Final Review

CSE 220: Systems Programming

Ethan Blanton & Carl Alphonce

Department of Computer Science and Engineering

University at Buffalo

Logistics

Your final will be Friday, December 15 at 7:15 PM.

It will be held in Knox 20. Watch HUB for changes.

You will need:

- Yourself
- A writing instrument
- Nothing else

If you are late, you will not be admitted to the room.

The exam is closed book, closed notes.

Integers and Integer Representation

- The CPU and memory deal only in words
- Buses and registers have native word widths
- Integers have different:
  - Bit widths
  - Endianness
  - Sign representation
- Ones' and two's complement representation
- Bits also have to represent fractional values.

Bitwise Operations

- C can manipulate individual bits in memory.
- Bit operations can be subtle and tricky!
- Signedness matters.
- Bit manipulations can force endianness or other representations.

Dynamic Memory Allocation

- The OS notion of the heap is very simplistic.
- The dynamic allocator has to manage the heap.
- Metadata is required for management.
- The heap can become fragmented:
  - Internal fragmentation is inside heap blocks.
  - External fragmentation is between heap blocks.

Virtual Memory

- Virtual memory:
  - uses a memory management unit
  - allows the CPU to operate in a virtual address space that may be different from the physical address space
  - the MMU translates virtual addresses to physical addresses
- Paging is a common model for virtual memory.
- Paged systems break both address spaces into pages.
- Pages can be mapped individually between virtual and physical addresses.
- Page tables allow the MMU to translate addresses.
- Page faults bring mapped but unallocated pages into memory.

Processes, Threads, and Concurrency

- Logical control flows are execution steps through programs.
- Concurrency is multiple logical control flows at one time.
- Multiprocessing versus Multitasking
- Processes versus Threads

Races and Synchronization

- A race is a situation where program correctness depends on the order of operations in concurrent flows.
- Data races are races involving modification of data.
- Synchronization is the deliberate ordering of events.
- A critical section is a region of code that must be accessed by at most one concurrent flow at a time.
- Synchronization primitives:
  - Atomic operations
  - Mutexes
  - Semaphores
  - Condition variables
- Deadlock is a program error caused by synchronization.

POSIX Threads and Synchronization

- The POSIX threads (pthreads) API provides a thread abstraction on Unix
- POSIX provides many synchronization primitives:
  - Mutexes
  - Semaphores
  - Condition variables
  - Thread joining
- CS:APP covers semaphores in detail

Programming Practices

- Cultivate good work habits
- Design your programs purposefully
- Use your tools!
- Practice good style and form
- Debug with a plan

The only way to become a good programmer is to write programs.

The Kernel and User Mode

- Exceptions are special control flow
- Protection domains control access to hardware resources
- Exception handlers run in supervisor mode in the kernel
- Special trap exceptions can be used to implement system calls
- System calls allow user mode programs to request access to the kernel

Input and Output

- Unix I/O is defined by the POSIX Standard
- Standard I/O is defined by the C Standard
- The kernel tracks open files with file descriptors
- All file I/O goes through the kernel
- The standard I/O library is buffered

Caching and Locality

- The CPU is much faster than memory or disks.
- The difference in speeds is growing.
- Programs exhibit locality:
  - Spatial
  - Temporal
- Caching depends on locality to improve performance.
- Writing good programs requires understanding locality.

License

To retrieve a copy of this material, or related materials, see `https://www.cse.buffalo.edu/~eblanton/`.