The Fu Foundation School of Engineering and Applied Science
Computer Engineering Program
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Computer Engineering: Graduate Student Orientation

Introduction

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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
  - Applicants: 2015 – 342; 2014 – 289; 2013 - 285; 2012 - 234; 2011 - 171; 2010 - 118
- 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]

Contacts:

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

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]
- 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)