CPSC 3220-003, Introduction to Operating Systems

Fall 2023

Course Details

- **Term:** August 23 to December 15
  - Last day to drop without record is September 6 (Wednesday).
  - Last day to drop without a final grade is November 1 (Wednesday).
  - Fall break is October 16-17 (Monday and Tuesday).
  - Thanksgiving Break is November 22-24 (Wednesday, Thursday, and Friday).

- **Class Meeting Time and Place:** TR 3:30-4:45, synchronous online meetings using Zoom
  - Please allow up to 15 minutes if I am late in starting a class meeting.
  - The Zoom sessions will be recorded. Links to the recorded Zoom sessions will be available from the Canvas course home page within a few hours after the class meeting (there is a delay for Zoom post-processing and linking). Please feel free to email me about any missing links after 24 hours.

- **Instructor**: Mark Smotherman

- **Department and College**: School of Computing, College of Engineering, Computing and Applied Sciences

- **Instructor Email**: mark@clemson.edu
  - You can expect a response to your email inquiries within 48 hours, excluding weekends and university holidays.

- **School of Computing Phone Number**: 656-3444 (this is the front office); please note that email is my preferred form of communication.

- **Office Address (Office Number)**: 309 McAdams Hall; please note that office hours and appointments will typically be held via Zoom

- **Student Hours**: 2:00-3:00 MW or by appointment, typically using Zoom. Emails are welcome anytime.

- **Teaching Assistant**: TBA

- **Discussion Forum**: Discussion pages will be linked from the Canvas course home page.

Course Description

Detailed study of management techniques for the control of computer hardware resources. Topics include interrupt systems, primitive level characteristics of hardware and the management of memory, processor, devices, and data.

Key Topics:

- hardware support of operating systems
- synchronization of concurrent threads
- scheduling of threads
- allocation of physical and virtual memory
- storage of data in files

Learning Outcomes

After completing this course, students will be able to:

- Explain the objectives and functions of a modern operating system.
- Contrast kernel and user mode in an operating system.
- Explain the actions of hardware in response to an interrupt.
- Describe the difference between processes and threads.
- Demonstrate the potential run-time problems arising from the concurrent operation of many separate threads.
- Use a synchronization technique to control concurrency among multiple threads.
- List the four necessary conditions for deadlock to occur.
- Compare and contrast the common algorithms used for both preemptive and non-preemptive scheduling of threads.
- Describe the data structures needed to support thread management and thread scheduling.
- Explain the need for dynamic priority adjustments in thread scheduling (e.g., priority aging and priority inheritance).
- Implement a policy for variable-length memory allocation.
- Describe how a virtual memory address is mapped into a physical memory address in a computer system with paged virtual memory.
- Describe how files are stored in secondary storage.
- Explain how an access control list protects files.

Prerequisites

CPSC 2120 and CPSC 2310 with grades of C or better; or, ECE 2230 and ECE 2720 with a C or better.

Required Materials

Required Textbook: Thomas Anderson and Michael Dahlin, Operating Systems: Principles & Practice, 2nd edition, Recursive Books, 2014. companion web site

Required Technical Skills

To be successful in this course, you must have a minimum working knowledge of your computer system, a web browser, a word processing program, the Canvas learning management system, and programming in C.

For technical assistance with the course site, students should contact ithelp@clemson.edu or visit https://ccit.clemson.edu/support/

Learning Environment

This course will require you to engage with the electronic textbook. Part of your semester grade will be the successful completion of textbook activities and open-book, open-note Canvas quizzes associated with the lectures or other after-class work. You are welcome to work together with classmates on the textbook activities and on the Canvas quizzes and activities.

The three in-term exams and the final exam for the course will also be open-book and open-note. However, you must take these exams individually, without help from anyone else, either in the course or not.

You will also be required to complete four programming projects, some or all of which will be in the C programming language. You must work on these programs individually, without help from anyone else, either in the course or not.

Assessment Activities and Grading

- 10% - pre-class activities (drop five lowest scores)
- 10% - after-class activities and quizzes (drop five lowest scores)
- 24% - 4 programs, first two @ 4%, second two @ 8%
- 42% - 3 in-class exams @ 14%
- 14% - final exam (students with 90 or above averages will exempt)

All exams will be online.

Semester Grades

A standard 10-point scale will be guaranteed (i.e., A is 90-100, B is 80-89). Fractional semester averages will be rounded normally. There will be no curves for the exams, etc. However, based on the distribution of the final semester averages, I reserve the right to widen one or more grade bands to account for the clustering of semester averages.

Course Feedback

You are welcome to ask questions or raise concerns about the course in class or to send me email anytime to give me feedback on the course. I will use EvalKit at the end of the semester for course evaluations.

Topical Outline

(numbers in parentheses refer to assignment numbers)

- **Thursday, August 24 - introduction to course** (slides)
  - Tuesday, August 29 (1) - OS definition, evaluation, and history (Chapter 1, slides)
  - Thursday, August 31 (2) - Kernels, interrupts, and processes (Chapter 2, part a slides)
  - Tuesday, September 5 (3) - Continued (part b slides)
  - Thursday, September 7 (4) - Programming interface (Chapter 3, slides, fork.c, pipe.c)
  - Tuesday, September 12 (5) - Threads and concurrency (Chapter 4, part a slides, create.c, bzero.c)
  - Thursday, September 14 (6) - Continued (part b slides)
- **Tuesday, September 19 - Exam 1**
  - Thursday, September 21 (7) - Synchronized access to shared objects (Chapter 5, part a slides)
  - Tuesday, September 26 (8) - Continued (part b slides)
  - Thursday, September 28 (9) - Semaphores (part c slides)
  - Tuesday, October 3 (10) - Multiprocessor locking (Chapter 6a, part a slides)
  - Thursday, October 5 (11) - Deadlock (Chapter 6b, part b slides)
  - Tuesday, October 10 (12) - Scheduling (Chapter 7, part a slides)
  - Thursday, October 12 (13)- Continued (part b slides)
  - Tuesday, October 17 – Fall Break
- **Thursday, October 19 - Exam 2**
  - Tuesday, October 24 (14) - Dynamic memory allocation (Wilson, et al., "Dynamic Storage Allocation: A Survey and Critical Review", slides);
  - Thursday, October 26 (15) - Address translation (Chapter 8, part a slides)
  - Tuesday, October 31 (16) - Continued (part b slides)

    - Thursday, November 2 (17) - Virtual memory and replacement policies (Chapter 9, slides)
    - Tuesday, November 7 (18) - Continued
    - Thursday, November 9 (19) - Advanced memory management (Chapter 10, slides)
- **Tuesday, November 14 - Exam 3**
    - Thursday, November 16 (20) - File systems (Chapter 11, slides)
    - Tuesday, November 21 (21) - Storage devices (Chapter 12, slides)
    - Thursday, November 23 – Thanksgiving Break
    - Tuesday, November 28 (22) - UNIX (Ritchie and Thompson, "The UNIX Time-Sharing System", slides)
    - Thursday, November 30 (23) - Files and directories (Chapter 13, part a slides)
    - Tuesday, December 5 (24) - Continued (part b slides)
    - Thursday, December 7 (25) - Reliable storage (Chapter 14, slides)
- **Friday, December 14 - Final Exam, 11:30 a.m. - 2:00 p.m.**

Examples of Past Programming Assignments

Spring 2023 Projects

- Client/server interprocess communication using MPI in Python
- Resource allocation using a lock and a condition variable
- Slab allocator - allocate and release fixed-size objects using bit maps
- Demand paging simulator

Other Resources

Online Resources for Similar Courses

- CS 111: Operating System Principles, John Ousterhout, Stanford
- CS 162: Operating Systems and Systems Programming, Natacha Crooks, UC Berkeley
- CS 422/522: Design and Implementation of Operating Systems, Zhong Shao, Yale
- CSE 451: Operating Systems, various instructors, UW
- CMPT 300 videos, Introduction to Operating Systems, Arvindh Shriraman, Simon Fraser University
- Allen Downey, The Little Book of Semaphores, 2nd ed., version 2.2.1, 2016
- pthread library links
    - Blaise Barney, POSIX Threads Programming, Lawrence Livermore National Laboratory, on-line tutorial
    - Alfred Park, Multithreaded Programming (POSIX pthreads Tutorial)
    - Remzi Arpaci-Dusseau and Andrea Arpaci-Dusseau, Operating Systems: Three Easy Pieces, on-line book
    - Oracle, Multithreaded Programming Guide, Programming with Synchronization Objects
    - Helgrind tool for detecting synchronization errors in pthread code (part of Valgrind tool set)

C/C++ Language Review

- Storage classes, pointers, and dynamic memory allocation
- Bitwise operators and shifts
- Command line arguments
- C++ as used in the textbook

Based on his experience with helping students at Clemson, Jacob Sorber has recorded over 100 videos about programming in C. The playlist is here.

Course Policies

Attendance

If a student does not attend the first class meeting or contact the course instructor by the second meeting or the last day to add, whichever comes first, the course instructor must drop that student from the roll.

Registered students who cease attending class or submitting work to be graded prior to the last day to withdraw without final grades ("drop day") must be withdrawn by the instructor. Instructors must notify a student prior to dropping that student.

Attendance at exams is expected. Missing an exam without a pre-approved excused absence or without extenuating circumstances will result in a grade of 0 for the exam.

Regular attendance is not separately graded. However, class meetings will have associated textbook activities and quizzes that are graded. You can drop the five lowest grades for class activities with no need to explain any absences.

If you have medical issues or conflicts because of approved university activities, we will make arrangements for you to make up the missed work. Note that Clemson students receiving Veteran Administration Educational benefits should interact at least weekly so that the University can certify weekly contact for an online course.

Notification of Absence

The Notification of Absence module in Canvas allows students to quickly notify instructors (via an email) of an absence from class and provides for the following categories: court attendance, death of immediate family member, illness, illness of family member, injury, military duty, religious observance, scheduled surgery, university function, unscheduled hospitalization, other anticipated absence, or other unanticipated absence.

The notification form requires a brief explanation, dates and times. Based on the dates and times indicated, instructors are automatically selected, but students may decide which instructors will receive the notification. This does not serve as an "excuse" from class. It is a request for an excused absence and students are encouraged to discuss the absence with instructors, as the instructor is the only person who

can excuse an absence. If students are unable to report the absence by computer, they may reach the Office of Advocacy and Success. Students with excessive absences who need academic or medical assistance can also contact the Office of Advocacy and Success.

Inclement weather or emergency

Any exam that was scheduled at the time of a class cancellation due to inclement weather will be given at the next class meeting unless contacted by the instructor. Any assignments due at the time of a class cancellation due to inclement weather will be due at the next class meeting unless contacted by the instructor. Any extension or postponement of assignments or exams must be granted by the instructor via email or Canvas within 24 hours of the weather-related cancellation.

Late Work

Pre-class activities will not be accepted late without a valid excuse. After-class activities or quizzes will not be accepted after the subsequent class day (i.e., Tuesday or Thursday) without a valid excuse. Each project assignment will have an associated due date but will also be accepted late up to three days.

Submission of Work from Other Courses

When appropriate and when fully documented, you may reuse your own work from a previous class. For example, if you are reusing parts of a program written for a previous course, add a notice to your program header comments about the scope of the reuse and the course in which the work was previously submitted.

Submission of AI-Generated Work

You may not submit answers or assignments generated by artificial intelligence. Using materials generated using artificial intelligence that are turned in without attribution is considered plagiarism.

Standard Academic Policies

Academic Integrity

As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form.

All infractions of academic dishonesty by undergraduates must be reported to Undergraduate Studies for resolution through that office. In cases of plagiarism instructors may use the Plagiarism Resolution Form.

Additionally, for undergraduate classes:

Plagiarism, which includes the intentional or unintentional copying of language, structure, or ideas of another and attributing the work to one's own efforts. Graded works generated by artificial intelligence or ghostwritten (either paid or free) are expressly forbidden.

See the Undergraduate Academic Integrity Policy website for additional information and the current catalogue for the policy.

For graduate students, see the current Graduate School Handbook for all policies and procedures.

Accessibility

Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to this class should let the instructor know and are encouraged to request accommodations through SAS (Student Accessibility Services) as soon as possible. To request accommodations through SAS, please see this link: (https://www.clemson.edu/academics/studentaccess/register.html). You can also reach out to SAS with questions by calling 864-656-6848, visiting SAS at the ASC Suite 239, or stopping by the office as a drop-in appointment.

The Clemson University Title IX Statement Regarding Non-Discrimination

Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. This Title IX policy is located on the Access and Equity website. Ms. Alesia Smith is the Clemson University Title IX Coordinator, and the Assistant Vice President of Equity Compliance. Her office is located at 223 Brackett Hall, 864-656-3181 and her email address is alesias@clemson.edu. Remember, email is not a fully secured method of communication and should not be used to discuss Title IX issues.

Clemson University aspires to create a diverse community that welcomes people of different races, cultures, ages, genders, sexual orientation, religions, socioeconomic levels, political perspectives, abilities, opinions, values and experiences.

Emergency Preparation

Emergency procedures have been posted in all buildings and on all elevators. Students should be reminded to review these procedures for their own safety. All students and employees should be familiar with guidelines from Clemson University Public Safety.

Clemson University is committed to providing a safe campus environment for students, faculty, staff, and visitors. As members of the community, we encourage you to take the following actions to be better prepared in case of an emergency:

1. Familiarize yourself with all possible exits, safer locations, and other key information on the emergency evacuation maps in this building, and those that you visit regularly.
2. Make a plan for how you would Run, Hide, and Fight in case of an active threat in this building, and those that you visit regularly. For example:
    a. Run – what are all the possible exits in this building, and the routes to them?
    b. Hide – what are the potential hiding locations in this room and building that are out of sight of doors and windows, how do you lock the door(s), how would you barricade the door(s) and windows, where do you turn off the lights?
    c. Fight – What tools are available in this room and building, should you have to fight?
3. Ensure you are signed up for emergency alerts. Alerts are only sent when there is a potential threat to safety, a major disruption to campus services, and once-monthly tests.
4. Download the Rave Guardian app to your phone. (https://www.clemson.edu/cusafety/cupd/rave-guardian/)
5. Learn what you can do to prepare yourself for the hazards that affect our locations. (http://www.clemson.edu/cusafety/EmergencyManagement/)

Other University Policies and Student Support Resources

Please see https://www.clemson.edu/otei/documents/syllabus-part-2-2023-2024-final.pdf for the statements and descriptions of other relevant University Policies and Student Support Resources in effect for Fall 2023.

Editing Log
August 17, 2023 – Initial version

August 17, 2023