Computer Engineering:
Graduate Student Orientation

Introduction

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Interim Chair, Computer Engineering Program

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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-15 MS class: 34 students

• Total # of MS students (Fall-14): 75 students

• Computer Engineering Faculty
  • 2015: 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) [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) [+ EE] [nowick@cs.columbia.edu]
• Prof. Dan Rubenstein (CS) [danr@cs.columbia.edu]
• Prof. Mingoo Seok (EE) [mingoo@ee.columbia.edu]
• Prof. Simha Sethumadhavan (CS) [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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Faculty: Prof. Charles Zukowski, interim chair (caz@columbia.edu)
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 take relevant 4000-/6000-level course here (… and do well!)
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]
- 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)
COLUMBIA UNIVERSITY
Computer Engineering Program
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

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)