

CS593: Principles in Computer Architecture

Fall 2024

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Class Room: tbd

Course Description

This course will cover fundamental concepts in computer architecture. Topics include instruction set architecture, pipelining, pipeline hazards, bypassing, dynamic scheduling, branch prediction, superscalar issue, memory-hierarchy design, advanced cache architectures, prefetching and other techniques to explore instruction level parallelism and thread level parallelism. Throughout the course we will discuss challenges in designing high-performance processors (e.g., power, energy, performance, and security). In particular, we will delve deep into the recent processor security issues. We will also have case studies as to how modern microprocessors are designed, we will look at recent Intel, AMD, and Apple processors. We will also briefly cover design principles and examples of domain-specific architectures including accelerators for machine learning applications.

Learning Objectives

- Understand the challenges involved in designing high performance processors
- Learn basic techniques for improving performance in modern processors and their tradeoffs
- Learn how to evaluate architectural solutions (performance, security, and power)
- Acquire in-depth knowledge of microarchitectural structures that can be used in other domains, e.g., writing highly-optimized high-performance software

Prerequisites

Prerequisites: Undergraduate Computer Architecture (CS250 or equivalent).

Assessments

- Research Project: 40%
- Programming Assignments: 20%
- Midterm: 20%
- Paper Presentations: 10%
- Online Quizzes (for readings): 10%

Course Format

- **Lectures:** 60-80% of the class will be lectures by the instructor. Lectures will be in-person. Students are expected to attend most of the lectures.
- **Student Presentations:** Students (individually or in groups, depending on the size of the class) are expected to present and lead the discussion of papers from the research literature to class. The papers will be selected by the instructor. A good presentation will include the necessary background and motivation, will explain overall merit and technical details, and provide answers to questions from the audience. While presenting a paper, a critical perspective will be encouraged and students do not need to necessarily defend the paper. All students are expected to read the paper before each class and participate in the class discussion.
- **Programming Assignments:** There will be two labs to prepare students for their research projects. The first lab will be on microarchitectural attacks where we implement multiple attacks on real systems. The second lab will be on microarchitectural mitigations, where we evaluate the performance overhead of a security mitigation strategy in a architecture simulator.
- **Research Projects:** Students will work on a research project within the scope of the course. Depending on the topic/class size the projects can be done individually or in groups. Students will present the project proposal, status, and results to class during the course.
- **Reading Quizzes:** There will be online quizzes due the start of each class to further encourage students to read the papers.
- **Office Hours:** Office hours attendance are optional. Office hours will be announced during lecture and/or Piazza.

Reading Materials

Course textbook

– Hennessy & Patterson, "Computer Architecture: A Quantitative Approach", Fifth Edition, Morgan Kaufmann (required)

Other background reading:

– We'll also be reading some research papers as well as referencing some books from the outstanding series Synthesis Lectures on Computer Architecture, which can be found here: [Synthesis Lectures on Computer Architecture](#). Those books will be free to access while you are on the Purdue domain.

– Hennessy & Patterson, "Computer Organization and Design: The Hardware/Software Interface" gives a lower-level treatment of the material (more from the design standpoint). This represents the assumed background/prerequisite for this class.

High-Level Course Outline

- Introduction
- Computer System Performance
- Instruction Set Architecture
- Pipelining
- Instruction-Level Parallelism
- Data Level Parallelism
- Thread level parallelism
- Domain Specific Accelerators
- Security