CS300: Special Topics in Computer Science: Embedded Systems and the Internet of Things

Calvin University

Spring 2020

Course Instructor: Prof. Derek Schuurman

Textbook: Edward Lee and Sanjit Seshia, *Introduction to Embedded Systems: A Cyber-Physical Systems Approach, 2nd Edition,* MIT Press, 2017. Available online at http://leeseshia.org/.

Other Tools: A customized Raspberry Pi IoT kit will be provided by the CS department at a reasonable cost. The kit contains parts that will be used for assignments and labs.

Course organization: There will be two lectures and a hands-on session each week. Lectures will be held in NH064 on Mondays and Wednesdays and hands-on sessions will be held in SB354 on Fridays.

Catalog Description

An introduction to topics in embedded systems and the Internet of Things (IoT) including hardware and software considerations for special-purpose computing applications that interact with the physical world. Hardware topics include microcontrollers, I/O interfacing, sensors, and actuators. Software topics include scheduling, considerations, IoT network protocols, the Web of things, state machines, and embedded programming. Additional topics include discussions of related social and ethical issues such as security, privacy, reliability, and the impact of automation. Lectures will be combined with hands-on lab exercises and a final project.

Prerequisites: Computer Science 112 (which may be taken concurrently) and Engineering 204 or 220, or permission of the instructor.

Student Learning Objectives: Upon successful completion of this course, a student will be able to:

- describe theoretical concepts in embedded systems and IoT
- analyze a problem in embedded systems and IoT and design an appropriate solution
- implement software that applies concepts in embedded systems and IoT
- discuss social and ethical implications related to embedded systems and IoT from a Reformed Christian perspective

Labs: There will be weekly labs, some of which will be completed in pairs. Weekly lab reports must clearly indicate the names of the lab partners and will be due by the following Thursday at midnight and must be submitted with Moodle. Labs submitted late will receive at most 75% full credit. No labs more than one week late will be accepted. Links to each lab are available in Moodle. *Before attempting any labs, students must read and understand the safety guidelines posted on Moodle.*

Quizzes: There will be regular quizzes scattered throughout the semester comprised of multiple choice questions, short answers, true/false questions, and definitions. The lowest quiz score will be dropped.

Assignments: There will be several assignments given throughout the semester culminating in a final project and presentation. Assignments and the final project will be done in pairs. Assignments submitted late will receive at most 75% full credit. No assignments which are more than one week late will be accepted (but students ought to still complete all exercises for practice). Students may discuss aspects of the assignments with each other, but every group must hand in their own work.

Grading: The marks for the course will be weighted as follows:

Quizzes	10%
Lab reports	20%
Assignments	20%
Final Project Presentation	5%
Final Project Report	20%
Final exam	25%

Grading queries must be raised within one week of the grades being posted. No work will be accepted after the last day of classes.

Laptop policy: Laptops used in lectures must be used strictly for note-taking. Regular "hands-on" practice will be provided in the weekly lab sessions. Furthermore, the use of cell phones is not permitted during classes or labs.

Course Outline: A *tentative* schedule for the course is shown below. The weekly reading assignments should be read since not all of the material in each chapter can be covered in detail during lectures.

Week	Text and Readings	Topics	Labs
Week 1 Feb. 3,5,7	Chapter 1 Chapter 8.1, 9.1	Introduction to embedded systems and IoT Introduction to the Raspberry Pi hardware and software Embedded processors, microcontrollers, DSPs, ASICs, FPGAs Memory architectures; flash memory considerations	Lab 1
Week 2 Feb. 10,12,14	Getting Started With Bash On The Raspberry Pi	Operating systems and software considerations Programming the Raspberry Pi • Bash shell, assembly language, GNU C/C++ compiler; cross compiling, Python, micro-python, Cython	Lab 2
Week 3 Feb. 17,19,21	Chapter 7	General Purpose I/O (GPIO) ports Sensors and actuators: models and examples Sensor issues: calibration, non-linearity, noise, and failures Sensor fusion example: Marzullo's Algorithm	Lab 3
Week 4 Feb. 24,26,28	Section 7.1 Section 10.1	A/D conversion: Quantization, noise, sampling, resolution Pulse Width Modulation (PWM) Microservos and actuators SPI, I2C, TIA232 and serial data communications	Lab 4
Week 5 Mar. 2,4,6	Chapter 3	State machines, diagrams Reachability analysis, traces	Lab 5
Week 6 Mar. 9,11,13	Sections 16.3, 16.4	Scheduling and timing analysis Interrupts and latency Real time operating systems (RTOS)	Lab 6
Week 7 Mar. 16,18,20	Sections 12.1, 12.2	Rate Monotonic Scheduling (RMS) Priority inversion and the Mars Pathfinder incident Watchdog timers Introduction to the Internet of Things (IoT)	Lab 7
Spring Break Mar. 23-37		No class	No lab
Week 8 Mar. 30 Apr. 1,3	MQTT and CoAP, IoT Protocols	IoT and machine-to-machine (M2M) communications Wireless: Bluetooth, WiFi, 5G, Zigbee, LoRaWAN Polling vs Publish/Subscribe protocols CoAP and MQTT Protocols Securing MQTT: SSL and payload encryption	Lab 8

Week 9 Apr. 6,8		The Web of Things (WoT) HTTP and webservers; HTTP request/response and polling MQTT over websockets WebRTC protocol	No lab
Week 10 Apr. 15,17	Short Take: Big Data and IoT in Practice *(CACM Blog)*	Cloud vs. Fog computing IoT Data and databases Big data, data analytics, machine learning for IoT, TinyML	Lab 9
Week 11 Apr. 20,24 Advising week	Chapter 17 6 Reasons Why IoT Security Is Terrible *(IEEE Spectrum)*	Regulatory compliance issues Security issues: • the problem of default passwords • authentication and encryption • software updates Testing considerations	Lab 10
Week 12 Apr. 27,29 May 1	How the Boeing 737 Max Disaster Looks to a Software Developer *(IEEE Spectrum)* Engineers, Ethics, and the VW Scandal *(IEEE Spectrum)*	Social and ethical issues: reliability, safety Privacy: California Consumer Privacy Act (CCPA) Big Data, Datafication, and "Dataism" Normative design principles: IoT for flourishing Case studies: the Therac-25 incident, the VW emissions scandal, the Boeing 737 Max 8 incident	Work on final project
Week 13/14 May 4, 6, 8, 11, 13, 14		Final Project Presentations Review	No labs

Academic Honesty: Students are expected to display honesty and responsibility in completing assignments. Students are responsible for understanding the information on plagiarism contained in the Student Conduct Code (Article IV. B). For more information, see following statement on plagiarism: https://www.calvin.edu/academic/engl/writing/plagiarism

Accommodations: Calvin University will make reasonable accommodations for persons with documented disabilities. Students should notify a disability coordinator in the Center for Student Success (located in Spoelhof Center 360) in order to arrange accommodations. Then, come and talk to me within the first two weeks of class so we can put your accommodations in place.

Communication outside of Class Times: Important announcements will be sent via Moodle to Calvin email, so students should check their Calvin email on a regular basis. Generally, the instructor will be happy to help you during lab times, during office hours (which are posted on my office door) or whenever I am in my office. Email is the preferred way of communication outside the classroom. Tutors are available by contacting the Center for Student Success.