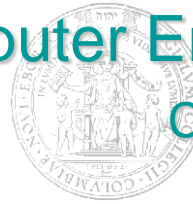


The Fu Foundation School of Engineering and Applied Science

Computer Engineering Program



COLUMBIA UNIVERSITY

IN THE CITY OF NEW YORK

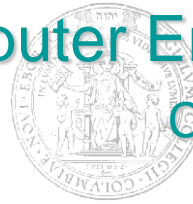
Computer Engineering: Graduate Student Orientation Introduction

Prof. Charles Zukowski

(caz@columbia.edu)

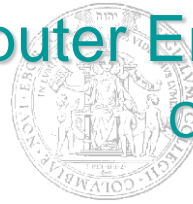
Interim Chair, Computer Engineering Program

September 3, 2015



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:

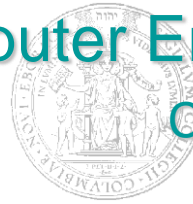
Administrative: Elsa Sanchez (elsa@ee.columbia.edu)

Faculty: Prof. Charles Zukowski, interim chair (caz@columbia.edu)



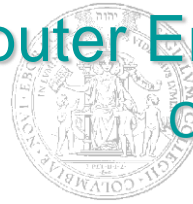
MS Project Opportunities

- 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!)



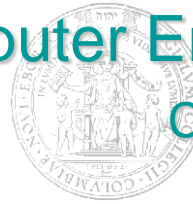
Computer Engineering Research

- 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

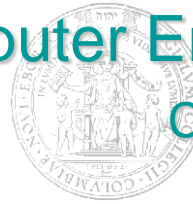
- Next-generation parallel computers (software/hardware) [Kim, Sethumadhavan]
- “Systems-on-chip (SoC)”/”networks-on-chip (NoC)” [Carloni, Nowick]
- Embedded systems (sw/hw): consumer electronics, automotive, robotics, medical [Edwards]
- Wireless sensor networks [Misra, Rubenstein, Zussman + other EE faculty: Kinget, et al.]
- Ultra-low energy digital/VLSI systems [Nowick, Seok, Zukowski + other EE faculty: Tsvividis]
- 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/compiler
- Shared memory parallel processors (synchronous, asynchronous)
- Automatic legacy code parallelization/compiler optimization
- Memory system design
- Simulation of complex parallel systems

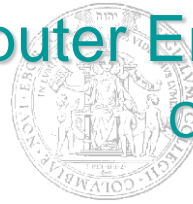
Faculty: Kim, Sethumadhavan (also, Carloni, Nowick)



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”

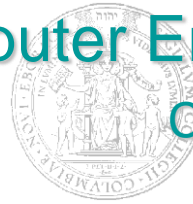
Faculty: Nowick



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 \leftrightarrow 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)