CS 537: INTRO TO OPERATING SYSTEMS

Shivaram Venkataraman

Spring 2019

WHO AM I?

First 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

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 (50%)

- Midterm and final exams
- Closed book
- Assess OS concepts, abstractions discussed in class

Projects (50%)

- Five 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, 2:30PM - 3:45PM
Location: 1125 BioChem

Lecture notes, in-class discussion
Links to textbook chapters

Discussion

Thu 5.30PM-7:00PM
Location: 105 Psychology

Hands-on code walk through
Explain programming projects

PERSONNEL

Instructor: Shivaram Venkataraman

Teaching assistants: Saurabh Agarwal, Ram Alagappan, Alex Anderson, Setareh Behroozi, Yunang Chen, Varsha Pendyala, Yufei Wang

16 course staff!

Peer mentors: Arpit Jain, Anshu Verma, Xianjie Zheng, Siddhant Bhagat, Benjamin Yin, Youmin Han, Varun Ravipati, Yingdong Chen

IMPORTANT LINKS

Course website
http://pages.cs.wisc.edu/~shivaram/cs537-sp19/

Piazza
https://piazza.com/wisc/spring2019/cs537

CS 537 Intro to Operating Systems - UW Madison, Spring 2019

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 2019, UW Madison, 4 units.
- Instructor: Shivaram Venkataraman, Office hours: M 10-11AM, W 1-2PM at 7367 CS
- Teaching Assistants
- Lecture
  - Time: Tuesday and Thursday, 2:30PM - 3:45PM
  - Location: 1125 BioChem
- Discussion
  - Time: Thursday, 5:30PM - 7:00PM
  - 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

We will be using the *free* OS textbook Operating Systems: Three Easy Pieces. You can also buy a printed copy if you like from the same website.

For the programming projects, there are two textbooks that are recommended but not required

- The C Programming Language (2nd ed.): A book written by the people who invented C
- Advanced Programming in the UNIX Environment (2nd ed.): This is a complete guide to programming in the Unix environment and is useful if you want to become a Unix expert.

Pre-requisites

This course assumes familiarity with basic computer organization (e.g., processors, memory, and I/O devices as covered in CS354) and data structures (e.g., stacks and hash tables as covered in CS367). You will need to be able to program in C (not C++, not Java, not Python, not Javascript, not Ruby, etc.) to perform the assignments in the course. We will spend some time covering background, but learning C on your own is important and valuable.

Components

- Projects: 50%
- Midterm exam: 25%
- Final exam: 25%
- Homeworks: Optional homeworks corresponding to each chapter in the textbook.

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

Slip days: Maximum of three slip days through the semester. Use with care!

Academic integrity for projects:

It is DEFINITELY OK to:

- discuss the project in general terms (what do they mean by a pipe?)
- 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 already done!)
- share your code directly with other people/project groups

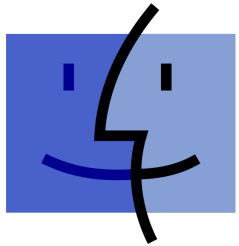
SUMMARY

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 ?



Mac OS

OS X Yosemite

Microsoft® Windows® xp

Users

Applications

Operating System

Hardware

WHAT DOES OS PROVIDE: ROLE #1

Abstraction: Provide standard library for resources

What is a resource?

- Anything valuable (e.g., CPU, memory, disk)
- What abstraction does modern OS typically provide?
  - CPU: process and/or thread
  - Memory: address space
  - Disk: files

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

Common layer to implement roles

Number of design, implementation challenges

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: Virtualize CPU and memory

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, please email

enrollment@cs.wisc.edu

NEXT STEPS

Register on Piazza

First programming assignment out by tonight!

- Due Jan 29th, (next Tuesday) at 11.59pm
- More details in discussion on Thursday

Welcome to CS 537!