CMPS 311

Operating Systems

Course Objectives

- Programming with Processes and Threads
- Evaluating and Analyze Scheduling, Synchronization, and Deadlock Algorithms
- Understand the design of Memory Management and Paging Systems
- Understand the design of File Systems
- Evaluate and Analyze Security issues within an OS

What this course is *not*

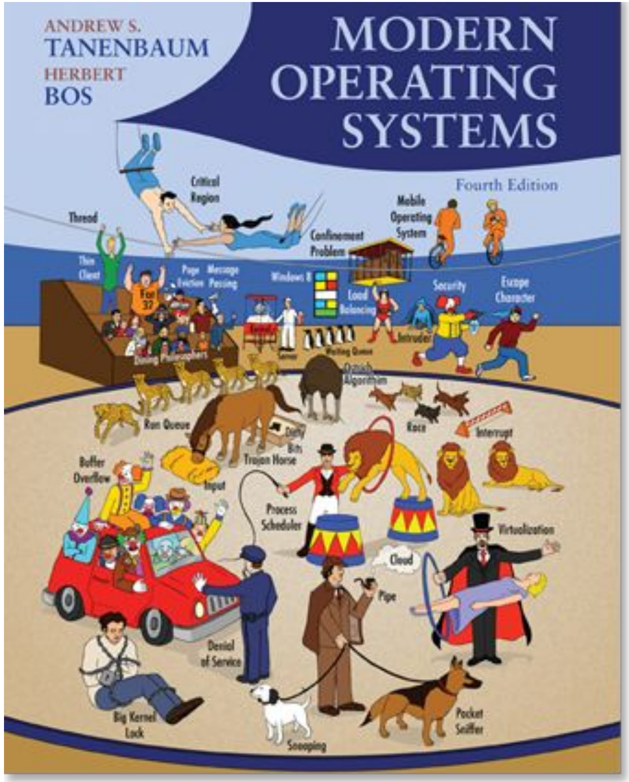
This is about the **design** of operating systems

- Its not about learning to *use* an operating system
- Its not about administering an operating system
- Its not a comparison of operating systems - we'll focus more on commonalities, not the differences.

Textbook

- Modern Operating Systems
  - Andrew Tanenbaum
  - Herbert Bos
  - **4th Edition**

- We will make heavy use of book - you need to buy it!



Using the Textbook

- This is **not** primarily a programming course
- This is a **concept** course
- I expect you to read the textbook carefully ***before class***. The concepts are difficult - and you'll find the lectures extremely confusing if you are unprepared.

This is **not an introductory course!**

Programming Environment

- Operating System programming is typically done in C (and a little C++... sometimes)
- We'll cover C - with the expectation that you already know C++ extremely well
- We will do our programing in the POSIX environment
  - This means if you use Windows, you need to install Linux
  - Mac OS X users - you're all set already.

Linux

I’ll cover this in more detail in the coming lectures… but for now:

If you are running Windows you can:

1. Dual Boot (use Ubuntu or Linux Mint)
2. Run Ubuntu or Mint in a Virtual Machine (Virtual Box)
3. Setup a smaller VM called Vagrant (recommended)

How you ask?

You are expected to read the course's website/syllabus carefully

- http://pages.ramapo.edu/~sfrees/courses/cmps311/
- Its also linked to from Moodle
- I have provided **detailed** instructions on setting up Vagrant.

Programming

- Programming is used to *reinforce* the concepts we are learning
- It will be critical that you are programming in the correct environment - so you need to **pay attention to directions!**
- You will also be expected to **learn on your own**. There will be many OS function calls that you'll need to call in your programs - and I won't cover them all in class!

Homework

- There will be (around) 7 homework assignments
  - Blend of written + programming
  - Homework is worth a ***total*** of 10% of your grade
  - All homework will be submitted through Moodle
  - 10 points per day late, maximum 5 days late.

Exams

We will have 3 exams (plus the Final)

- 2/18 - Chapters 1.1 - 2.2
- 3/14 - Chapters 2.3 and 2.4
- 4/15 - Chapter 3
- Final Exam covers Chapter 1-6 + parts of Chapter 9

Each exam is worth 20% of your final grade

The final exam is worth 25%

Exams

Exams are:

Closed book.

Closed notes.

Closed computer.

I will allow you to bring in one sheet of notes (double sided).

You will have the entire class period to complete them.

Written Requirement

- This is a **writing intensive (WI)** course
- You will have a 10 page paper due at the end of the semester
- Don’t worry about it just yet - I will discuss further in mid-March.
- It is worth 2.5% of your grade.

Attendance and Participation

I measure your attendance not just by your physical presence…

- Participation and Alertness

Simply showing up to every class, only to sleep or watch YouTube will result in a poor attendance grade.

Class Participation

- Your participation **makes** this class.
- Operating systems can be a really interesting topic - because you are learning about something you use **every day**.
- The class is about **design** of Operating Systems - and there are often no perfect answers - which lends itself to discussion!
- Ask questions, we have time!

Contact Information

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Email is the best method of contact

Operating Systems Overview

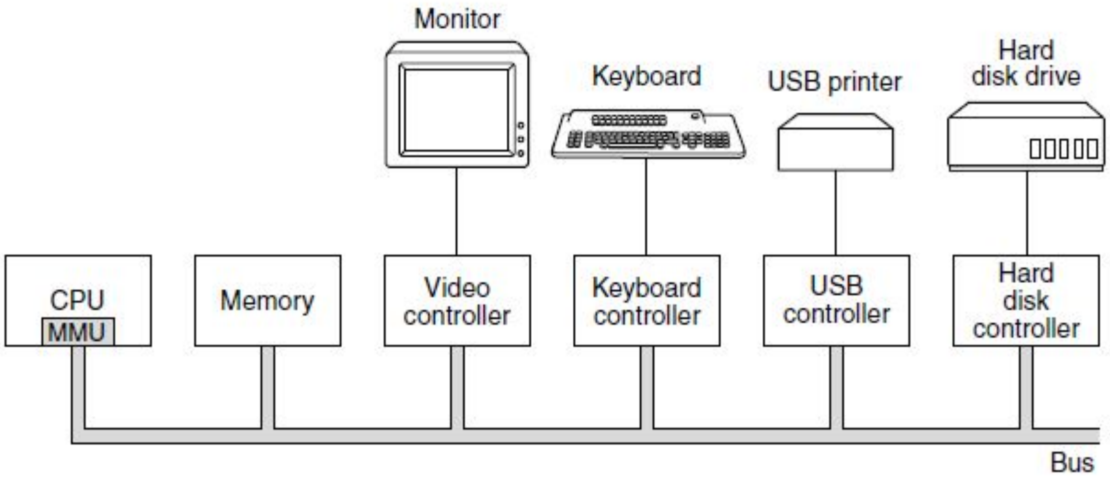
Module 02

Textbook

This module covers Chapters 1.1-1.5 in the textbook.

Anatomy of a (Personal) Computer

An operating system manages devices - often called resources. What sort of devices?



Categories of Devices (my terminology)

Core Devices: CPU, Memory, Storage (Disc)

- We'll spend the bulk of the semester here
- About 50-60% of the semester is just CPU and memory!

Peripherals: *Everything else*

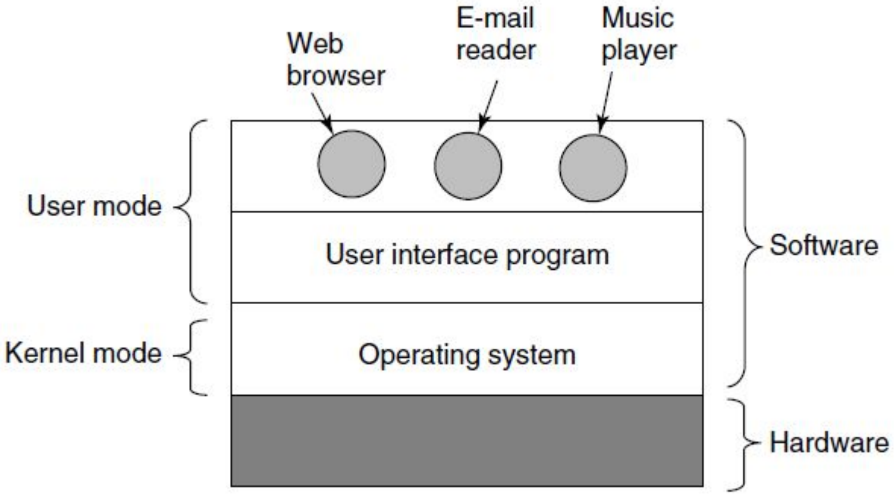
Where is the OS?

An operating system ***is a program***.

- Its written in a normal language (C and C++ with a little Assembly).
- It is stored on disc
- It is loaded into memory
- It’s instructions are executed by the CPU

It's not really all that special!

Where is the OS?



Conceptually, the OS is different

It sits between "User programs" and the hardware

Types of Programs

The operating system can be thought of as a ***collection*** of programs - commonly called the kernel

All other programs are called user programs

Some are used by real people, others are behind the scenes - but none have direct access to the hardware.

What's a user?

When we say user, we don't mean a person…

We mean a **program** that is not part of the kernel.

- This distinction is **critical**
- User programs might have a real user interface - but that's besides the point!

Why do we call a program a user?

- The operating system provides access to devices through function calls
  - An **Application Programming Interface (API)**
  - Programs **<u>are</u>** the "customer" - they call the OS's API to do things like:
    - print to the screen
    - read data from disc
    - draw to the frame buffer

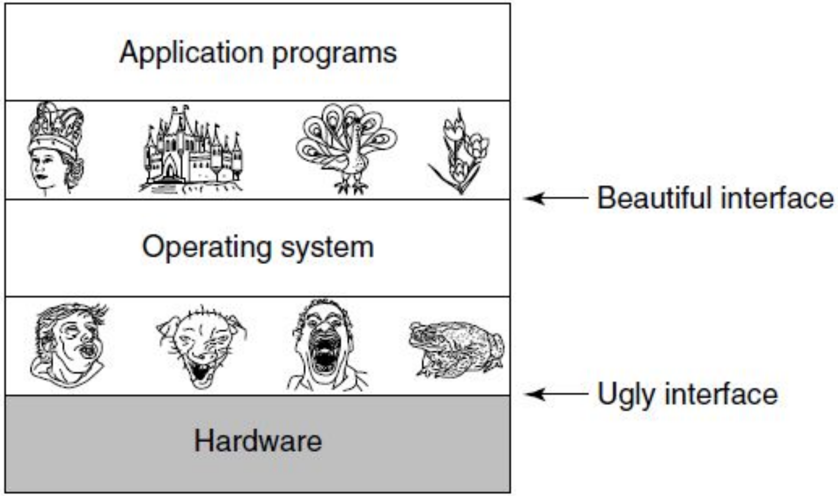
Why not?

Why don’t user programs have access to devices?

You probably don’t want access...

Sure, the OS needs to ensure everyone is sharing the resources...

However in addition, its the OS that shields programs from the **horrors of all the device API’s!**



Summarizing the OS's role

Bottom-up view: Ensures orderly, safe, and fair use and allocation of resources

Top-down view: Provides abstractions to simplify access to a diverse set of devices

The most important resource: CPU

Lets diagram a CPU - what are the important components?

- ALU
- Registers
- Control Unit
- Special Registers - PC, PSW (Program Status Word), etc.

This is overly simplistic - but is sufficient

The most important resource: CPU

Programs are stored in memory - linear arrays of *instructions*

- Instructions are **fetched** by examining the PC
  - Instruction decoded
  - For mathematical operations
    - Operands flow into ALU
    - Results flow out of ALU, stored in registers
  - For load/store operations
    - Memory addresses are read into registers
    - Or registers values are saved to memory
  - And then… there’s I/O instructions

Instruction Fetch is endless... until I/O

- Mathematical, Jump, and Load/Store operations are done completely by the CPU
    - CPU just keeps... going...
        - It runs a single program!

I/O and the CPU

- I/O instructions require another device:
    - Write to frame buffer (screen)
    - Read from Disk
    - Wait for Key-press
- This is very bad…
    - If there are other programs that *could* run, it would be nice to let the CPU keep running - **those programs**.

Multiprogramming

- On an I/O call, the current state of the CPU is copied into memory
  - Registers, PC, etc.
- Another program is **selected** and its next instruction is **loaded** into the PC.
- And the CPU goes on its way...

The CPU will get notified when the I/O device is done, we'll deal with this in a few minutes...

Who does all this?

The Operating System!

- The OS runs when there is an I/O call, or when a program terminates (we'll see how shortly)
- The OS picks a new program, and loads the PC with the appropriate memory address for the instruction
- This is called a **context switch**.
- This portion of the OS is called the ***Scheduler***

This is called Multiprogramming

I/O Devices and Interrupts

Once an I/O device is started (read data) - it must have some way of **interrupting** the CPU - which will be furiously running the computations of another program

I/O Device when it's done

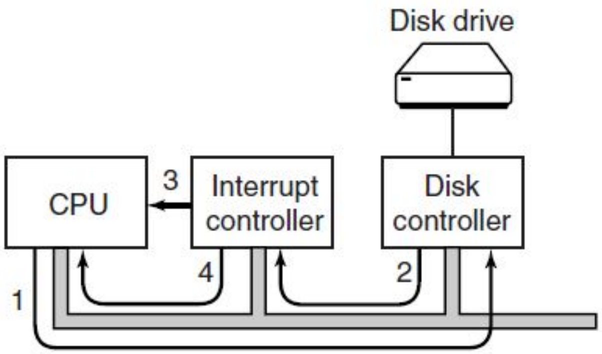
CPU

Interrupt

The CPU is simply a circuit

There are "wires" fed into it that trigger logic

One wire, if "**signaled**" will break the normal instruction fetch cycle



Interrupt Handlers

The CPU is configured to automatically set the PC to a predefined location in memory

- This location is called the interrupt vector
- It contains code that will
  - Examine the signal (stored in a register now) to determine which type of interrupt was fired
  - Handle/Process the interrupt
    - The interrupt vector is part of the OS

Timers as Interrupts

Let's say the CPU is running a user program:

```
while (true) {
    // I’m doing stuff...
}
```

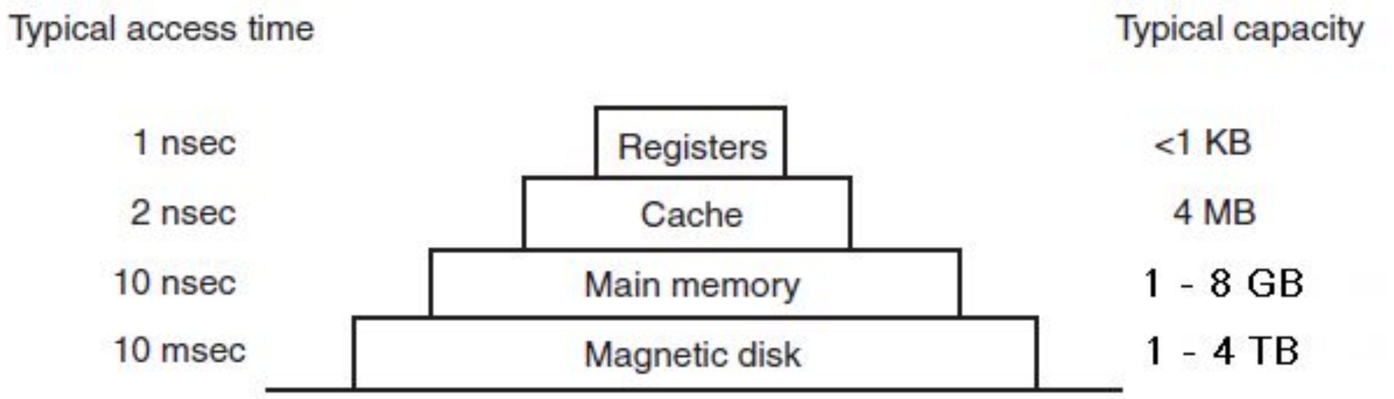
Unless the OS has a way of ***interrupting*** the user program - the OS might never be able to run again!

The Memory System

Memory ***should*** be as fast as the registers on the CPU, large enough to hold all of our programs, and cheap

No memory device is all three

A bit about caching



Part of the OS’s responsibility is to work with the hardware to make this seamless to the user program.

The Memory System - Protection

Multiprogramming tells us *multiple* programs are in memory:

- Another job of the OS is to make sure programs can't access each other's memory addresses
- This is harder than it seems, since they all think they "own" address 100 (for example)
- Its called Memory Management and Virtual Memory - and we'll cover it in **late February**

Fundamental OS Abstractions

Processes - a running program (plus its state). We'll be covering this first.

Address Space - the list of memory addresses available for variables, code, and the like. We'll be covering this in more detail in October

Files and Devices - common interface for user programs to read/write data. March & April

Next time

Read Chapters 1.5-1.6 on System Calls and OS Organization