Operating Systems

CS 4410

Fall 2023

Lorenzo Alvisi

[Agarwal, Alvisi, Bracy, Crooks, Schneider, Sirer, van Renesse]
Welcome!

You belong here!

We strive to make CS4410/CS4411 welcoming, inclusive, respectful, and supportive environments, consistent with Cornell’s commitments.
Ph.D. C.S., Cornell University
At UT Austin: 1996-2015
Physics MS from University of Bologna
Father and husband of Cornellians
I love motorcycles, teaching, classical music, research, dark chocolate
My research builds distributed systems and databases that scale and are resilient to arbitrary failures
Keeton Fellow
Founding Director of CMMRS

About me
An outstanding team

- Aaron Biederman
- Miles Bramwit
- Charlie Brush
- Michael Carr
- Andrew Cheng
- Stephanie Ginting
- Cameron Goddard
- Willy Jiang
- CJ Lee
- Ian Lee
- Kate Liang
- Shenni Liang
- Ahmend Moustafa
- Zach Nelson
An outstanding team

Chuhan Ouyang
Noah Rebei
Soorya Rethinasamy
Benny Rubin
Jorge Tapias Gomez
Stephan Verderame

Yifan Wang
Rian Xu
Cindy Zhang
Emily Zhang
Kevin Zhen
Why?

Operating Systems...
The OS is everywhere!!

- Every device, from your smartwatch, your smart light bulb, to your mobile phone and laptop runs an operating system.

- Every program you will ever write will run on an operating system.
  - Its performance and execution behavior will depend on the operating system.

You’ll be a better software engineer!
Pollà ta deînà...

The OS is an awesome piece of software
Across a huge variety of devices...
Across widely different timescales...

<table>
<thead>
<tr>
<th>Task</th>
<th>Time (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 cache reference</td>
<td>0.5</td>
</tr>
<tr>
<td>Branch mispredict</td>
<td>5</td>
</tr>
<tr>
<td>L2 cache reference</td>
<td>7</td>
</tr>
<tr>
<td>Mutex lock/unlock</td>
<td>25</td>
</tr>
<tr>
<td>Main memory reference</td>
<td>100</td>
</tr>
<tr>
<td>Compress 1K bytes with Zippy</td>
<td>3,000</td>
</tr>
<tr>
<td>Send 2K bytes over 1 Gbps network</td>
<td>20,000</td>
</tr>
<tr>
<td>Read 1 MB sequentially from memory</td>
<td>250,000</td>
</tr>
<tr>
<td>Round trip within same datacenter</td>
<td>500,000</td>
</tr>
<tr>
<td>Disk seek</td>
<td>10,000,000</td>
</tr>
<tr>
<td>Read 1 MB sequentially from disk</td>
<td>20,000,000</td>
</tr>
<tr>
<td>Send packet CA -&gt; Italy -&gt; CA</td>
<td>150,000,000</td>
</tr>
</tbody>
</table>

8 Orders of Magnitude!!!
...facing increasing complexity

Millions of lines of code

- Modern Car: 93 million
- Mac OS X "Tiger": 65 million
- Facebook: 37 million
- Windows Vista: 28 million
- Microsoft Office 2013: 17 million
- Windows 7: 11 million
- Linux 3.1 (2012): 9 million
- Android: 4 million
- Firefox: 2 million
- Mars Curiosity Rover: 1 million
- Linux 2.2.0: 0.1 million
- Mouse Chromosome Base Pairs: 0.01 million
...but even if none of this were true....

...studying an OS teaches about developing abstractions

expressive
performant
simple to use and implement

an art that is at the core of what defines a computer scientist
Who is who

Before you take this class..

Communication

- Lectures, OHs, FAQ, etc.
- Getting help

Homework, Exams

Grades and Policies
Prerequisites

- CS 3410, CS 3420 or equivalent

Otherwise (or if in doubt):

- Come and talk to me, explain your situation and request permission
Course Content

Four Components

- Lectures
- Readings
- Assignments
- Exams

You are expected to keep up with all four
Draft Syllabus

- Introduction
- Architectural Support for OSs
- Processes and Threads
- Synchronization
- Scheduling
- Memory Management
- Storage systems
- File systems
- Security (if time allows)
Textbooks

- Free online
- Can buy PDF or printed copy
Textbooks

Concurrent Programming with Harmony

Robbert van Renesse
Cornell University

- Free online
- Free pdf download, or read online
Who is who

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Homework, Exams

Grades and Policies
Communications

- Web page
- Lectures
- Recitation
- Ed Discussion
- Office Hours
- Gradescope
- CMSX
Communications

- Web page
- Lectures
- Recitation
- Ed Discussion
- Office Hours
- Gradescope
- CMSX
Course Web Page

https://www.cs.cornell.edu/courses/cs4410/

- Schedule, exam & due dates
- Homework release and due dates
- Slides posted before each lecture
CMSX & Gradescope

CMSX: https://cmsx.cs.cornell.edu

Gradescope: accessible through Canvas
- Assignments
- Grades & Regrades
Office Hours

In flux... but we should have great coverage
Ed Discussion

- Ask anything you want, but do not share code unless posted privately for the course staff
- May be anonymous to other students, not to the staff
- Help one another
  - Each student should feel safe, welcome, respected
  - Respect diverse talents and ways of learning
Email

- **cs4410-staff@cornell.edu**: time sensitive matters
  - Goes to Lorenzo and TAs

- **cs4410-prof@cornell.edu**: sensitive matters
  - Goes to Lorenzo only
## Non technical help

<table>
<thead>
<tr>
<th>Service</th>
<th>Website</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Advising</td>
<td><a href="http://www.engineering.cornell.edu/resources/advising">www.engineering.cornell.edu/resources/advising</a></td>
<td>Academic advising for engineering students</td>
</tr>
<tr>
<td>Arts College Student</td>
<td><a href="http://as.cornell.edu/advising">as.cornell.edu/advising</a></td>
<td>Listing of general support services for a variety of concerns</td>
</tr>
<tr>
<td>Cornell Health</td>
<td><a href="http://www.health.cornell.edu">www.health.cornell.edu</a></td>
<td>Cornell University Health Service</td>
</tr>
<tr>
<td>CAPS</td>
<td><a href="http://health.cornell.edu/services/mental-health-care">health.cornell.edu/services/mental-health-care</a></td>
<td>If you experience emotional stress, contact Counseling and Psychological services</td>
</tr>
<tr>
<td>Student Disability Services</td>
<td><a href="http://sds.cornell.edu">sds.cornell.edu</a></td>
<td>Ensures that all aspects of student life are accessible, equitable, and inclusive of those with disabilities. Send accommodation letters to Ms. Coralia Torres (ct635), by Feb. 23.</td>
</tr>
</tbody>
</table>

Get help. Get documentation. The earlier, the better.

And look out for each other!
Before you take this class..

Communication
- Lectures, OHs, FAQ, etc.
- Getting help

Homework, Exams

Grades and Policies
Exams

- 2 prelims, 1 final
  - best 2 out of 3

Dates:
- September 28
- November 21 (Yikes!)

Questions will cover lectures, books, homework

Regrade requests due within a week
Homework

Available on Gradescope

- Fully auto-graded (no TAs involved)

Problems designed to help you prepare for the exam

- worth a lot in terms of prep
- not worth much in terms of credit
  - 6%, all homework combined
- do them for the practice, not the credit
- do them on your own
- regrade requests due within a week
Programming Assignments

- Three different concurrent programming assignments
- Work in groups of 2 or 3 students, or do it by yourself if you prefer
Group Code of Conduct

- Each student should feel safe, welcome, respected
- Participate, but don’t dominate
- Be patient
- Respect diverse talents and ways of learning
- Fight your implicit biases
Academic Integrity and Honor Code

All submitted work must be your own

- OK to discuss concepts with any other student
- Students in the same group can submit the same code
- Different groups are not allowed to share code

Violations will be prosecuted
Why not cheat?

It is a betrayal of trust
and you are better than that!

If you need help, get it early!
RESERVED FOR ADMINISTRATION

- Who is who
- Before you take this class..
- Communication
  - Lectures, OHs, FAQ, etc.
  - Getting help
- Homework, Exams
- Grades and Policies
Practicum: CS4411

- CS4410 assignments are “small”
- In CS4411, you’re going to have hands-on C development experience with an almost-real operating system: EGOS
  - Write a queue
  - Write a threading package
  - Write a scheduler
  - Write a file system cache
  - Write a file system
- Teams of 2/3 programmers

Lots of fun!
What is an OS?

An Operating System implements a virtual machine whose interface is more convenient* that the raw hardware interface.

* easier to use, simpler to code, more reliable, more secure...
We study a system
What is a system?

“A complex unit formed of many often diverse parts subject to a common plan or serving a common purpose”

Webster Third New International Dictionary
What is a system?

“"A complex unit formed of many often diverse parts subject to a common plan or serving a common purpose""

Webster Third New International Dictionary

“A set of interconnected components with an expected behavior observed at the interface with its environment”
Common systems challenges

- Emergent properties
- Propagation of effects
- Incommensurate scaling
- Trade-offs
Emergent Properties

Evident only when components are combined
Emergent Properties
Millenium Bridge London
Emergent Properties
Millenium Bridge London
Emergent Properties
Millenium Bridge London

The bridge's movements were caused by a positive feedback phenomenon, known as synchronous lateral excitation. The natural sway motion of people walking caused small sideways oscillations in the bridge, which in turn caused people on the bridge to sway in step, increasing the amplitude of the bridge oscillations and continually reinforcing the effect;\textsuperscript{[7][8]} the maximum sway was around 70mm.\textsuperscript{[9]}