When and Where?

- When: Monday & Wednesday 7:00-8:50 PM
- Where: PCC Willow Creek 312
- Office hours: After class, or by appointment
- TA: Daksh Dharod
  - Office hours Tue & Thu 4-5 PM, WCC 313
- Webpage: [http://www.cecs.pdx.edu/~alaa/ece588/](http://www.cecs.pdx.edu/~alaa/ece588/)
- Go to webpage for:
  - Class slides and papers
  - Homework and project assignments
  - Changes in class schedule
Course Description

- Parallel computing and multiprocessors
  - Symmetric Multiprocessors (SMPs)
  - Chip Multiprocessors (CMPs), aka multi-core processors
  - Multithreading and parallel programming models
  - Multiprocessor memory systems

- Emphasis on papers readings NOT on a textbook
  - Tutorial papers
  - Original sources and ideas papers
  - Papers covering most recent trends
Expected Background

- ECE 587/687 or equivalent
  - Superscalar processor microarchitecture
  - Branch prediction
  - Cache organization
  - Memory ordering
  - Speculative execution
  - Multithreading
- Programming experience in “C”
Grading Policy

- Class Participation: 5%
- Paper reviews: 10%
- Homeworks: 25%
- Project: 30%
- Final Exam: 30%

Grading Scale:

- A: 92-100%
- A-: 86-91.5%
- B+: 80-85.5%
- B: 76-79.5%
- B-: 72-75.5%
- C+: 68-71.5%
- C: 64-67.5%
- C-: 60-63.5%
- D+: 57-59.5%
- D: 54-56.5%
- D-: 50-53.5%
- F: Below 50%
Important Dates

- Final Exam: Friday March 17th 7-8:30 PM, location TBD
- Project Presentations: Wednesday March 15th (in class)
- Project Reports Due: Tuesday March 21st (email)
- No class next Monday (holiday). Other classes may get combined/cancelled/moved.
Why Study Computer Architecture

- Technology advancements require continuous optimization of cost, performance, and power
  - Moore’s law
    - Original version: Transistor scaling exponential
    - Popular version: Processor performance exponentially increasing

- Innovation needed to satisfy market trends
  - User and software requirements keep on changing
  - Software developers expecting improvements in computing power
Why Study Parallel Computing

- Technology made multi-core processors both feasible AND necessary for performance
  - Moore’s law: too many transistors on a die than can be used (efficiently) for a single processor
  - Traditional out-of-order processors face memory and power walls

- Software requirements need more computing power than a single processor
  - Scientific computations
  - Commercial applications
Moore’s Law (1965)

Almost 75% increase per year
Memory Wall

- CPU cycle time: 500 times faster since 1982
- DRAM Latency: Only ~5 times faster since 1982
Why Not Build Larger OoO Processors?

- **Memory Wall**
  - 1980 Memory Latency ~ 1 instruction
  - Now ~ 1000 instructions

- **Power Wall**
  - Dynamic power increases quadratically with frequency, static power increases exponentially

- **ILP Limitations**
  - Serial programs don’t have an infinite amount of instructions to execute in parallel

- **Other Problems**
  - Temperature & cooling
  - On-chip interconnect
  - Complexity & testing
Technology Trends: Growing #Transistors Causes Inflection Points

- Most famous inflection point enabled simple microprocessor
  - 1971 Intel 4004
  - 2300 transistors
  - Could access 300 bytes of memory (0.0003 megabytes)

- Bigger and better-performing processors were enabled by more transistors

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Microprocessor Design Complexity

- Millions of Transistors
- Bit-level Parallelism (BLP)
  - 64-bit multiply in one/two cycles
- Instruction-Level Parallelism (ILP)
  - Dozens of instruction in flight
  - Branch prediction
  - Out-of-order
- Dominating Use of Caches
  - Level-one cache
  - Level-two cache
- Emerging Chip Multiprocessing

PowerPC 750 (1998)
Multi-core Processors (Chip Multiprocessors)

- Replicate
  - processor “core” &
  - Caches

- Uses more transistors
- Tolerates “memory wall”
- Simpler lower-power cores
- Reduces complexity

IBM Power 4
Software Trends

- TPC-C Throughput increased by more than 75% per year over eight years
- What about desktop applications?
- What about scientific applications?
Multi-Core Performance

- Recall Popular Moore’s Law:
  - Microprocessor performance doubles every 1.5-2 years

- Future Multi-Core Performance Doublings Require
  - Effective multithreaded programming
  - Better communication
  - Faster synchronization
  - More cores
Which design is better?
- Balance cores, caches, and pin bandwidth
Programming Models

- Single-core
  - One program runs on core
  - Programmers write efficient programs
  - Architects design for fast execution of instructions

- Multi-core
  - Each core can run a thread/task/program
  - Programmers can split up their programs?

- Multiprocessors
  - Shared memory
  - Message passing
  - Threads
  - Data Parallel
Introduction to Parallel Computing

- Serial vs. Parallel Computation (tutorial pictures)
- Parallel computing includes
  - Break up problem into smaller discrete parts that can be solved concurrently
  - Break each part further into a sequence of (serial) instructions
  - All parts are run simultaneously on different CPUs
- Why use parallel computing?
  - Save time
  - Solve larger problems
  - Provide concurrency (do more than one thing at the same time)
  - Save money (use multiple cheaper resources vs. a single expensive supercomputer)
  - Use more memory than available on a single computer
  - Use non-local resources
- Who uses parallel computing and why? (tutorial graphs)
Reading Assignment

- Introduction to Parallel Computing, Lawrence Livermore National Laboratory tutorial
  - Read before Wed class
- Submit review before the beginning of class:
  - Paper summary
  - Strong points (2-4 points)
  - Weak points (2-4 points)
- Review due before 7PM on day of class
  - Send by email to daksh AT pdx DOT edu
  - Plain text, no attachments
  - Subject line has to be: “ECE588_REVIEW_01_18”