CS 537: INTRO TO OPERATING SYSTEMS

Shivaram Venkataraman

Spring 2020

WHO AM I?

Second year faculty in Computer Science!

PhD Thesis at UC Berkeley:
System Design for Large Scale Machine Learning

Industry: Google, Microsoft Research
Open source: Apache Spark committer

CALL ME

Prof. Shivaram or Shivaram

TODAYS AGENDA

What will you do in this course?

What is an operating system and why do we need one?

Why study operating systems?

COURSE SYLLABUS

COURSE LEARNING OUTCOMES

- Explain the fundamental types of OS abstractions

- Design and implement system libraries and kernel calls

- Assess system performance

- Explain the impact of algorithms and data structures

ASSESSMENTS

Exams (45%)

Midterm and final exams: Closed book, short questions

Quiz (5%)

In-class: Bring your computing device (or use paper)!

Assess OS concepts, abstractions discussed in class

Projects (50%)

Programming projects done on CS Linux labs

Gain hands-on experience, Build your own OS system calls!

Measure, understand performance

FORMAT

Lecture

Tue and Thu, 1PM - 2:15PM
Location: 3650 Humanities

Lecture notes, in-class discussion
Links to textbook chapters

Discussion

Thu 5.30PM-6:45PM
Location: 105 Psychology

Explain programming projects
Practice for exams

PERSONNEL

Instructor: Shivaram Venkataraman

Teaching assistants: Setareh Behroozi, Vibhor Goel, Shivangi Kamat, Konstantinos Kanellis, Abigail Matthews, Kaiwei Tu, Yien Xu

20 course staff!

Peer mentors: Anthony Barthell, Siddhant Bhagat, Kesong Cao, Tyler Gu, Ayush Kumar, Kieran Mulligan, Conor Waity, June Werner, Jerry Yu, Xinyu Zeng, Shawn Zhong, Zhenyu Zou

IMPORTANT LINKS

Course website
http://pages.cs.wisc.edu/~shivaram/cs537-sp20/

Piazza
https://piazza.com/wisc/spring2020/cs537

CS 537 Intro to Operating Systems - UW Madison, Spring 2020

Welcome to CS 537! This course will introduce you to the the broad field of operating systems. Operating systems include a wide variety of functionality. This is an introductory course and topics we will cover include basic operating system structure, process and thread synchronization and concurrency, file systems and storage servers, memory management techniques, process scheduling and resource management, and virtualization. The learning outcomes for this course are that at the end of the course you will be able to:

- Explain the fundamental types of operating system abstraction including processes, synchronization, virtual memory and persistence.
- Design and implement system libraries and kernel calls, which are mechanisms provided to user to access and develop new operating system functionality.
- Assess system performance and explain the impact of applying various algorithms and data structures to the complex operation of an operating system.

Logistics

- Course Number: CS 537, Spring 2020, UW Madison, 4 units.
- Instructor: Shivaram Venkataraman, Office hours: 2.30-3.30pm on Tue at 7367 CS or by appointment
- Teaching Assistants – If you need help from the TAs during office hours please use this form
- Lecture
  - Time: Tuesday and Thursday, 1:00PM - 2:15PM
  - Location: 3650 Humanities
- Discussion
  - Time: Thursday, 5:30PM - 6:45PM
  - Location: 105 Psychology
- Labs
  - There are no lab sessions for this course. Programming projects are a very important part of this course and the projects should be done on departmental PCs running the Linux operating system. We will cover some aspects of Unix/Linux in class and discussion.
- Discussion: We will be using Piazza for outside-class Q&A and for all announcements. **Please make sure you read Piazza often especially around project deadlines.** The system is highly catered to getting you help fast and efficiently from classmates, TAs and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza.

MATERIALS

Operating Systems: Three Easy Pieces

Remzi H. Arpaci-Dusseau and Andrea C. Arpaci-Dusseau

Blog: Why Textbooks Should Be Free

Quick: Free Book Chapters - Hardcover - Softcover (Lulu) - Softcover (Amazon) - Buy PDF - EU (Lulu) - Buy in India - Buy T-shirt - Donate - For Teachers - Homework - Projects - News - Acknowledgements - Other Books

COMING SOON: Computer Systems: Three Easy Steps --- ALSO COMING SOON: Distributed Systems: Three Easy Steps

Welcome to **Operating Systems: Three Easy Pieces** (now **version 1.00** -- see book news for details), a free online operating systems book! The book is centered around three conceptual pieces that are fundamental to operating systems: **virtualization, concurrency,** and **persistence.** In understanding the conceptual, you will also learn the practical, including how an operating system does things like schedule the CPU, manage memory, and store files persistently. Lots of fun stuff!

This book **is and will always be free** in PDF form, as seen below. For those of you wishing to **BUY** a copy, please consider the following:

- Lulu Hardcover (v1.00): this may be the best printed form of the book (it really looks pretty good), but it is also the most expensive way to obtain *the black book* of operating systems (a.k.a. *the comet book* or *the asteroid book* according to students). Now just: **$38.00**
- Lulu Softcover (v1.00): this way is pretty great too, if you like to read printed material but want to save a few bucks. Now just: **$22.00**
- Amazon Softcover (v1.00): Same book as softcover above, but printed through Amazon CreateSpace. Now just: **$27.50** (but works with Prime shipping)
- Downloadable PDF (v1.00): this is a nice convenience and adds things like a hyperlinked table of contents, index of terms, lists of hints, tips, systems advice, and a few other things not seen in the free version, all in one massive DRM-free PDF. Once purchased, you will always be able to get the latest version. Just: **$10.00**
- Kindle: Really, just the PDF and does not include all the bells and whistles common in e-pub books.

COURSE POLICIES: TIME MANAGEMENT

Time management is a skill to learn!

Projects are mostly back-to-back – start early

Ask for help (email or OH) if you have any issues

Slip days: Maximum of four slip days.

Two for the first half (individual projects)

Two for the second half (group projects)

No credit for late submissions if you are out of slip days. Use with care!

COURSE POLICIES: ACADEMIC INTEGRITY

It is DEFINITELY OK to:

- discuss the project in general terms (what do they mean by a file?)
- discuss how different library routines/system calls work
- ask the TA or professor or both for as much help as you need!

It is NOT OK to:

- bug someone else for a lot of help (particularly if they are done!)
- share your code directly with other people/project groups

COURSE POLICIES: INCLUSION

Create an environment where everyone can learn and thrive

Always feel free to ask a question!

Create a climate where we treat everyone with respect

SUMMARY

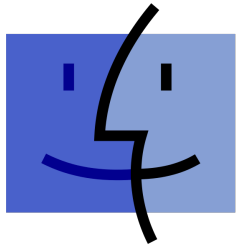
Course outline

- OS abstractions: Principles + Code
- Exams, programming projects
- Operating system: Three Easy pieces textbook

Action items: Register on Piazza and check course website!

WHAT IS AN OPERATING SYSTEM ?

EXAMPLES OF OPERATING SYSTEMS



Mac OS

OS X Yosemite

Microsoft®
Windows® xp

Applications

Hardware

WHAT DOES OS PROVIDE: ROLE #1

Abstraction: Provide standard library to access resources

What is a resource?

Anything valuable (e.g., CPU, memory, disk)

Examples of abstractions OS typically provide?

CPU:

Memory:

Disk:

WHY SHOULD OS DO THIS ?

Advantages of OS providing abstraction?

- Allow applications to reuse common facilities
- Make different devices look the same
- Provide higher-level or more useful functionality

Challenges

- What are the correct abstractions?
- How much of hardware should be exposed?

WHAT DOES OS PROVIDE: ROLE #2

Resource management – Share resources well

What is sharing?

- Multiple users of the system
- Multiple applications run by same user
- Multiple devices for same functionality

WHY SHOULD OS DO THIS ?

Advantages of OS providing resource management

- Protect applications at a common layer
- Provide efficient access to resources (cost, time, energy)
- Provide fair access to resources

Challenges

- What are the correct mechanisms?
- What are the correct policies?

OPERATING SYSTEM ROLES SUMMARY

Two main roles

- Abstraction
- Resource management

Goals

- Ease of use
- Performance
- Isolation
- Reliability
- …

COURSE APPROACH

OPERATING SYSTEMS: THREE EASY PIECES

Three conceptual pieces

1. Virtualization

2. Concurrency

3. Persistence

VIRTUALIZATION

Make each application believe it has each resource to itself

Demo

CONCURRENCY

Events occur simultaneously and may interact with one another

Need to

- Hide concurrency from independent processes
- Manage concurrency with interacting processes

Provide abstractions (locks, semaphores, condition variables etc.)

Demo with threads

PERSISTENCE

Lifetime of data is longer than lifetime of any one process

Machine may lose power or crash unexpectedly

Issues:

- High-level abstractions: Files, directories (folders), links
- Correctness with unexpected failures
- Performance: disks are very slow!

ADVANCED TOPICS

Virtualization

Concurrency

Persistence

Advanced Topics

- Virtual Machines
- Network File Systems
- SSDs

WHY STUDY OS ?

Build, modify, or administer an operating system

Understand system performance

- Behavior of OS impacts entire machine
- Tune workload performance
- Apply knowledge across many layers

Fun and challenging to understand large, complex systems

WAITLIST

If you are on the waitlist

- Keep attending classes
- Start working on projects
- Email enrollment@cs.wisc.edu

NEXT STEPS

Register on Piazza

First programming assignment out by tonight!

- Due Jan 29th (next Wednesday) at 10.00pm
- More details in discussion on Thursday

Welcome to CS 537!