CSE 536: Advanced Operating Systems

Contact Information

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Course Overview and Topics

The Operating System (OS) is one of the most critical component of modern machines—all the way from Raspberry Pis to supercomputers—because it controls hardware resources allocated to all other software.

In this course, we will start by answering fundamental questions about operating systems and gradually progress all the way to shattering traditional assumptions regarding trust on an OS. For instance, we will start by answering the question: *How does the operating system get to start when a machine boots up?* At the end, we will answer the question: *what should I do when I cannot trust the operating system to correctly protect my programs?*

Provided below is a tentative list of topics we will discuss:

- Kernel bootloader execution
- Process scheduling (e.g., time sharing with context management)
- Simultaneous multi-processing (e.g., locks, semaphores)
- Memory management (e.g., page tables, demand paging, page faults)
- Kernel-process interactions (e.g., system calls, interrupts)
- File systems (e.g., different kinds, transparent compression mechanisms)
- Device management (e.g., UART, storage, network)
- Kernel-level logging for forensic analysis (e.g., at system calls)
- Kernel attacks and protection mechanisms (e.g., ASLR, Data Execution Prevention)
- Virtualization extensions (e.g., Intel VMX, AMD SVM)
- Process protection mechanisms (e.g., enclaves)

Learning Outcomes

At the end of this course, students will have a theoretical and practical understanding of how an OS works, all the way from how it starts to how it can spawn even new operating systems through virtualization techniques. With this understanding, they will be expected to become proficient in systems-level programming on any operating system codebase (e.g., Linux, Windows).

Prerequisite

The student must have taken two courses at the undergraduate-level: (a) a course in systems (or C) programming and (b) a course on OS or computer networks. A knowledge of computer architecture is a plus!

It is expected that SCAI graduate students in CS/CSE have taken the pre-requisite courses, hence this course is open to all graduate student. Graduate students who have not taken these courses are welcome to enroll, but they will be expected to learn C programming (e.g., pointers, memory allocation) and basic OS material on their own.

Textbook and Reading

The course will heavily rely on the xv6 Operating System, hence the following is the recommended book:

- xv6 Operating System Handbook
  https://pdos.csail.mit.edu/6.828/2022/xv6/book-riscv-rev3.pdf

The following are the optional books for this course:

- Operating System Design: The XINU Approach (2nd Edition)
  https://www.amazon.com/Operating-System-Design-Approach-Second/dp/1498712436

- Operating Systems: Three Easy Pieces
  https://pages.cs.wisc.edu/ remzi/OSTEP/

There is also many other optional interesting readings/links on Operating Systems:

- The Benefits and Costs of Writing a POSIX Kernel in a High-Level Language
  https://www.usenix.org/system/files/osdi18-cutler.pdf

- OSDevWiki
  https://wiki.osdev.org/Getting_Started

Feel free to ask the instructor for other recommendations!

Assessment (tentative)

This course will have a letter grade (A-E), assigned through a relative grading scheme. There are three main components for assessment.

1. **Laboratory Assignments (50%).** Depending on time constraints, the course will have 4 to 6 laboratory assignments. Provided below are some important details about the assignments:

   - Each assignment will have an equal score. For instance, if there are 4 assignments, each assignment will count as 12.5% towards your grade.
   - Students will be given 2 to 3 weeks for each assignment.
   - Students will be provided a Linux virtual machine environment for development. The virtual machine environment can be accessed from anywhere.
   - Each assignment will require implementing crucial OS functionality (e.g., scheduling, memory management) on top of a base OS implementation using C code.
   - Students must submit their modified code alongside a well-written 1-page README file explaining the steps taken to implement the solution.
   - If modified code does not compile correctly, a student will get a zero. The base code provided compiled correctly, and there is no reason for modified code not to compile.
   - Students will be provided some basic tests to run on their code before submission.

2. **Mid-term Examination (20%).** This will include all course material covered till a week before the midterm.

3. **Final Examination (30%).** This will include all the material learnt in the class and through assignments. Both the midterm and final exams might have some extra questions that can help boost your grade.

Late/Absent Work. Throughout the semester, each student will have a cumulative N (to-be-decided) late days for submission of assignment materials (e.g., source code, READMEs, and final report). Additional late days can be arranged under other circumstances (e.g., military duty, university-sanctioned activities, religious reasons, family circumstances, etc.). Except as by prior arrangement or notification of an extension before the deadline, missing or late work (after late days) will be counted as a zero/fail.

How Long Students Should Wait for an Absent Instructor: In the event the instructor fails to indicate a time obligation, the time obligation will be 15 minutes for class sessions lasting 90 minutes or less, and 30 minutes for class sessions lasting more than 90 minutes. Students may be directed to wait longer by someone from the academic unit if they know the instructor will arrive shortly.

Syllabus Changes. Any information in this syllabus (other than grading and absence policies) may be subject to change with reasonable advance notice.

Other Important Course Policies

Generative AI. Generative AI is a technology that can often be useful in helping students learn the theories and concepts in this course. However, unless explicitly allowed by your instructor, the use of generative AI tools to complete any portion of a course assignment or exam will be considered academic dishonesty and a violation of the ASU Academic Integrity Policy. Students confirmed to be engaging in non-allowable use of generative AI will be sanctioned according to the academic integrity policy and FSE sanctioning guidelines.

Disability Accomodations. Suitable accommodations will be made for students having disabilities. Students needing accommodations must register with the ASU Disabilities Resource Center and provide documentation of that registration to the instructor. Students should communicate the need for an accommodation in sufficient time for it to be properly arranged. See ACD 304-08 Classroom and Testing Accommodations for Students with Disabilities.

Academic Integrity. All engineering students are expected adhere to ASU's academic integrity policy, which can be found at ASU Academic Integrity Policy Link. Students are responsible for reviewing this policy and understanding each of the areas in which academic dishonesty can occur. If you have taken this course before, you may not reuse or submit any part of your previous assignments without the express written permission from the instructor. All student academic integrity violations are reported to the Fulton Schools of Engineering Academic Integrity Office (AIO). Withdrawing from this course will not absolve you of responsibility for an academic integrity violation and any sanctions that are applied. The AIO maintains a record of all violations and has access to academic integrity violations committed in all other ASU college/schools.

Expected Classroom Behavior. Every student is expected to behave in a courteous manner. You are free to use a cellphone, tablet, or audio/video recording device, to aid your study.

Copyright. Course content, including lectures, are copyrighted materials and students may not share outside the class, upload to online websites not approved by the instructor, sell, or distribute course content or notes taken during the conduct of the course (see ACD 304–06, "Commercial Note Taking Services" and ABOR Policy 5-308 F.14 for more information). You must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum, material that is not the student's original work, unless the students first comply with all applicable copyright laws; faculty members reserve the right to delete materials on the grounds of suspected copyright infringement.

Threatening Behavior Reporting. Students, faculty, staff, and other individuals do not have an unqualified right of access to university grounds, property, or services. Interfering with the peaceful conduct of university-related business or activities or remaining on campus grounds after a request to leave may be considered a crime. All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students.

Harrassment and Sexual Discrimination. Arizona State University is committed to providing an environment

free of discrimination, harassment, or retaliation for the entire university community, including all students, faculty members, staff employees, and guests. ASU expressly prohibits discrimination, harassment, and retaliation by employees, students, contractors, or agents of the university based on any protected status: race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, and genetic information.

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at Sexual Violence Prevention FAQs.

Mandated sexual harassment reporter: As a mandated reporter, I (the instructor) am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services is available if you wish discuss any concerns confidentially and privately.

Photo Requirements. Arizona State University requires each enrolled student and university employee to have on file with ASU a current photo that meets ASU's requirements (your "Photo"). ASU uses your Photo to identify you, as necessary, to provide you educational and related services as an enrolled student at ASU. If you do not have an acceptable Photo on file with ASU, or if you do not consent to the use of your photo, access to ASU resources, including access to course material or grades (online or in person) may be negatively affected, withheld or denied.