15-410

"...This is a transformative class..."

Review
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Synchronization

Time is running out

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- **http://cmu.OnlineCourseEvaluations.com**

Synchronization

The end is nigh

Synchronization

The end is nigh

- But you can take 15-449/749 in the spring
  - http://www.cs.cmu.edu/~15-610/
  - Questions? satya@cs
- And/or 15-412 in the fall
  - http://www.cs.cmu.edu/~412
  - Questions? Eckhardt
- Compilers (15-411) is pretty transformative too
- 15-440 (Distributed), 15-441 (Networks), 15-712 (Grad OS), 15-418 (Parallel Architecture)
- We also have a nice database class, 15-415
  - More concurrency, more lock types, logging

Synchronization

Homework 2 due tonight

- Solutions will be released "immediately"
- ⇒ No late days
- ~ 1/3 have already turned in all or part (good)
- Don't forget to try storing files in your hand-in directory *before* the deadline!

Book report due tonight

Exam some time in the next month

- http://www.cmu.edu/hub/docs/final-exams.pdf

Synchronization

P3 grading guidance reminder

- Weights are approximate

~50% shell works (w/o horrible hacks)

~30% tests

- 10% basic
- 15% stress, trickiness, argument verification
- 5% threads

~10% structure/style

~10% concurrency (preemption, locking, synch)

Synchronization

Exam will be closed-book

- *But you may bring a 1-sided 8.5x11 sheet of notes*
  - WRITTEN BY YOU IN YOUR OWN HAND
  - WRITTEN BY YOU IN YOUR OWN HAND
- *Weakly* non-cumulative
  - Emphasis on new material, design questions
  - You will need to use some "old" knowledge
  - We didn't really test on "P2 knowledge" (nor P3)
  - Recall: VM was off-limits on mid-term (and you've done it)
- Mixture of fact/concept testing and *design*

Synchronization

About today's "review"

- More "reminders" than "course outline"
  - Un-mentioned topic implies "text & lectures straightforward"
- Reading *some* of the textbook is advisable!

Read Your Code

- Re-read your P2
- Re-read your P3
- Go over feedback
- Talk about code with your partner
  - Schedule a time
- You should understand “the hard parts”
  - Focus on whichever part you know least well
    - (or fear the most)

"Concept" Lectures

We *could* ask a question about these topics...

- **...we would give you guidance/refresh your memory**

Examples

- **Windows device-driver architecture**
- **Lock-free programming**
  - **As an educated person in 2013, you should understand the motivation and basic approach**
- **Transactions**
  - **As an educated person, you should understand write-ahead logging**
  - **Fancy locking that only transaction systems use is not your responsibility**

Core “Phase I” concepts

Machine model

- Registers
  - “regular”
  - “special”
- Interrupt (vs. exception – how they differ, why)

Process model

- You should be a memory-map *expert*
  - Kernel space, user space, virtual memory
- Process vs. thread
- *Exactly* what goes on a stack, where it comes from...

Core “Phase I” concepts

Mutual exclusion

- mutex, cvar, what's inside, why

Concurrency

- Race-condition expert!
- Be able to explain one to your nephew
  - (the one you'll visit over break)

Deadlock

- Ingredients
- Various approaches to coping

Virtual Memory

The Game

- Maintain multiple illusions (aka “address spaces”)

Players

- High-level info (what uses which regions, COW/ZFOD)
- Mapping data structure (typically set by processor)
- TLB – cache of v-to-p translations from that data structure
  - “flush” - when, why, how?

Behavior of the Players

- Mappings are *sparse*
- This explains the ways they're implemented

Thread Scheduling

Round-Robin

Things people do

- **Multi-level feedback queues**

Be careful!

- **Priority**

Disk scheduling

- Spinning platter/waving arm model
- Seek time vs. rotational latency
- FCFS, SSTF, SCAN, LOOK, C-SCAN, C-LOOK, SPTF, WSPTF
- Fairness, mean response time, variance, starvation

Disk Array Overview

Historical practices

- Striping, mirroring

The reliability problem

- More disks ⇒ *frequent* array failures
- *Cannot* tolerate 1/N reliability

Parity, ECC, why parity is enough

- Erasure channels
  - Good terminology to display at parties

Disk Array Overview

RAID “levels” (really: flavors)

- Understand RAID 0 & 1, 4 vs. 5
- What they're good for, why

File Systems

Data access model

- What it means for a file to be “open”

Cache issues

Naming

- Directory flavors, mounting

Core problem: block mapping

- Compare data structures to VM
- “Holes”

Architecture

- Layering to support multiple file system types, ...

IPC

Communicating process on one machine

Naming

- Name server?
- File system?

Message structure

- Sender id, priority, type
- Capabilities: memory region, IPC rights

Synchronization/queueing/blocking

IPC

Group receive

Copy/share/transfer

A Unix surprise

- **sendmsg()/recvmsg() pass file descriptors!**

RPC Overview

RPC = Remote Procedure Call

Extends IPC in two ways

- **IPC = Inter-**Process **Communication**
  - **OS-level: bytes, not objects**
- **IPC restricted to single machine**

Marshalling

Server location, call semantics

Marshalling

Values must cross the network

Machine formats differ

- Serialize/de-serialize
- Format/packing
- Type mismatch issues

"The pointer problem"

RPC Overview

Call semantics

- Asynch? Batch? Net/server failure?

Client flow, server flow

- Client stub routines, server dispatch skeleton

Java RMI

- (have some sense - obviously, we didn't make you use it)

Parallelism: Introduction

Why parallelism is here to stay

- "Power density wall"

Parallel programming models

- Shared address space
- Message passing
- Data-parallel

Keys to achieving high performance with parallelism

- *Avoid time in serial execution phases* (Amdahl's Law)
- Evenly *balance work* across threads
- *Minimize communication* between threads
- *Minimize synchronization time* (time threads are stalled)
- *Minimize extra work* spent managing parallelism

Parallelism: Memory Hierarchy

TLB shoot-down

- What is it? Why do we need it?
- How does it work?
- Why does it get slower as we add processors?

Cache coherence

- Standard “MESI” invalidation protocol
  - Modified/Exclusive/Shared/Invalid
- New sources of cache misses
  - “True sharing” vs. “False sharing”
  - How false sharing might occur in the kernel, how to avoid it

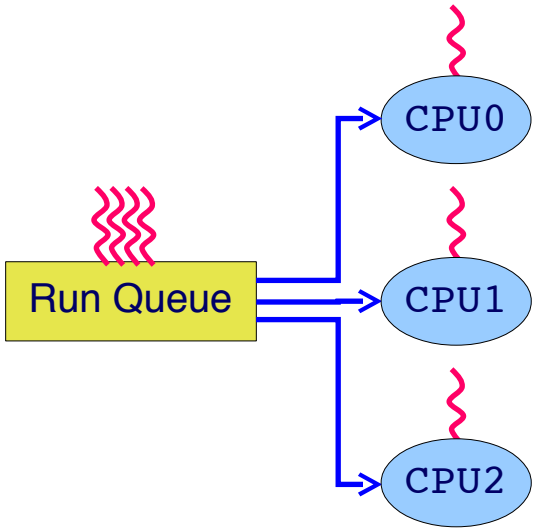
Parallelism: Multiprocessor Scheduling

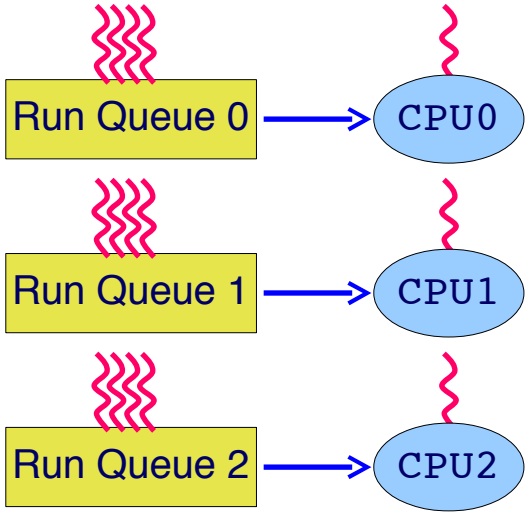
New scheduling goals

- *Load balancing* and *affinity*

Tradeoffs between *centralized* vs. *distributed* queues

- Distributed queues with *work stealing*





Parallelism: Memory Consistency

Sequential consistency

- What programmers intuitively expect...
- ...but which few machines actually provide

Weaker consistency models

- "Total Store Ordering", "Release consistency"

Data Races

Properly synchronized programs

- All synchronization explicitly identified
- All data accesses ordered through synchronization

Fence operations

- Explicit (MFENCE, etc.) or implicit (XCHG)
- Do *not* use "regular load/store" for synchronization

Parallelism: Synchronization Re-visited

Spinning vs. blocking

Coherence traffic **from a simple spin lock**

```
while (!xchg(&lock_available, 0)) continue;
```

"Test-and-test-and-set" lock

- How they work and why they help

Avoiding a lock-release traffic burst

- Backoff, "ticket locks"

Queueing locks

- Array-based, list-based

Transactional memory

- Motivation and programmer model

Protection Overview

Protection vs. Security

- Inside vs. outside "the box"

Objects, operations, domains

Access control *(least privilege)*

3 domain models

Domain switch (setuid example)

Multics ring architecture

Access Matrix

- Concept and real-world approaches

Security Overview

Goal / Threat / Response tuples

Malware

- Trojans, trapdoors
- Buffer overflow
- Viruses, worms

Password files, salt

- What is the threat, how does the technique help

Biometrics vs. cheating

Security Overview

"Understand cryptography"

- What *secure* hashing is good for
- One-time pad
- Symmetric (private-key) crypto
  - Small, "password-like" keys
- Asymmetric (public-key) crypto
  - Has private keys and public keys
  - And, in practice, symmetric session keys – know how/why
- The mysterious nonce
- Kerberos
  - Symmetric crypto
  - Central server avoids the n^2 key problem

Transactions

Basic concept

- ACID properties
- Begin/Commit/Roll-back

Write-ahead logging

- Why it works
- Value logging (ok to skip operation logging)
- Crash-restart processing (undo/re-do)

Preparation Suggestions

Sleep well (***two*** nights)

Scan lecture notes

Read any skipped textbook sections

- **Well, the most-important ones, anyway**

Understand the code you turned in

- **Even what your partner wrote**
- **What are the hard issues, why?**

Preparation Suggestions

Prepare a sheet of notes

Read comp.risks & Effective Java

- Ok, after the exam will suffice

Don't panic!

- Budget time wisely during exam
  - (don't get bogged down on one question)

15-410 on One Slide

What a process/thread *really is*

- (the novel-length version, not the fairy tale)

Concurrency & synchronization

- Issues, mechanisms, *hazards*

How the pieces of hardware fit together

- ...to make a "system" which can run "programs"

A sense of "what's out there" beyond the kernel

Skills for non-small software artifacts

- Design, debugging, partnering
- Documenting, source control

Closing Thought

To understand a program you must become both the machine and the program.

-Alan Perlis