Advanced Embedded Software

CS / ECE 5785 / 6785

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Today

- **Administrative stuff**
  - **Perspective taken by this course**
  - **Expectations and prerequisites**
  - **Components of the course**
- **Embedded systems intro**
  - **What are they?**
  - **What is it that they do?**
  - **Why do we care?**

Course Perspective #1: Software-Centric

- 5780/6780 is a basic course and tries to give a broad overview of microcontroller system issues, especially low-level interfacing

- This class is about building embedded software:
  - What it does
  - How it does it
  - How to build it
  - How to make sure it works

Course Perspective #2: Holistic

- Can t just look at an embedded system as a collection of parts
- Many important issues involve the whole system
  - Debugging
  - Security
  - Timeliness
  - Power and energy use

- **Q: Why focus on a holistic view of embedded software?**
- **A: You are extremely valuable if you:**
  1. **Have a deep understanding of both the HW and SW sides of embedded system design, and how they interact**
  2. **Can see the big picture about a software design in order to spot potential problems and opportunities**

- **What does extremely valuable mean?**

- **Another view: You are extremely valuable if you…**
  1. **Are really good at something**
  2. **Can talk to people who are really good at things you're not good at**
  3. **Can work on a team to accomplish goals that are too large to accomplish alone**

- **We will spend a lot of time working on these skills this semester**

Prereqs and Expectations

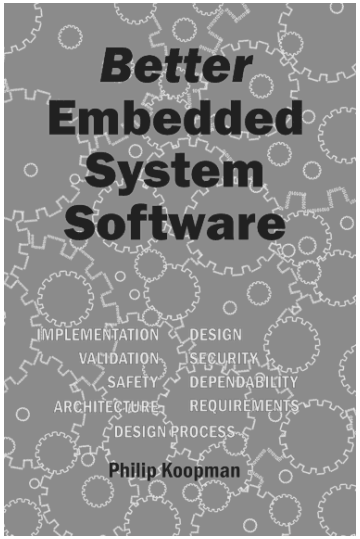
- Everyone should already:
  - Be able to write and debug C programs
  - Understand basic systems concepts – interrupts, device interfacing, etc.
    - From CS/ECE 5780, CS 4400, CS 5460, …
- CS folks need to be willing to learn:
  - Breadboarding
  - Logic analyzer use
  - How to read vendor reference manuals
- ECE folks need to be willing to learn:
  - How to think about software

Course Components

- **Lecture**
  - **I expect good attendance**
  - **If attendance is too bad I start giving pop quizzes**
- **Homework**
  - **Pretty minimal – handful of assignments**
- **Group programming assignments**
  - **These will take up the bulk of your time in this course**
- **Exams**
  - **1 midterm, 1 final**

Good Books

- **Better Embedded System Software, by Phillip Koopman**



- **The C Programming Language 2e, Kernighan and Ritchie**

Labs

- ECE digital lab is available for us to work in
- No regularly schedule lab time
- But: I will be meeting with each group each week outside of class
- You'll work in groups of 3 or 4
- Assignments will run on Raspberry Pi boards
  - Small ARM-based development boards
  - Runs full Linux
  - You will each buy one

To Do

- **Get on the cs5785 course mailing list**
  - **See https://sympa.eng.utah.edu/sympa**
  - **One list for all course sections**
  - **To mail just me and the TA use**
    - **teach-cs5785@list.eng.utah.edu**

- **Look for a number starting with 2* on the back of your Ucard**
  - **If this number isn't there, you need a new card**
  - **The 2* indicates a modern card that contains the RFID chip that will get you into the lab**

More ToDo

- **Order a Raspberry Pi**
  - **$35**
  - **Do this right away! There is a shipping delay**
  - **Use Element14 / Newark**
  - **Find links at the course web page or the Raspberry Pi site:**
    - **http://raspberrypi.org/**

- **Order or find these accessories:**
  - **Micro-USB charger**
  - **4 GB or larger SD card**
  - **HDMI-to-whatever cable**
  - **USB keyboard, mouse**

More ToDo

- Read the Launch Interceptor Program specification
- Register for a Github account
  - http://github.org/

- **Questions?**

Embedded Systems

- **Account for >99% of new microprocessors**
  - **Consumer electronics**
  - **Vehicle control systems**
  - **Medical equipment**
  - **Etc.**

Definitions of "Embedded System"

1. A special-purpose computer that interacts with the real world through sensing and/or actuation
2. A computer that you don t think of as a computer
3. Almost any computer that isn't a PC
4. …

- **Is smartphone and tablet programming "embedded programming"?**

More definitions

- Microprocessor: A regular CPU
- Microcontroller: A system on chip that contains extra support for dealing with the real world
  - Analog to digital and digital to analog converters
  - Embedded networks: serial, I2C, CAN, USB, 802.15.4, etc…
  - General-purpose I/O pins
  - Lots of interrupt lines
  - Low-power sleep modes
  - Voltage / frequency scaling
  - Temperature / vibration / radiation resistance
  - Onboard volatile and nonvolatile RAM
  - What else?

Embedded Characteristics

- Close interaction with the physical world
  - Often must operate in real time
- Constrained resources
  - Memory
    - SRAM, DRAM, flash, EEPROM, …
  - Energy
  - CPU cycles
  - Pins
  - Flash memory read / write cycles
  - What else?

More Characteristics

- Concurrent
  - Easy to make concurrency errors
  - Hard to find and fix them
- Often lack:
  - Virtual memory
  - Memory protection
  - Hardware supported user-kernel boundary
  - Secondary storage
- Have to be developed rapidly
- Cost sensitive
  - Per-unit cost often dominates overall cost of a product

Important Difference

- **Unlike PC software, embedded software is developed in the context of a particular piece of hardware**
  - **This is good:**
    - **App can be tailored very specifically to platform**
    - **In many cases writing portable software is not a concern**
  - **This is bad:**
    - **All this tailoring is hard work**

What Do Embedded Systems Do?

- 5 main kinds of functionality:
  - Digital signal processing
  - Open loop and closed loop control
  - Wired and wireless networking
  - User interfacing
  - Storage management
- Most embedded systems do 1-4 of these
- Which apply to:
  - Cell phone?
  - LinkSys home router?
  - Cruise control?
  - Stoplight?

Digital Signal Processing

- **Idea:**
  - Operate on discrete approximations of continuous signals
- **Origins in the 1960s and 70s:**
  - Radar and sonar
  - Space program
  - Oil exploration
  - Medical imaging
- **Far broader applicability today**

More DSP

- **Applications:**
  - **Telecom: Compression, echo control, wireless**
  - **Audio: Music, speech generation and recognition**
  - **Echo location: Radar, sonar, medical, seismology**
  - **Image processing: Compression, feature recognition, manipulation**
- **You could take years of courses on DSP**
  - **Extremely broad topic**
  - **Extensive theoretical underpinnings**

Control

- Idea
  - Make stuff happen in the world
- Open loop control
  - No feedback
  - E.g. toaster, stoplight
- Closed loop control
  - Uses feedback to adjust output
  - E.g. thermostat, cruise control
- You could take years of courses on control
  - But you better enjoy differential equations…

Networking

- Idea
  - Computers want to talk to each other
- Differences from PC networking
  - Communication is often local
    - E.g. “unlock the driver’s side door”
  - Specialized protocols
    - Often not TCP/IP
  - Topology may be fixed
  - Often low-bandwidth
    - Faster networks not necessarily better
  - Wireless increasingly important
  - Real-time deadlines

User Interfacing

- Idea
  - Present functionality directly to humans
- Modes:
  - Visual – screens
  - Tactile – keyboards
  - Aural – sounds, speech recognition
- This aspect of embedded systems shouldn't be ignored
  - Bad interfaces kill people
    - E.g. anesthesia, radiation therapy
- But we will mostly ignore it
- Doesn’t really fit in with rest of course
  - We have a UI course if you’re really interested

Storage

- Idea
  - Make today's huge persistent storage devices available to embedded applications
- Sometimes embedded storage is special-purpose
  - Car needs to remember if passenger-side airbag is enabled or disabled
- But often, general-purpose storage management can be embedded
  - iPods, digicam flash cards, etc. use standard filesystems

Why do we care?

- Embedded systems are amazingly useful
- Your life depended on dozens of them already today
  - What were they?
- By mid-2012, 30 billion ARM processors had shipped
  - > 4 per person on Earth!
- These trends are growing in importance
- You are the people who will design, develop, test, and maintain these systems for the next 40 years