CS 318 Principles of Operating Systems

Fall 2022

Lecture 21: Midterm 2 Review

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WHITING SCHOOL
of ENGINEERING

Course Plug

Reliable Programming with Rust

- EN.601.206 (13)
- A new course in January 2023 intersection
- Taught by the TA Yuzhuo Jing
- Rust is an increasingly popular systems programming language
- Recommend you to check it out

Midterm 2

Date & Location: Dec. 8th (Thursday), 1:30-2:45 pm, Hodson 311

Covers material in the second half of the class

- Most questions about lecture 10 to lecture 16
- A few basic questions for lecture 17 to lecture 20

Closed book, one and half double-sided 8.5”x11” pages of notes

Can use a calculator but no other electronic devices

Based upon lectures, homework, and project

- Do the homework to practice for the exam

Overview

Memory management

Paging

Page replacement

Disk I/O

File systems

The End

Memory Management

Why is memory management useful?

- Why do we have virtual memory if it is so complex?

What are the mechanisms for implementing MM?

- Physical and virtual addressing
- Partitioning, paging, and segmentation
- Page tables, TLB

What are the policies related to MM?

- Page replacement

What are the overheads related to providing memory management?

Virtualizing Memory (1)

What are the issues with physical addressing?

- Protection, transparency, resource exhaustion

What are the goals of virtual memory?

What are the advantages of virtual memory?

What is the difference between a physical and virtual address?

Which component does the translation and management?

Virtualizing Memory (2)

How does load-time linking work?

- What are its advantages and disadvantages?

How does partitioning work?

- Fixed-sized partitioning (base)
- Variable-sized partitioning (base + bound registers)
- What are its advantages and disadvantages?

What is internal fragmentation?

What is external fragmentation?

Segmentation

What is segmentation?

What is a segment table?

How is virtual address translated with segmentation?

What are its advantages and disadvantages?

How does it compare/contrast with paging?

How can paging and segmentation be combined?

Paging

How is paging different from partitioning?

What are the advantages/disadvantages of paging?

What are page tables?

What are page table entries (PTE)?

Know these terms

- Virtual page number (VPN), physical page number (PPN)/page frame number (PFN), offset

Know how to break down virtual addresses into page numbers, offset

How have you implemented paging in Pintos?

Page Table Entries

What is a page table entry? (In Pintos?)

What are all of the PTE bits used for?

- Modify
- Reference
- Valid
- Protection

Page Tables

Page tables introduce overhead

- Space for storing them
- Time to use them for translation

What techniques can be used to reduce their overhead?

How do two-level (multi-level) page tables work?

Know how to break down virtual addresses into page directory, page numbers, offset

TLBs

What problem does the TLB solve?

How do TLBs work?

Why are TLBs effective?

How are TLBs managed?

- What happens on a TLB miss fault?

What is the difference between a hardware and software managed TLB?

Page Faults

What is a page fault?

How is it used to implement demand paged virtual memory?

What is the complete sequence of steps, from a TLB miss to paging in from disk, for translating a virtual address to a physical address?

- What is done in hardware, what is done in software?

Advanced Mem Management

What is shared memory?

What is copy on write?

- Why is CoW useful?

When is copy on write used?

What are memory mapped files?

- What is the benefit of memory mapped file?
- What is its drawback?

Page Replacement

What is the purpose of the page replacement algorithm?

What application behavior does page replacement try to exploit?

When is the page replacement algorithm used?

Understand

- Belady's (optimal), FIFO, LRU, Approximate LRU, LRU Clock, Working Set, Page Fault Frequency

What is thrashing?

Dynamic Memory Allocation

What does dynamic memory allocator do and what it cannot do?

What are the decisions to make?

What is the strategy of a best-fit and first-fit allocator, respectively?

- What the potential problems for them

Why is buddy allocator proposed?

Why is slab allocator proposed?

Disk

Understand the memory hierarchy concept, locality

Physical disk structure

- Platters, surfaces, tracks, sectors, cylinders, arms, heads

Disk interface

- How does the OS make requests to the disk?

Disk performance

- What steps determine disk request performance?
- What are seek, rotation, transfer?

Disk scheduling: FCFS, SSTF, SCAN, C-SCAN

File Systems

Topics

- Files
- Directories
- Sharing
- Protection
- Layouts
- Buffer Cache

What is a file system?

Why are file systems useful (why do we have them)?

Files and Directories

What is a file?

- What operations are supported?
- What characteristics do they have?
- What are file access methods?

What is a directory?

- What are they used for?
- How are the implemented?
- What is a directory entry?

File System Layouts

What are file system layouts used for?

What are the general strategies?

- Contiguous, linked, indexed?

What are the tradeoffs for those strategies?

How do those strategies reflect file access methods?

Unix inodes

What is an inode?

- How are inodes different from directories?
- How to use inodes and directories used to do path resolution and find files?
  - Like in homework 3 exercise

How Unix inodes enable both efficient access of small files and growth of large files

- Direct blocks, in-direct blocks
- How to calculate file and disk access info given some inode info?
  - Like in homework 3 exercise

Where are inodes stored?

- What about data blocks?

File Buffer Cache

What is the file buffer cache, and why do operating systems use one?

What is the difference between caching reads and caching writes?

What are the tradeoffs of using memory for a file buffer cache vs. VM?

Protection

What is file protection used for?

How is it implemented?

What are access control lists (ACLs)?

What are capabilities?

What are the advantages/disadvantages of each?

Advanced File Systems

What is FFS, and how is it an improvement over the original Unix file system?

What is LFS, and how is it an improvement over FFS?

What is the file system consistent update problem?

- What are the possible crash scenarios and consequences?
- What are the different strategies to do the updates?
- What problems can the file system checkers (FSCK) fix?
- What is journaling and its steps?

Virtual Machine Monitors

What are the benefits of using virtual machines?

How to virtualize the CPU?

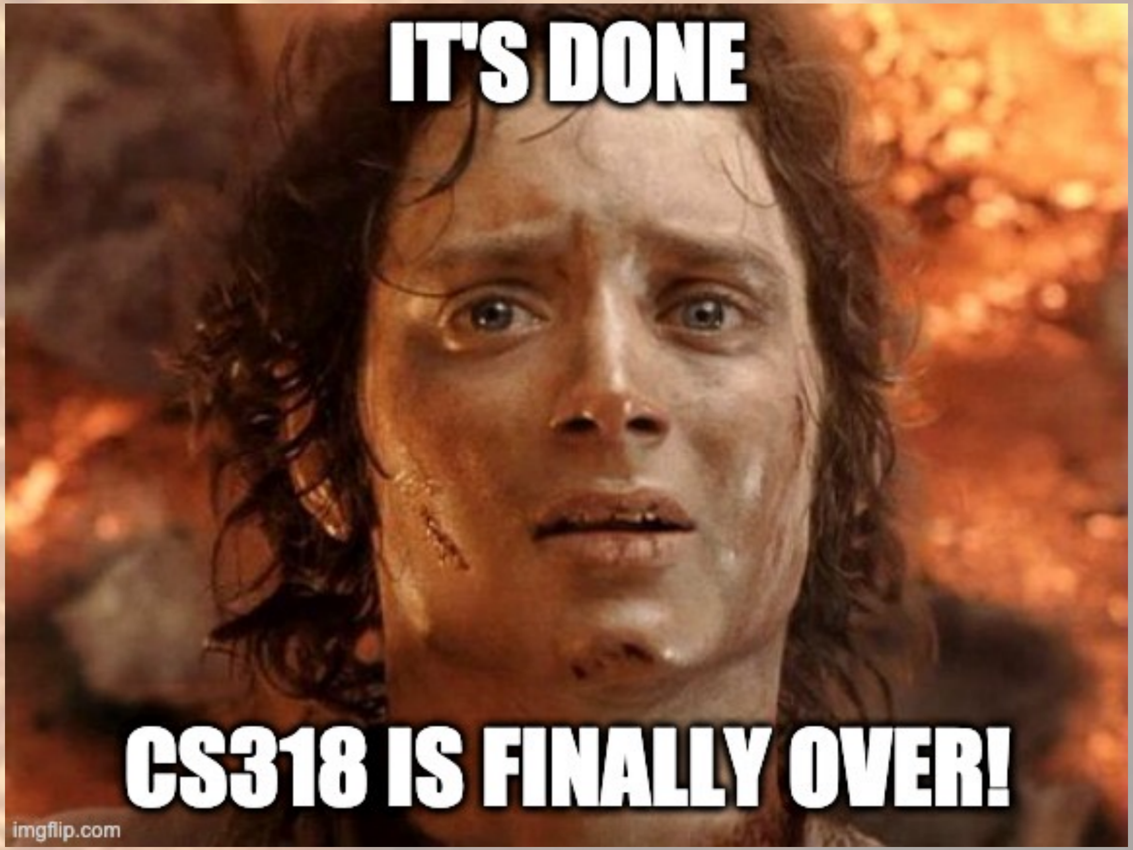
What is shadow page table and how does the VMM setup it?

Summary

Any remaining questions?

Concluding Remarks

Congratulations on (almost) surviving CS 318!



Concluding Remarks

It’s a challenging course

- It takes grit to take the course and stick to the end

But I hope you found it worthwhile

- that it helps improve your system programming skills

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- … and that you look at (& appreciate) OSes in a new way

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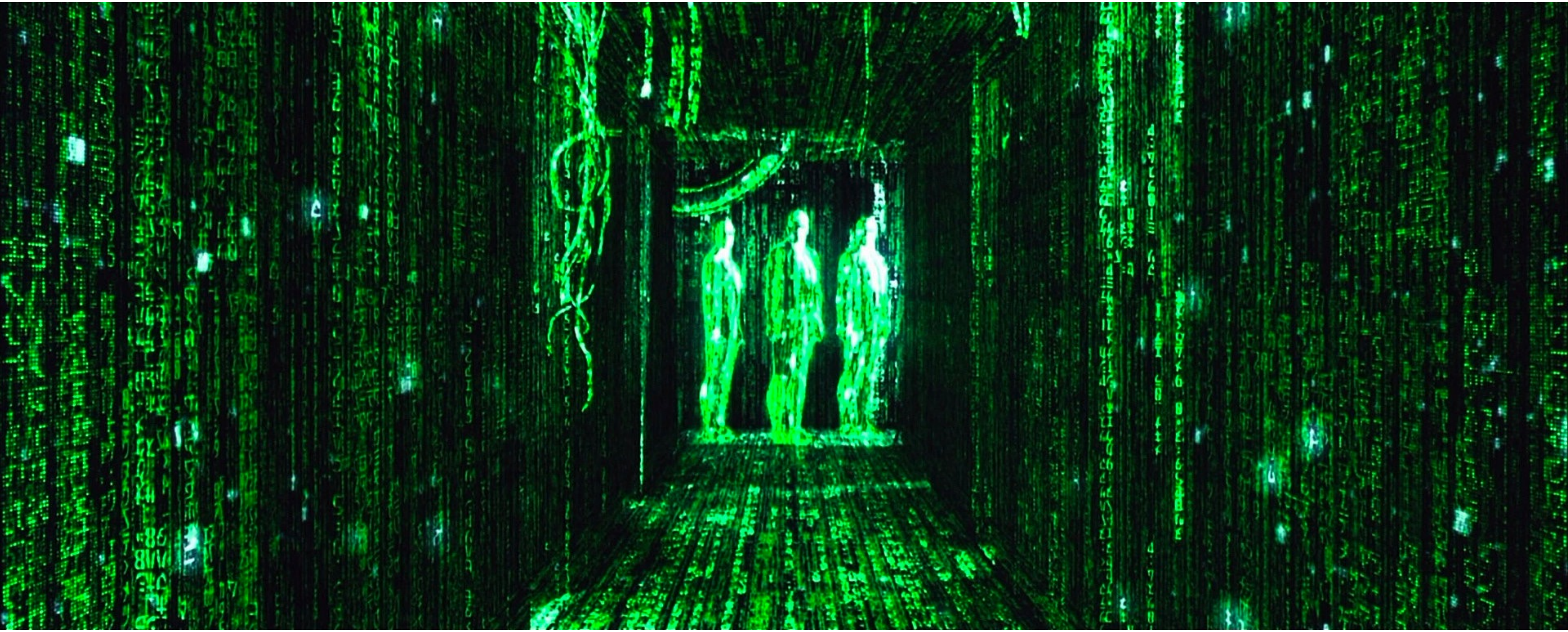


Acknowledgement

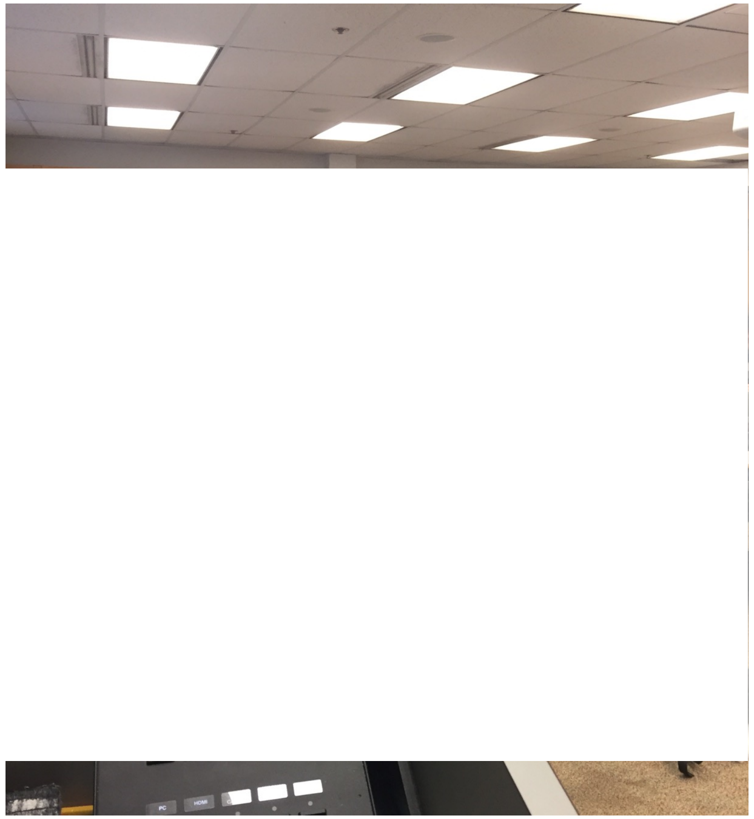
Special thanks to students who regularly attend the class

- It made a big difference

Thanks to Yuzhuo, Tony, and Brian

- This is a challenging course for both students and the TA/CAs
- They spread the much of the load to make the course possible

My Last Lecture at Hopkins



How it started (2017 Fall)

Four Take-Away Messages

1. **The devil is in the detail**
   - building systems needs elegant ideas, but just having ideas is far from enough

2. **Never underestimate the power of abstraction & indirection**
   - "All problems in computer science can be solved by another level of indirection" -- Butler Lampson

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3. **Dare to inspect, modify and rewrite any "mysterious" software**
   - You've gone through the [illegible] software is as complex as the OS
   - Hack like a champion

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3. **Dare to inspect, modify and rewrite any "mysterious" software**
   - "Every good work of software starts by scratching a developer's personal itch."
4. **System thinking**
   - Even if you forget how OS works, I hope you develop the habit of system thinking

The End

Good luck and take care!