TCSS 422: OPERATING SYSTEMS

INTRODUCTION

Wes J. Lloyd
Institute of Technology
University of Washington - Tacoma

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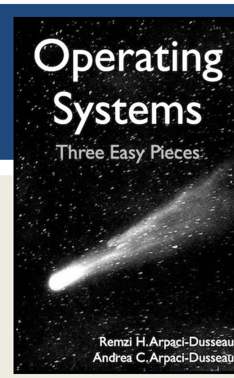
OBJECTIVES



- Syllabus, Course Introduction
- C Review
- Demographics Survey
- Chapter 4: Operating Systems – Three Easy Pieces
  - Introduce operating systems
  - Management of resources
  - Concepts of virtualization/abstraction
  - CPU, Memory, I/O
  - Operating system design goals

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TCSS422 – SPRING 2018
COMPUTER OPERATING SYSTEMS

- Syllabus
- Grading
- Schedule
- Assignments

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TCSS 422 – Spring 2018
Special features!

TCSS 422 SPRING 2018

- ***Going green...***
  - 20% reduction of carbon footprint
- 16 in person class meetings
  - Online lectures:
    Monday April 16, Wednesday April 18
  - No class:
    Monday April 9, Monday May 28
- Saves commuting time
  - Less fuel expenses
- Easier to achieve perfect attendance
- Final exam Monday June 4th
  - 71 days from now...

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TCS422 COURSE WORK

- **Assignments**
  - Assignment 0: Linux /scripting
  - Assignments 1 – 3 *(4)*: roughly every two weeks
- **Quizzes**
  - ~ 6-8 quizzes
  - Drop lowest two
  - Variety of formats: in class, online, reading, tutorial / activity
- **Exams: Midterm and Final**
  - Two pages of notes, calculator
  - Final exam is comprehensive, with emphasis on new material

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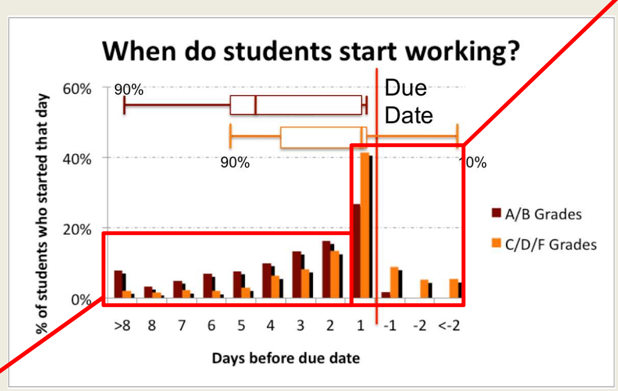
TCSS 422: PROGRAM DUE DATES

- Programs - please start early:

Less than 50% chance of A/B



Better than 50% chance of A/B

From Virginia Tech Department of Computer Science - 2011

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TCSS 422: PROGRAM DUE DATES

- Programs - please start early
  - Work as if deadline is several days earlier
  - Allows for a "buffer" for running into unexpected problems
    - Underestimation of the task at hand
    - Allows time to seek C help from SCI 106/108 lab mentors
    - If less familiar with C/pointers (TCSS 333), ***BUDGET MORE TIME***
  - This quarter: 5% bonus for submitting *on the original posted due date*
    - Excludes any class-wide extensions

UBUNTU 16.04 – VIRTUAL MACHINE

- Ubuntu 16.04
  - Open source version of Debian-package based Linux
  - Package management: "apt get" repositories
    - See: https://packages.ubuntu.com/
- Ubuntu Advantages
  - Enterprise Linux Distribution
  - Free, widely used by developers
  - Long term releases (LTS) every 2 years, good for servers
  - 6 month feature releases, good for sharing new features with the community

UBUNTU 16.04 – VIRTUAL MACHINE INSTALLATION

- Ubuntu 16.04
- Search online for YouTube videos, tutorials
- Search how to install the "Guest Additions"
  - Provides file system sharing, clipboard integration, mouse tricks
- Windows 10
- https://www.youtube.com/watch?v=DPIPC25xzUM
- Mac OS X
- https://www.youtube.com/watch?v=sNixOS6mHIU

C PROGRAMING IN TCSS 422

- Many OSes are coded primarily in C and Assembly Language
- Computerworld, 2017 Tech Forecast Survey

What legacy platforms do you still support and hire for?

None	65%
DB2	13%
C	10%
Cobol	9%
Assembly language	8%
Perl	5%
Delphi Object Pascal	3%
Fortran	3%
REXX	3%
Pascal	2%
Other	9%

C MENTORING

- https://www.tacoma.uw.edu/institute-technology/student-support-workshops-mentors
- Institute of Technology Mentors
- Located in Science 106 / 108 Labs
- Monday – Thursday: ~10 am – 7 pm
- Friday: ~ 12-5pm
- Spring quarter hours to be posted

INSTRUCTOR HELP

- Office hours: to be announced, and by appointment
- End of class: good for quick questions, assignment Q&A
- It will be difficult to tutor ***all*** 50 students individually on C
- Take ***ownership*** of your educational outcome
  - Time spent in TCSS 422 is just ~0.4% of an IT career
  - Make the most of this ***limited*** time
    - Maximize your educational investment
  - *** Ask questions in class ***
  - Also questions after class, email, Canvas discussion boards
  - Seek help using UWT resources, the internet, YouTube videos (video.google.com) and online tutorials

CLASS PARTICIPATION

- **Questions and discussion are strongly encouraged**
  - Leverage your educational investment
  - All questions are encouraged! All are good!
  - Better to ask redundant questions, than to be unsure!
- **Daily feedback surveys**
  - Helpful to know if topics are not clear
  - Use the survey to write questions that come to you during the lecture
- **Poll-EV to be introduced**

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C REVIEW

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DEMOGRAPHICS SURVEY

http://faculty.washington.edu/wlloyd/courses/tcss422/announcements.html

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INTRODUCTION TO OPERATING SYSTEMS

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VIRTUAL MACHINE SURVEY

- Please complete the Virtual Machine Survey is wanting an Institute of Technology hosted Ubuntu 16.04 VM

- https://goo.gl/forms/w9VWqkX756yXBUBt1

OBJECTIVES

- Chapter 2: Operating Systems – Three Easy Pieces
  - Introduction to operating systems
  - Management of resources
  - Concepts of virtualization/abstraction
  - THREE EASY PIECES:
    - Virtualizing the CPU
    - Virtualizing Memory
    - Virtualizing I/O
  - Operating system design goals

OPERATING SYSTEMS

- Responsible for:
  - Making it easy to **run** programs
  - Allowing programs to **share** memory
  - Enabling programs to **interact** with devices

OS is in charge of making sure the system operates correctly and efficiently.

RESOURCE MANAGEMENT

- The OS is a resource manager
- Manages CPU, disk, network I/O
- Enables many programs to
  - **Share** the CPU
  - **Share** the underlying physical memory (RAM)
  - **Share** physical devices
    - Disks
    - Network Devices
    - …

VIRTUALIZATION

- Operating systems present **physical resources** as **virtual representations** to the programs sharing them
    - Physical resources: CPU, disk, memory, …
  - The virtual form is "**abstract**"
  - The OS presents an illusion that each user program runs in isolation on its own hardware
  - This virtual form is general, powerful, and easy-to-use

ABSTRACTIONS

- What form of abstraction does the OS provide?
  - CPU
    - Process and/or thread
  - Memory
    - Address space
    - → large array of bytes
    - All programs see the same "size" of RAM
  - Disk
    - Files

WHY ABSTRACTION?

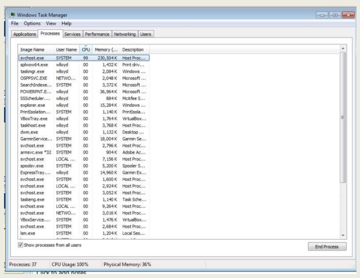
- Allow applications to reuse common facilities
- Make different devices look the same
  - Easier to write common code to use devices
    - Linux/Unix Block Devices
- Provide higher level abstractions
- More useful functionality

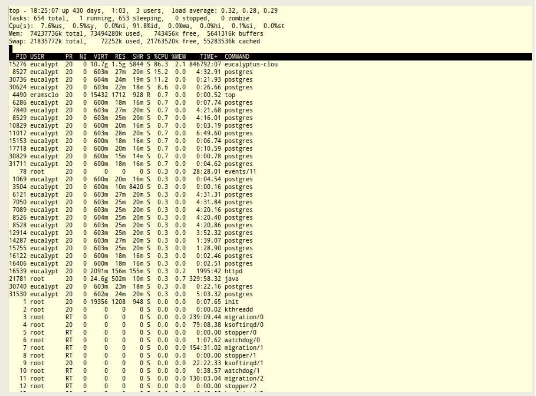
ABSTRACTION CHALLENGES

- What level of abstraction?
  - How much of the underlying hardware should be exposed?
    - What if **too much**?
    - What if **too little**?
- What are the correct abstractions?
  - Security concerns

VIRTUALIZING THE CPU

- Each running program gets its own "virtual" representation of the CPU
- Many programs seem to run at once
- Linux: "top" command shows process list
- Windows: task manager





VIRTUALIZING THE CPU - 2

- Simple Looping C Program

```
#include <stdio.h>
#include <stdlib.h>
#include <sys/time.h>
#include <assert.h>
#include "common.h"

int
main(int argc, char *argv[])
{
        if (argc != 2) {
                fprintf(stderr, "usage: cpu <string>\n");
                exit(1);
        }
        char *str = argv[1];
        while (1) {
                Spin(1); // Repeatedly checks the time and returns once it has run for a second
                printf("%s\n", str);
        }
        return 0;
}
```

VIRTUALIZING THE CPU - 3

```
prompt> gcc -o cpu cpu.c -Wall
prompt> ./cpu "A"
A
A
A
^C
prompt>
```

- Runs forever, must Ctrl-C to halt…

VIRTUALIZATION THE CPU - 4

```
prompt> ./cpu A & ; ./cpu B & ; ./cpu C & ; ./cpu D &
[1] 7353
[2] 7354
[3] 7355
[4] 7356
A
B
D
C
A
B
D
C
A
C
B
D
...
```

Even though we have only one processor, all four of programs seem to be running at the same time!

VIRTUALIZING MEMORY

- Computer memory is treated as a large array of bytes
- Programs store all data in this large array
  - Read memory (load)
  - Specify an address to read data from
  - Write memory (store)
  - Specify data to write to an address

VIRTUALIZING MEMORY - 2

- Program to read/write memory:

```
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>
#include "common.h"

int
main(int argc, char *argv[])
{
        int *p = malloc(sizeof(int));  // a1: allocate some
                                          memory
        assert(p != NULL);
        printf("(%d) address of p: %08x\n",
                getpid(), (unsigned) p);  // a2: print out the
                                          address of the memmory
        *p = 0;  // a3: put zero into the first slot of the memory
        while (1) {
                Spin(1);
                *p = *p + 1;
                printf("(%d) p: %d\n", getpid(), *p); // a4
        }
        return 0;
}
```

VIRTUALIZING MEMORY - 3

- Output of mem.c

```
prompt> ./mem
(2134) memory address of p: 00200000
(2134) p: 1
(2134) p: 2
(2134) p: 3
(2134) p: 4
(2134) p: 5
^C
```

- int value stored at 00200000
- program increments int value

VIRTUALIZING MEMORY - 4

- Multiple instances of mem.c

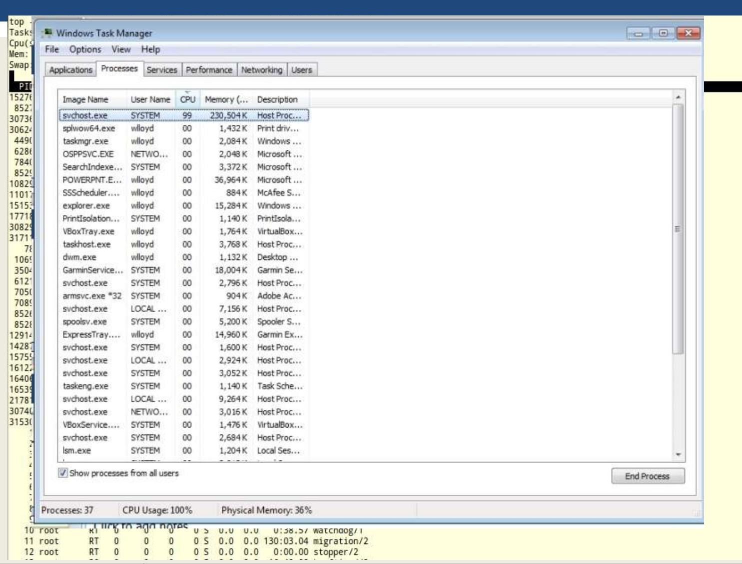
```
prompt> ./mem &; ./mem &
[1] 24113
[2] 24114
(24113) memory address of p: 00200000
(24114) memory address of p: 00200000
(24113) p: 1
(24114) p: 1
(24114) p: 2
(24113) p: 2
(24113) p: 3
(24114) p: 3
...
```

- (int*)p receives the same memory location 00200000
- Why does modifying (int*)p in program #1 (PID=24113), not interfere with (int*)p in program #2 (PID=24114) ?
  - The OS has “virtualized” memory, and provides a “virtual” address

VIRTUAL MEMORY

- Key take-aways:
- Each process (program) has its own ***virtual address space***
- The OS maps virtual ***address spaces*** onto ***physical memory***
- A memory reference from one process can not affect the address space of others.
  - ➢ ***Isolation***
- Physical memory, a <u>shared resource</u>, is managed by the OS

CONCURRENCY



CONCURRENCY

- Linux: 654 tasks
- Windows: 37 processes
- The **OS** appears to run many programs at once, juggling them
- Modern **multi-threaded** programs feature concurrent threads and processes
- ***What is a key difference between a process and a thread?***

CONCURRENCY - 2

```
#include <stdio.h>
#include <stdlib.h>
#include "common.h"

volatile int counter = 0;
int loops;

void
}
...
```

Not the same as Java volatile:
Provides a compiler hint than an object may change value unexpectedly (in this case by a separate thread) so aggressive optimization must be avoided.

Listing continues …

CONCURRENCY - 3

```c
int
main(int argc, char *argv[])
{
        if (argc != 2) {
                fprintf(stderr, "usage: threads <value>\n");
                exit(1);
        }
        loops = atoi(argv[1]);
        pthread_t p1, p2;
        printf("Initial value : %d\n", counter);

        Pthread_create(&p1, NULL, worker, NULL);
        Pthread_create(&p2, NULL, worker, NULL);
        Pthread_join(p1, NULL);
        Pthread_join(p2, NULL);
        printf("Final value : %d\n", counter);
        return 0;
}
```

- Program creates two threads
- Check documentation: "man pthread_create"
- worker() method counts from 0 to argv[1] (loop)

Linux "man" page

example

PTHREAD_CREATE(3) Linux Programmer's Manual PTHREAD_CREATE(3)

NAME top

pthread_create - create a new thread

SYNOPSIS top

```c
#include <pthread.h>

int pthread_create(pthread_t *thread, const pthread_attr_t *attr,
                   void *(*start_routine) (void *), void *arg);
```

Compile and link with *-pthread*.

DESCRIPTION top

The **pthread_create**() function starts a new thread in the calling process. The new thread starts execution by invoking *start_routine*(); *arg* is passed as the sole argument of *start_routine*().

The new thread terminates in one of the following ways:

* It calls pthread_exit(3), specifying an exit status value that is available to another thread in the same process that calls pthread_join(3).

* It returns from *start_routine*(). This is equivalent to calling pthread_exit(3) with the value supplied in the *return* statement.

* It is canceled (see pthread_cancel(3)).

* Any of the threads in the process calls exit(3), or the main thread performs a return from *main*(). This causes the termination of all threads in the process.

The *attr* argument points to a *pthread_attr_t* structure whose contents are used at thread creation time to determine attributes for the new thread; this structure is initialized using pthread_attr_init(3) and related functions. If *attr* is NULL, then the thread is created with default attributes.

CONCURRENCY - 4

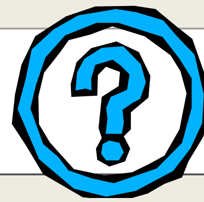
- Command line parameter argv[1] provides loop length
- Defines number of times the shared counter is incremented

- Loops: 1000

```
prompt> gcc -o thread thread.c -Wall -pthread
prompt> ./thread 1000
Initial value : 0
Final value : 2000
```

- Loops 100000

```
prompt> ./thread 100000
Initial value : 0
Final value : 143012 // huh??
prompt> ./thread 100000
Initial value : 0
Final value : 137298 // what the??
```



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CONCURRENCY - 5

- When loop value is large why do we not achieve 200000 ?

- C code is translated to (3) assembly code operations
1. Load counter variable into register
2. Increment it
3. Store the register value back in memory

- These instructions happen concurrently and VERY FAST
- (P1 || P2) write incremented register values back to memory, While (P1 || P2) read same memory
- Memory access here is **unsynchronized** (**non-atomic**)
- *Some of the increments are lost*

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QUESTIONS