Computer Engineering:
MS Program Overview, Fall 2013

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Overview of Program

• Interdisciplinary program: joint between CS and EE
  • Covers cross-cutting areas in overlap between the 2 departments
  • Focus = “systems” ➔ hardware/software (and networking)

• Popular area in many top schools:
  • Computer (systems) Engineering programs (Stanford, UCLA, USC)
  • ECE departments (CMU, UCSD, U. Wisconsin)
  • CSE departments (U. Washington, UCSD)
  • EECS departments (MIT, UC Berkeley, U. of Michigan)

• History at Columbia:
  • BS program: since 1994
  • MS program: since 2004
    • largest interdepartmental major within Engineering School
Overview of Program (cont.)

- Incoming Fall-13 MS class: 27 students
- Total # of MS students (Fall-13): 59 students
- Computer Engineering Faculty
  - 2013: 11 total
    CS (7): Carloni, Edwards, Kim, Misra, Nowick, Rubenstein, Sethumadhavan
    EE (4): Seok, Shepard, Zukowski, Zussman
  - 1994: 3 total
    CS (2): Nowick, Unger
    EE (1): Zukowski
Computer Engineering Faculty: Summary

- Prof. Luca Carloni (CS) (sabbatical ’13-’14) [luca@cs.columbia.edu]
- Prof. Stephen Edwards (CS) [sedwards@cs.columbia.edu]
- Prof. Martha Kim (CS) [martha@cs.columbia.edu]
- Prof. Vishal Misra (CS) [misra@cs.columbia.edu]
- Prof. Steven Nowick (CS) (sabbatical ’13-’14) [nowick@cs.columbia.edu]
- Prof. Dan Rubenstein (CS) [danr@cs.columbia.edu]
- Prof. Mingoo Seok (EE) (leave F’13) [mingoo@ee.columbia.edu]
- Prof. Simha Sethumadhavan (CS) (sabbatical F’13) [simha@cs.columbia.edu]
- Prof. Ken Shepard (EE) [shepard@ee.columbia.edu]
- Prof. Charles Zukowski (EE) [caz@ee.columbia.edu]
- Prof. Gil Zussman (EE) [gil@ee.columbia.edu]

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Administrative: Elsa Sanchez (elsa@ee.columbia.edu)
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MS Project Opportunities

- Worked out individually with faculty
  - for credit: signing up for project courses
  - for stipend: over summers
- Typically requires student:
  - to demonstrate sufficient background (and strengths)
  - usually, must first do well in relevant 4000-/6000-level course
Computer Engineering Research

• Faculty strength across wide range of high-impact/cutting-edge areas
  • many collaborative research projects + grants

• 7 main research areas:
  • Digital/VLSI Design
  • Computer Architecture/Parallel Systems
  • Embedded Systems
  • System-on-Chip (SoC)/Network-on-Chip (NoC)
  • Asynchronous/Mixed-Timing Design
  • Computer-Aided Design (CAD)
  • Networking and Communications

• 2-5 faculty per area (including overlaps)
Highlights: Some Faculty Research Projects

• Next-generation parallel computers (software/hardware) [Kim, Sethumadhavan]
• “Systems-on-chip (SoC)”/”networks-on-chip (NoC)” [Carloni, Nowick]
• Embedded systems (sw/hw): consumer electronics, automotive, robotics, medical [Edwards]
• Wireless sensor networks [Misra, Rubenstein, Zussman + other EE faculty: Kinget, et al.]
• Ultra-low energy digital/VLSI systems [Nowick, Seok, Zukowski + other EE faculty: Tsividis]
• Mixed photonic/digital systems [Carloni + other EE faculty: Bergman]
• Clockless digital systems (“asynchronous”) [Nowick]
• Bio-chips: interfacing electronics + DNA/proteins [Shepard]
• Gene network simulation [Zukowski]
• Secure computers [Sethumadhavan + other CS faculty: Bellovin, Keromytis]
• Intelligent buildings [Carloni]
Research: Digital/VLSI Design

- Designing complex, high-speed and low-power digital systems:
  - pipelined interconnect fabrics
  - “security-hardened” components
  - fault-tolerant circuits
  - ultra-low power systems
  - high-speed arithmetic circuits

- Advanced VLSI design:
  - clocking structures: resonant clocking
  - A/D converters, filters, sensors, memories, biochips, neural networks
  - adaptive voltage scaling

Faculty: Nowick, Seok, Shepard, Zukowski
Research:  Computer Architecture/Parallel Systems

- Composable lightweight processors
- Tile-based multicore systems
- Parallel software: programming/compilers
- Shared memory parallel processors (synchronous, asynchronous)
- Automatic legacy code parallelization/compiler optimization
- Memory system design
- Simulation of complex parallel systems

Faculty: Kim, Sethumadhavan (also, Carloni, Nowick)
Research: Embedded Systems

- “Embedded systems” = processors used for dedicated applications
  - automotive, cell phones, digital cameras, aerospace, sensors, medical, ...
- Challenge: integrated design/optimization of hardware + software
- Areas:
  - software/hardware compilers
  - precision real-time systems
  - modeling and synthesis of device drivers
  - domain-specific languages

Faculty: Edwards (also, Carloni)
Research: System-on-Chip/Network-on-Chip

- Goal: scalable structures for complex heterogeneous digital systems
- “System-on-Chip” (SoC) = integrate entire system on single chip
- “Network-on-Chip” (NoC) = connected with flexible communication fabric
- Areas:
  - composable “latency-insensitive” systems
  - “GALS” (globally-async, locally-sync) systems
  - performance analysis optimization
  - photonic on-chip networks

Faculty: Carloni, Nowick
Research: Asynchronous/Mixed-Timing Design

- Asynchronous = “clockless” systems
  - Digital components communicate flexibly on local channels
  - Potential benefits:
    - low power, modularity ("plug-and-play" assembly)
    - ease-of-design, no clock distribution
  - Applications:
    - consumer electronics
    - high-speed interconnection networks for parallel processors

- Mixed-Timing = “GALS-style” systems (globally async/locally sync)
  Potential benefits:
  - integrate different clocked components using asynchronous “fabric”

Faculty: Nowick
Research: Computer-Aided Design (CAD)

- Goal = software design/optimization tools for digital systems
- Major driver for advances in microelectronics: multi-billion dollar industry
- Includes:
  - develop sophisticated optimization algorithms
    - for circuits and systems
  - software tool package development
- Targets:
  - cost functions: power, area, latency, throughput, robustness
- Integrated cross-cutting research: software+theory (algorithms)+hardware

Faculty: Carloni, Nowick (also Edwards)
Research: Networking and Communications

- Basic problem: managing and moving information
- Physical <-> logical layers
- Performance modeling/analysis/design of communication algorithms
- Internet, ad-hoc, local communications
- Optics, wireless
- Mobile sensor networks
- Secure/resilient communication strategies
- Self-tuning/adaptive structures

Faculty: Misra, Rubenstein, Zussman (...more in EE/CS networking groups)