Embedded System Education at Carnegie Mellon

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Other embedded educators: Gary Fedder
Bruce Krogh
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JoAnn Paul
Raj Rajkumar
Dan Siewiorek
Don Thomas

... and others who touch upon this area:
- DSP
- MEMS
- Robotics
- …
Embedded Systems Courses

**Sophomores:**
- Hardware Design
  - Single-CPU Systems
  - C/Java Programming

**Juniors:**
- Signals & Systems
- Software/System Engineering
- Rapid Prototyping/Wearable Computers
- Distributed Embedded Systems
- Signals & Systems

**Seniors/Grads:**
- HW/SW Codesign
- Reconfigurable Computing
- Mechatronics
- Dependability
- Various Topics
- Engineering Process “War Stories”
- Linear/Discrete Systems

What Does It Take To “Do” Embedded?

- We’ve been doing it for a long time
  - More a continual evolution process than a redirection

- 1980s: Intro. to embedded systems & real time control lab

- Early 1990s: Wearable computer course – taught twice/yr. since 1992
  - Radar/Sonar graduate course – now defunct
  - Dependability graduate course – now human factors

- Late 1990s: Redirect bit-slice CPU design course to HW/SW Codesign

- 1999: Distributed embedded system (e.g., cars)

- By 2001: Encourage universal software engineering literacy
HW/SW Codesign

- **ECE 18-545: Advanced Digital Design Project**
  - Assumes hardware design (procedural Verilog) and programming (C) skills
  - Lab-centered on *building a real system* on a wire-wrapped breadboard
  - Project completion requires HW/SW tradeoff & co-simulation

- **Typical projects: JPEG encoder, Chess Game**
  - Spec is given as C program, executable on Unix
  - Design goals set by students at beginning of term
  - Design variants such as speed, size, extensibility, and student-defined

- **Teams of 4 students**
  - All ECE students
  - Course-defined project goal
  - FPGA + Processor + RAM as building blocks
  - 60 students every Fall
**Distributed Embedded Systems**

- **ECE 18-540: “Distributed Embedded Systems”**
  - Assumes general embedded systems skill set
  - Multiple small processors on an embedded/real time network (e.g. CAN)
  - System partitioning, scheduling, and performance evaluation
  - *Analysis, simulation* from cars, elevators, trains, …
  - *Realistic situations* used for discussions/case studies
  - 35+ students every Fall
Distributed Embedded Project

- **Distributed Elevator Implementation**
  - Done in simulation; framework provided
  - Groups of 3 students
  - Performance competition for
    - 1% of course grade bonus
    - Industry sponsor gear as prizes

- **Hands-on emphasis of:**
  - Concurrency
  - Failure mode response
    - Dropped messages
    - Failed nodes
  - Emergent behaviors
  - Requirements changes
Rapid Prototyping/Wearable Computers

- ECE 18-843 “Mobile Computing Systems and Applications”
  - Assumes *some* students have general hardware and software background
  - *Real-world product design*

- **Real project + Real customer**
  - Information appliance & Internet-based embedded applications
  - Every semester is different, but involves a real customer
  - System requirements through delivery in one semester
  - *Including* component purchase & fabrication/assembly of hardware prototype

- **Learn by doing**
  - Historically most projects have been wearable computers
  - Examples of real-world issues are sure to crop up in a real design project
    - But which issues crop up depend on the specific project
Rapid Prototyping Project

Example:

- MoCCA, a mobile computing and communications
- Real prototype for Compaq for field sales force collaboration
- Single project for multi-disciplinary team of 25-30 students twice per year
  - Computer Engineering, Design (Fine Arts), Mechanical Engineering, Software Engineering, Human Computer Interaction, and others

Prototype  Final Design Concept

- Mocca received the prestigious Industrial Design Excellence Awards (IDEA) from award co-sponsors Business Week magazine and the Industrial Designers Society of America (IDSA).
Common Themes

- Both real and realistic design experiences
  - Real experiences with real customers are, well, real
  - Realistic experiences provide a way to ensure controlled breadth
  - Students tell us these are the courses they talk about in interviews

- Key embedded education areas:
  - Software / Digital hardware / Controls / System-level issues / Life cycle
  - Different group sizes: 1-2 / 3-4 / 20-30 per project
  - Different perspectives: hands-on project; analysis; case study

- Contact with industrial sponsors for courses and projects
  - Compaq sent people nearly every week for MoCCA meetings
What Have We Learned?

- **Key element: must have frequent industry interactions**
  - Parts/tools: Altera / Motorola / Cadence / Synplicity
  - On-campus industry representatives:
    - Adtranz / Bosch / Caterpillar / Emerson Electric
  - Multi-project relationships with other companies
    - General Motors / DaimlerChrysler / ABB / …
  - *BUT*, still building up course partners
    - Ideally not only support, but also active participation in course projects

- **Biggest problem:** scarce faculty (same as everywhere else)
  - Especially difficult for mid-career switchovers  
    - industry ⇒ academia

- **Biggest asset:** industry participation

- **Biggest victory:** injecting reality into the courses

- **Biggest cost:** dedicated staffing for large project courses!

- **Biggest challenge:** multi-disciplinary design *methodology*