ECE 463-563: Microprocessor Architecture

Spring 2024

Tues/Thurs, 1:30 pm - 2:45 pm, EB3 2124

Course Syllabus

Instructor: Michela Becchi: *mbecchi@ncsu.edu* (office hours posted on course calendar)

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Course Overview

The course explores basic microprocessor architecture concepts and mechanisms. These include: performance measurement, instruction-set architectures; memory hierarchies (including caches, prefetching, program transformations for optimizing cache use, and virtual memory); processor architecture (including pipelining, hazards, branch prediction, static and dynamic scheduling, instruction-level parallelism, superscalar and VLIW processors). The course involves major programming projects.

Prerequisites

- ECE209 and ECE212 or equivalent course
- Familiarity with assembly language programming and logic design
- Proficiency in C/C++

Student Learning Outcomes

By the end of the course, students should be able to do the following:

1. Explain the functionality of each component in a diagram of a modern microprocessor;
2. Identify the pros and cons of a given instruction set architecture;
3. Show how different cache organizations work for an address stream;
4. Analyze the performance of memory hierarchy quantitatively;
5. Design the basic hardware support for a RISC-style instruction set architecture;
6. Show the cycle-by-cycle behavior of processor pipelines, including in-order scalar pipelines and out-of-order superscalar pipelines, based on a segment of assembly code;
7. Evaluate the performance of different processor designs, such as different pipelines, different cache organizations, different branch predictors, etc., for a segment of code written in C;
8. Write programs to simulate caches, branch predictors, and instruction schedulers.

Textbooks and Other Course Material

Textbook: Computer Architecture: A Quantitative Approach, Sixth Edition. John Hennessy and David Patterson. Morgan Kauffman (Elsevier), 2017, eBook ISBN: 9780128119068, Paperback ISBN: 9780128119051

Note: Editions 3, 4 and 5 of this textbook cover the course material as well and are acceptable.

Other resources (not required): Modern Processor Design: Fundamentals of Superscalar Processors. John Paul Shen and Mikko H. Lipasti. Waveland Press, 2013, ISBN-13: 978-1478607830.

Course Schedule

A tentative course schedule (subject to change) is below:

Week	Date	Topic	Textbook Chapters	Deadlines (tentative)
Week 1	January 9	Introduction		
	January 11	Introduction & Technology trends	Chapter 1.1-1.8	
Week 2	January 16	Quantitative analysis	Chapter 1.9	
	January 18	Pipelining – unpipelined datapath (MIPS/RISC V)	Appendix A, C3	
Week 3	January 23	Pipelining – pipelined datapath; CPI; structural, data and control hazards	Chapter 3.1 Appendix C1-C5, C6 (skim)	
	January 25	Pipelining – handling structural, data and control hazards		Homework #1 due
Week 4	January 30	Pipelining – multicycle pipeline		
	February 1	Pipelining – branch prediction		
Week 5	February 6	Out-of-order execution	Chapter 3.4-3.5, Appendix C7	Homework #2 due
	February 8	Out-of-order execution		
Week 6	February 13	*Wellness day (no classes)*		
	February 15	Out-of-order execution	Chapter 3.6, 3.8, 3.9	Project #1 due
Week 7	February 20	Out-of-order execution		Project #1 due (*563+*)
	February 22	*Overflow lecture (review)*		
Week 8	February 27	Midterm		
	February 29	Out-of-order execution		
Week 9	March 5	Branch prediction	Chapter 3.3, 3.9	
	March 7	Branch prediction		Homework #3 due
Week 10	March 12	*Spring break*		
	March 14	*Spring break*		
Week 11	March 19	Superscalar processors	Chapter 3.8	Project #2 due
	March 21	*Overflow lecture*		Project #2 due (*563+*)
Week 12	March 26	Physical and Virtual memory	Appendix B1-B4, Chapter 2.1, 2.2 (skim), 2.3.	
	March 28	Caches I		
Week 13	April 2	Caches II		
	April 4	Caches III		
Week 14	April 9	Cache IV		Homework #4 due
	April 11	Cache V		
Week 15	April 16	Cache VI		
	April 18	Software techniques for ILP/VLIW	Chapter 3.2, 3.7, Appendix H	Project #3 due
Week 16	April 23	Review Session		
	April 25	Final Exam		

Note: For ECE563 students, the submission of projects 1 and 2 will be split in two stages. The first deadline will apply to the portion of the project in common with ECE463 students. The second (flagged as *563+* in the course schedule) will apply to the graduate-level specific project extension.

Exams

There will be two in-class exams. The midterm exam, accounting from 20% of the grade, is scheduled around the midpoint of the semester (February 27, class time). The final exam, accounting for 30% of the grade, will be given during the final exam period (12-2:30pm, April 25, EB3 2124). The final exam will be a cumulative 120-minute exam. Exams can include questions on the homework assignments and projects. Exams will be closed-book, but students are allowed to use a one-page cheat sheet written on both sides.

Homework Assignments and Projects

There will be 4 homework assignments and 3 projects. The projects require good C/C++ programming skills. Unless otherwise specified, all assignments and projects will be performed individually. *Consulting or reusing (even partially) code from other students or online resources is strictly forbidden and is considered academic dishonesty*. Students should indicate in their report any resources used other than the textbook. For ECE463 students, all homework assignments will be graded. For ECE563 students, homework assignments will be sampled for grading and the overall score of the homework assignments will be provided at the end of the semester. The complexity of the projects will be lower for students taking the course at the undergraduate level.

Class participation

Students (unless in the EOL program) are expected to attend class and participate in discussions. To facilitate class participation, we will use the Top Hat system. Top Hat participation will account for 3% of the grade, and the correctness of the questions asked through Top Hat will account for 2% of the grade. For EOL students, the quizzes will be done offline. The instructor will email the students ahead and provide a time window to complete the quiz.

Grading

ECE463

The overall grade will be a weighted average of the following components:

- Exams (50%) – two exams (20% midterm, 30% final)
- Homework assignments (10%) – weights: lowest score discarded, 33% each of remaining assignments
- Projects (35%) – weights: project1=40%, project2=40%, project3=20%
- TopHat (5%) – 3% for participation, 2% for correctness

ECE563

The overall grade will be a weighted average of the following components:

- Exams (50%) – two exams (20% midterm, 30% final)
- Homework assignments (5%) – see below
- Projects (40%) – weights: project1=40%, project2=40%, project3=20%
- TopHat (5%) – 3% for participation, 2% for correctness

Course Grade

The total course grade is a weighted average, with the weights described above. I guarantee the following assignment of grades based on the weighted average:

- 98-100: A+
- 93-97: A
- 90-92: A-
- 87-89: B+
- 82-86: B
- 79-81: B-
- 76-78: C+

- 71-75: C
- 68-70: C-
- 60-67: D
- < 60: F

I reserve the right to shift the numerical cutoff points down (but never up), based on overall class performance, problems with a particular assignment, etc.

Class Policies

Late work **–** A 3-day delay will be allowed on both homework assignments and projects, *with 5% grade deduction for each day of delay*. If you have a certified medical excuse or instructor approval, you may receive full credit if the assignment is turned in as soon as possible. *A missed exam can only be made up in the case of a university-excused absence*.

Attendance **–** Students should attend all lectures (in person or remotely). No makeups will be given for missed in-class business (e.g., discussions, Top Hat questions and exercises).

Credit-only requirements **–** If you are taking this course for credit-only, your grade must be equivalent to C- or better to receive an S (Satisfactory) grade. Otherwise, you will receive a U (Unsatisfactory) grade.

Audit requirements **–** If you are auditing this course, you must perform the midterm and final exam, and participate in the TopHat quizzes. You are not required to submit any homework assignments or projects. The weights of midterm exam, final exam and TopHat score will be 40%, 55% and 5%, respectively. You should score at least 70% to receive an AU (Audit) grade. Otherwise, you will receive a NR (No Recognition) grade. You are not required to submit any homework assignments or projects.

Information for EOL students

- Homework assignments and projects will be submitted through Moodle. Graded material will be returned within 2 weeks from submission. Grades will be posted in Moodle.
- Besides regular office hours, additional office hours can be scheduled by appointment.
- Exams will be held according to the calendar above. More information will be provided over the course of the semester.
- EOL students will perform TopHat quizzes offline. The instructor will notify students via email every time new quizzes are posted.

Course webpage and mailing list

Course page: Moodle: https://moodle-courses2324.wolfware.ncsu.edu/course/view.php?id=6711

Course mailing list: Piazza: https://piazza.com/ncsu/spring2024/ece463563

The course Moodle page will contain the syllabus, lecture notes, homework assignments, projects and other relevant information. All class announcements will be posted on Piazza.

What kind of information can I post on Piazza in response to other students' questions? If the question concerns a homework assignment/project, you are not allowed to post code (or the solution to the problem's posed). You can post information helping the student to find an answer to the question, but each student should then independently come up with his/her own solution.

My preferred mode of communication is Piazza, followed by email. *If you email me directly, please prepend "[ECE463]" or "[ECE563]" (whatever applies) to the subject of your email*. Try to reserve email for questions that require privacy.

Other links

Course calendar (Google):
https://calendar.google.com/calendar/u/0/embed?src=c_0cuig9e7t6esm95h6dt5ukuq9o@group.calendar.google.com&ctz=America/New_York

Panopto (recordings and webcasting):
https://ncsu.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderID=156932b9-a635-456c-b5f0-b05500e522d4

TopHat link: https://app.tophat.com/e/467270

Academic Integrity

All exams, quizzes, projects and homework assignments are individual assignments, unless otherwise stated in writing. In case of projects and homework assignments performed in teams, both team members must be able to explain all parts of the assignments. *Not being able to explain a homework assignment/project submitted is considered cheating*.

*This course has a **strict no-code reuse policy**.* Under no circumstances is it allowed to ***consult or reuse*** code from other individuals or online resources. Code reuse (**even if partial**) from other students, online or other resources will be considered an academic integrity violation. In case of doubts, please ask the instructor in advance.

Evidence of cheating, plagiarism, or other violations of the Code of Student Conduct will be investigated and, if appropriate, referred to the Office of Student Conduct for disciplinary review. When an academic integrity violation is detected, the student will be reported to the Office of Student Conduct and will receive a 0 score in the related exam, project or assignment. In the presence of multiple academic integrity violations by the same student, the student will fail the class (in addition to be reported to the Office of Student Conduct).

The Code of Student Conduct can be found at: http://policies.ncsu.edu/policy/pol-11-35-01.

Inclement Weather

The class will follow the University's closure policy. If you are wondering whether classes are cancelled due to inclement weather, please check the University website or the weather hotline (513-8888).

Statement for Students with Disabilities

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the Disability Services Office at Suite 2221, Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (REG 02.20.01)

N.C. State University Policies, Regulations, and Rules (PRR)

Students are responsible for reviewing the PRRs that pertain to their course rights and responsibilities. These include:

- http://policies.ncsu.edu/policy/pol-04-25-05(Equal Opportunity and Non-Discrimination Policy Statement)
- http://oied.ncsu.edu/oied/policies.php (Office for Institutional Equity and Diversity)
- http://policies.ncsu.edu/policy/pol-11-35-01 (Code of Student Conduct)
- http://policies.ncsu.edu/regulation/reg-02-50-03 (Grades and Grade Point Average).