CPS1: Special Topics in Cyber-Physical Systems:
Comm, Test-Beds & Policy
ENGR 6559

Abbreviated Course Description

*This course is designed to develop cross-competency in the technical, analytical and professional capabilities necessary for the emerging field of Cyber-Physical Systems (CPS). It provides convergence learning activities that are based around understanding distributed sensing systems in **CPS test-beds** and exploring the **ethical, social** and **policy** dimensions of CPS work. The course also introduces and emphasizes the importance of **communication** as a necessary skill.*

Overview

CPS as a discipline integrates the cyber, physical and social worlds. The responsibilities of CPS professionals are then to *sense*, *analyze* and *actuate* upon the world with *efficient*, *safe*, *secure* and efficacious engineered systems. To do this effectively, CPS professionals need to develop *cross-competency* in technical, analytical and professional capabilities that are necessary for the efficacious and safe functioning of CPS systems. CPS is an inherently interdisciplinary discipline and practicing engineers must build systems and create knowledge at the *inter*-section of multiple knowledge domains. The best way to learn to do this is by participating in convergence learning activities that integrate an interdisciplinary CPS perspective from the onset.

Bridging the physical and cyber worlds requires CPS engineers to scalably capture data about the physical world, derive understanding from that data, and then actuate in the physical world based on that understanding. This closed-loop operation is a fundamental aspect of CPS, but requires wirelessly connected, low power, and embedded devices to realize at the large scales that CPS applications require. CPS engineers must understand the principles of how real-world data is collected, and be able to prototype their own designs in a controlled environment. Test-beds provide the environment to simulate real-world conditions and enable engineers to carefully observe the impact of their designs, changes and interventions.

CPS engineers also need to understand the role policy plays in shaping the possibilities of CPS systems and how technical standards can be utilized in achieving societally desirable goals of safety and resiliency. They must be able to perform critical analyses of systems with an eye towards, safety, ethics, compliance and human welfare. As all engineered systems reconfigure social relationships and hierarchies in ways that can have profound and important long-term societal implications. CPS engineers must have the analytical skills to describe and understand the interaction of their design on various human agents including users, regulators, non-users and various publics.

CPS as a discipline is at the fore-front of engineering new cyber-physical capabilities that could have significant effects on entire industries and job categories and engineers need to be prepared to participate in debates about the future that they are shaping from an informed and ethical perspective.

This course is designed to teach these necessary competencies.

Course Objectives

At the end of this course, you will be able to do the following:

1. Understand the fundamentals of wireless sensor networks and the tradeoffs of different designs concerning power, communication, reliability, update rate, latency, and ease-of-use.
2. Describe and critically comment on social and policy debates surrounding the field of CPS.
3. Be capable of building a wireless sensor node and applying it to an existing CPS test-bed.
4. Understand the principles of user centered design design and how users and non-users are implicated in design.
5. Understand the IEEE Ethically Aligned Design Framework and how to utilize it to design cyber-physical systems.
6. Describe and critically comment on social and policy debates surrounding the field of CPS.

Assessments

Your progress in the course will be assessed on all the dimensions described in the course objectives above. We will release detailed instructions for each assessment on Collab as we progress throughout the semester.

A. **Build a Wireless Sensor (10 Points)**: Working in teams, you will develop a wireless sensor based on an embedded development platform using an operating system designed for low power wireless systems. The sensor will collect information from sensors, process that information locally, and transmit the results wirelessly.

B. **Develop an Application using the Living Link Lab Test-bed (10 Points):** Working in teams, you will use the existing data streams from the Living Link Lab test-bed to prototype a smart office space application.

C. **Integrate a New Wireless Sensor into the Living Link Lab (10 Points):** Working in teams, you will apply your experience developing embedded devices and leveraging data streams to prototype an end-to-end application leveraging the existing Living Link Lab infrastructure.

D. **Case study on Living Link lab using EAD framework (10 Points)**: In this project, you will work in teams to develop a case study of the Living Link Lab utilizing the IEEE Ethically Aligned Design Framework.

E. **Case Study on 787 Max (10 Points):** This project will be a retrospective analysis of the 787 Max using publicly available knowledge, you will prepare a report integrating your new knowledge on user centered design and how to think about non-users.

F. **Discussion (10 Points):** This course can be truly transformational in your course of study here at SEAS. However, the level of benefit you will receive is directly proportional to your level of engagement and effort. Active participation is therefore essential to getting the most out of the course. As CPS engineers work in groups, you will need to apply all that we will teach you about group work to ensure that your groups are high-functioning groups.

G. **Final Exam (20 Points):** Your team will present the motivation, technical details, social, ethical, and policy implications, and results of your integrated Living Link Lab project. The final will provide an opportunity to highlight you new integrated understanding of CPS projects and the different kinds of expertise required of a CPS engineer.

Here is a breakdown of grading weights for each assessment in the class.

- Assessment A   10%
- Assessment B   10%
- Assessment C   10%
- Assessment D   10%
- Assessment E   10%
- Assessment F   10%
- Assessment G   20%
- Attendance   10%
- Self & Peer Assessment   10%

   Total   100%

Final grades are determined by the schedule below:

A+	97-100	A	93-96	A-	90-92
B+	87-89	B	83-86	B-	80-82
C+	77-79	C	73-76	C-	70-72
D+	67-69	D	63-66	D-	60-62
F	below 60				

Class Schedule

When do we meet?
Lecture: meets Tuesdays in Rice 032   -   9:30am – 10:45am
Lecture + Lab: meets Thursdays in Rice 032   -   9:30am – 10:45am

How should we meet?
Prepared, excited, and ready to learn and contribute each and every day.

Below is the abbreviated class schedule. Please consult the collab site for the full class schedule.

	Classes Tuesday thursday 9:30 - 1045				
Weeks	**Dates**		**Description**	**Instructor**	**Notes**
1	Tuesday, August 27th	Classes Begin	Course Introduction – what is CPS; overview of the Link Lab testbed; goals; teams; hands-on	Taught Jointly	
	Thursday, August 29th		Course Introduction – what is CPS; overview of the Link Lab testbed; goals; teams; hands-on	Taught Jointly	
2	Tuesday, Sept 3rd		Issues in CPS Ethics 1	Odumosu	
	Thursday, Sept 5th		Applications (Outdoors) – why CPS – special problems at the intersection of cyber and physical	Campbell	
3	Tuesday, Sept 10th		CPS Design & STS: Case Study 1: What do engineers actually do when they design systems?	Odumosu	
	Thursday, Sept 12th		CPS Systems Overview: Embedded - Gateway - Cloud	Campbell	
4	Tuesday, Sept 17th		Users and Non-Users	Odumosu	
	Thursday, Sept 19th		Hands-on Embedded OS Case Study: Tock	Campbell	
5	Tuesday, Sept 24th		CPS Ethics Conversation 1: Standards and the Consequences of Classification	Odumosu	
	Thursday, Sept 26th		Sensors. What can we measure, and how do devices do it?	Campbell	

6	Tuesday, Oct 1st		CPS Ethics Conversation 2: Real, Imagined and Constituted Users	Odumosu	
	Thursday, Oct 3rd		The Living Link Lab Testbed: A Technical Overview	Campbell	*Assessment A - Sensor*
7	Tuesday, Oct 8th	Reading Day	No Class		
	Thursday, Oct 10th		The Macroscope: Wireless Sensor Networks	Campbell	
8	Tuesday, Oct 15th		Writing in Context 1	Odumosu	*Assessment D - Case Study 1 - Living Link Lab*
	Thursday, Oct 17th		WSN Services: Time, Location, and Others	Campbell	
9	Tuesday, Oct 22nd		Writing in Context 2	Odumosu	
	Thursday, Oct 24th		Alternative Network Architectures: Single-hop, other radios, and interoperability.	Campbell	
10	Tuesday, Oct 29th		Entrepreneurship & CPS	Odumosu	
	Thursday, Oct 31st		Power: Mains vs. Batteries vs. Energy-Harvesting	Campbell	*Assessment B - LLL*
11	Tuesday, Nov 5th		CPS Case Study 1	Odumosu	
	Thursday, Nov 7th		CPS Programming Models	Campbell	
12	Tuesday, Nov 12th		CPS Case Study 1	Odumosu	*Assessment E - Case Study 2 - 737 MAX*
	Thursday, Nov 14th		The Edge/Fog: Processing near the sensors	Campbell	
13	Tuesday, Nov 19th		On Presentations and Communication	Odumosu	
	Thursday, Nov 21st		The Cloud: Processing at scale	Campbell	
14	Tuesday, Nov 26th		Presentations	Odumosu	
	Thursday, Nov 28th	Thanksgiving	No Class		
15	Tuesday, Dec 3rd		Presentations	Odumosu	

	Thursday, Dec 5th	Final Day of Class	Future of Sensing	Campbell	
	Friday Dec 6th	Classes End			*Assessment C - LLL + Sensor*
	Tuesday, Dec 10	2 - 5pm	**Exam**		*Assessment G - Final Presentation*

General Course FAQs

How will we communicate in this course?
We will make extensive use of the course website, Collab and e-mail. You are expected to be courteous, respectful and professional in your e-mail. To distinguish between course matters and everyday business, please begin each e-mail you write with "ENGR 6559" in the subject line. As a professional we expect that you will pay close attention to all e-mail from all instructors.

What texts and supplies do I need for the course?
You do not need to purchase any books for this course. We will read a number of book chapters and articles, all of which will be available under the Resources tab on Collab.

How should I submit my written work?
To facilitate accurate and speedy responses, please submit assignments electronically as **PDF** files to the appropriate folder in Collab. We are unable to process any other file type (e.g. doc or .docx). Late or missing work will lose points. To protect yourself from computer crashes, always make and keep a hard copy of each assignment. Remember that we grade the document as it appears on Collab. Please make sure to turn in your work correctly (i.e. not a Word doc. or a rough draft) and on time by the deadline and to check Collab to verify that it was submitted. Any late or missing work will lose significant points regardless of the reason (and even if you can produce an electronic time-stamped document that shows you haven't made any changes since before the deadline). It is your responsibility to make sure your work is turned in correctly and on time.

What practices can hinder my performance in the course?
While we anticipate that all students will pass this course, previous unpleasant experiences require that we explain in advance the ways in which it is possible to fail the course. First, you can fail the course if you do not turn in all of the assignments and/or the quality of your work is below what we deem as the acceptable minimum. Second, we have the option to fail you if you do not submit any or all of the assignments on the due dates. And third, you can fail if you have an inordinate number of class absences, excused or unexcused.

What accommodations are there for students with learning needs?
Should you have learning needs that require accommodation, please provide the appropriate documentation from the SDAC to your Lab Heads at least two weeks before the mid-term exam. We are not necessarily able to provide accommodation once an assignment or exam is underway.

What is the Attendance Policy?
Attendance is required for all classes and is considered part of your practice of professionalism.

To whom do I go if I have a question that has not been addressed by this FAQ?
It depends. If it is a question about material discussed in lecture, please email the faculty member who gave the lecture. If it is any other question about policies or assignment or other kinds of material needs, please email Prof. Odumosu or Prof. Campbell.

Statement on Safety and Wellbeing

The University of Virginia is dedicated to providing a safe and equitable learning environment for all students. To that end, it is vital that you know two values that we and the University hold as critically important:

1. Power-based personal violence will not be tolerated.
2. Everyone has a responsibility to do their part to maintain a safe community on Grounds.

As a result, the School of Engineering and Applied Science proudly serves as a safe space for its students and aims to promote their safety and wellbeing. If you are feeling overwhelmed, stressed, or isolated, there are many individuals here who are ready and wanting to help. If you wish, you can make an appointment with any of your SEAS faculty, and go to their office to talk in private.

As your professors, know that we care about you and your well-being and stand ready to provide support and resources as we can. You should also be aware that as faculty members, we are responsible employees, which means that we are required by University policy and federal law to report what you tell us to the University's Title IX Coordinator.

The Title IX Coordinator's job is to ensure that reporting students receive the resources and support that they need, while also reviewing the information presented to determine whether further action is necessary to ensure survivor safety and the safety of the University community. If you would rather keep this information confidential, there are Confidential Employees you can talk to on Grounds (http://www.virginia.edu/justreportit/confidential_resources.pdf). The worst possible situation would be for you or your friend to remain silent when there are so many here willing and able to help.

If you or someone you know is struggling with gender, sexual, or domestic violence, there are many community and University of Virginia resources available. The Office of the Dean of Students, Sexual Assault Resource Agency (SARA), Shelter for Help in Emergency (SHE), and UVA Women's Center are ready and eager to help. Contact the Director of Sexual and Domestic Violence Services at 434-982-2774 as necessary.

Alternatively, there are also other University of Virginia resources available. The Student Health Center offers Counseling and Psychological Services (CAPS) for its students. Call 434-243-5150 (or 434-972-7004 for after hours and weekend crisis assistance) to get started and schedule an appointment. If you prefer to speak anonymously and confidentially over the phone, call Madison House's HELP Line at any hour of any day: 434-295-8255.

Course Teaching Team

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