sites:

- http://barnard.edu/primarycare
- https://barnard.edu/about-counseling
- http://barnard.edu/wellwoman/about
- Stressbusters Support Network

Center for Accessibility Resources & Disability Services

If you believe you may encounter barriers to the academic environment due to a documented disability or emerging health challenges, please feel free to contact me and/or the Center for Accessibility Resources & Disability Services (CARDS). Any student with approved academic accommodations is encouraged to contact me during office hours or via email. If you have questions regarding registering a disability or receiving accommodations for the semester, please contact CARDS at (212) 854-4634, cards@barnard.edu, or learn more at barnard.edu/disabilityservices. CARDS is located in 101 Altschul Hall.

Affordable Access to Course Texts & Materials

All students deserve to be able to study and make use of course texts and materials regardless of cost. Barnard librarians have partnered with students, faculty, and staff to find ways to increase student access to textbooks. By the first day of advance registration for each term, faculty will have provided information about required texts for each course on CourseWorks (including ISBN or author, title, publisher, copyright date, and price), which can be viewed by students. A number of cost-free or low-cost methods for accessing some types of courses texts are detailed on the Barnard Library Textbook Affordability guide (library.barnard.edu/textbook-affordability). Undergraduate students who identify as first-generation and/or low-income students may check out items from the FLIP lending libraries in the Barnard Library (library.barnard.edu/flip) and in Butler Library for an entire semester. Students may also consult with their professors, the Dean of Studies, and the Financial Aid Office about additional affordable alternatives for having access to course texts. Visit the guide and talk to your professors and your librarian for more details.

Description of Structure and Workload

This course is heavily project-focused. The course is divided into six modules that build on each other over the course of the semester. At the end of each module students will demonstrate their knowledge of the topics presented via:

- a written blog that contains log entries detailing their personal progress
- aural/visual artifacts: output in the form of audio and video
- video demonstrations of hardware systems
- source code

Students will compile the documentation that are submitted throughout the course of the semester into a final course portfolio.

Additional Texts

In addition to the course texts, students will need to consult a variety of additional documentation in each module. Below is a limited (incomplete) bibliography of sources referenced throughout the course. In addition to these readings, students will find it necessary to consult technical documents for their specific applications.

Recommended Texts

"man" (manual) pages and reference documents for software (SuperCollider, Processing, Python, etc.) and hardware (ESP32, Raspberry Pi, passive components and sensors, etc.).

Boden, Margaret A. *The Creative Mind: Myths and Mechanisms*. London: Routledge, 2004.

Bullock, Jamie. *Designing Interfaces for Musical Algorithms.* In The Oxford Handbook of Algorithmic Music: Oxford University Press, 2018-02-22. Online Book Link.

Gläveanu, Vlad Petre, et al. *The Cambridge Handbook of Creativity across Domains*. Cambridge University Press, 2017.

Reas, Casey, and Ben Fry. *Processing: a programming handbook for visual designers and artists*. Cambridge, MA: MIT, 2007.

Wilson, Scott, Nick Collins, and David Cottle. *The SuperCollider Book*. Cambridge, MA: MIT Press, 2011.

A Note on Remote

When this course is taught in either a remote or hy-flex model, there will be additional challenges regarding access to hardware. The course materials listed above will be available to student's as they are required purchases for the course. However, students may not have access to on-campus resources, such as the Athena Design Center. These centers have important tools (e.g. soldering irons) and safe spaces to work with these tools.

In the case that students do not have access to such infrastructure, students should make safe operating procedures a priority. If there is not a safe space at home to solder, we will focus on using breadboards and protowires. Much of this planning with happen on a case-by-case basis with the instructor.

Additionally, some modules may need to be adjusted for remote work. None of the remote module versions are "lesser" than the in-person module versions. In fact, the remote modules will in many cases allow us to explore more content areas than we would normally cover. As this course focuses on embedded computing and developing the practice of "art in place", a diversity of physical locations of students stands to enrich the modules in new ways. Some modules will be more challenging - for example the distributed systems module - but also a great learning opportunity, as you the student will not have the option to fall back on simpler means (a wire) of communication between devices.

Finally, it is worth noting that working remote will in fact help reinforce one of the key learning objectives of this course - *documentation*. In this course, we will stress the importance of documentation, both for the goal of reproducibility, as well as presentation. Since remote work means that the creative embedded systems you build will only be viewed by your classmates and peers through your documentation, the importance of this will naturally be reinforced.

In terms of attendance, when this course is remote, the expectation is still that you will attend all class meetings and labs, regardless of timezone. Since much of the labs will be completed in a pair-programming model, if due to timezone difficulty, you and your partner are able to find another time to complete the lab within 24 hours of the scheduled lab section, this is also acceptable. However, in this case, there may be limited instructor availability. When we are remote, the laptop policy is only that you give your undivided attention to the matter at hand during class.

Class Schedule

This schedule is provisionary and subject to changes throughout the semester.

MODULE 1: Generative Art

Weeks 1-3	In the first module we explore basic tools, techniques, and applications for generative art with embedded devices. In 2022, we will focus on the TTGO ESP32 device with a builtin 1.14 inch color display. We consider digital outputs of visuals using the small display available on the TTGO ESP32. We will explore the use embedded systems in guerilla art, a la the Boston Mooninite panic. Students will be asked to create their own guerilla art to be publicly displayed.
Learning Objectives	Gain confidence in working with non-traditional computing devices. Understand the context of digital art in public spaces. Document a single-device embedded project for both reproduction and presentation.
Project	Write generative code for the TTGO display and deploy your device with a battery in the wild. Record and reflect on the interactions of passerbys.

MODULE 2: Interactive Devices

Weeks 4-6	In module 2, we expand our previous system by adding the ability to take input from the environment (while still producing digital output). This requires interfacing between a laptop and a microcontroller device (the ESP32). We will also build small circuits to interface with the physical world. We consider hardware inputs such as adjustable pots, light sensors, distance sensors, microphones, and more. At the end of the module, we break the physical link between the microcontroller and the laptop and explore wireless methods of data communication including wi-fi, BlueTooth, BlueTooth Low Energy, and more. Simultaneously, we encounter and incorporate technical and artistic motivations for autonomous creative systems that are potentially transparent to the viewer/listener. Those technologies include power considerations. This system configuration falls into the broad scope of digital instrument design. The aesthetic considerations relate to the acousmatic – heard, but not seen.
Learning Objectives	Gain confidence in interfacing circuity with computing devices. Develop creative embedded system configurations within a restricted set of parameters. Apply basic knowledge of voltage, current, resistance, etc. to build novel circuits. Document a multi-device embedded project for both reproduction and presentation. Send real-time interaction data from microcontroller to a creative computation process on a laptop.
Project	Build a physical controller with the ESP32 that sends data to a interactive media process on your laptop. Record and reflect on the interaction of a peer with your system.

MODULE 3: Kinetic Sculpture

Weeks 7-10	Module 4 introduces actuators (motors, LEDs) to allow our system to take action in the physical world. We will look at examples of this work, such as the installation Kinetic Rain by the Art+Com group. This system configuration is particularly well suited to commercial installation art, for example in the synchronized drone swarms as popularly displayed at the opening ceremony of the Beijing Olympics. We combine all previous system configurations to build installations that can take user input and actuate accordingly. This system configuration is utilized for purposes of augmented experience design. We will look at the work of the MIT Media Lab group Opera of the Future, which has utilized this configuration in much of their work.
Learning Objectives	Understand various styles of actuators, and the software interfaces to control them.
Project	Build a device with motors and enable the movement to be controlled remotely over the internet.

MODULE 4: Distributed networks

Weeks 10-12	In the final guided module, we introduce distributed sensing and actuating networks for larger scale installations. This module does not introduce new modes of expression, but rather gives the artist the tools to scale up the previous configurations to match real world use cases. In the remote setting, this is a particularly motivating topic, as groups will be forced to coordinate data formats and communication protocols more clearly. We additionally consider the role of distributed systems in the context of large crowds. We explore the amoral nature of the technology itself, and look at applications such as protest organization, protest suppression, and contact tracing.
Learning Objectives	Appreciate the challenges of collaborative development of distributed systems, and the importance of continuously developed documentation. Document a collaborative, multi-device embedded project with custom circuitry for both reproduction and presentation.
Project	A class group project - every student's device must communicate with every other student's device. As a class, build a sensor network.

MODULE 5: Final Project

Week 13-15	The final module of the class is an open-ended exploration of system configurations we have explored in class. Students are required to use a minimum set of sensors, actuators, and digital outputs in their own designs. This final module also includes the compilation of the complete portfolio of student work from the semester. Here week 16 is considered the end of exam period, the point at which all projects must be presented and turned-in.
Learning Objectives	Be able to seek help and resources from domain experts, and offer help as a domain expert. Develop a creative embedded system without a restricted set of parameters. Collect documentation and compile a portfolio.
Project	Synthesize what you have learned in this class into the project you always wanted to build.

Note This syllabus is subject to any change at any time as deemed necessary by the instructor. Anything mentioned verbally in class overrides what is written in this document. Anything posted on the course website or SSOL overrides what is written in this document.