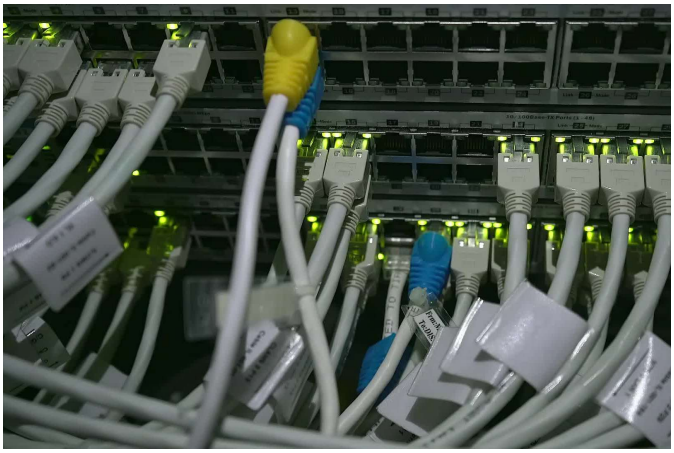
Data-Intensive Distributed Computing CS431/451/631/651

Fall 2022 – Dan Holtby



Today's Agenda

Who am I?

What is "Big Data?"

Why is it different than regular Data?

How is the course structured?

(When and Where is on your schedule already…)

Who am I?

- PhD from UW (2013)
- Bioinformatics Research Group
- Bioinformatics involves lots of big data
  - (A single human's genome is about 3.5GB!)
  - Humans aren't even the most complicated species
- Masters Thesis was on Distributed Computing

Who are you?

CS451 / CS651 – CS Majors or Data Science Majors / MDSAI

Expectations: Comfortable in Java and Scala (you'll be expected to pick it up **quickly** if not)

CS431 / CS631 – Non-CS Majors, or Data Science majors / MDSAI

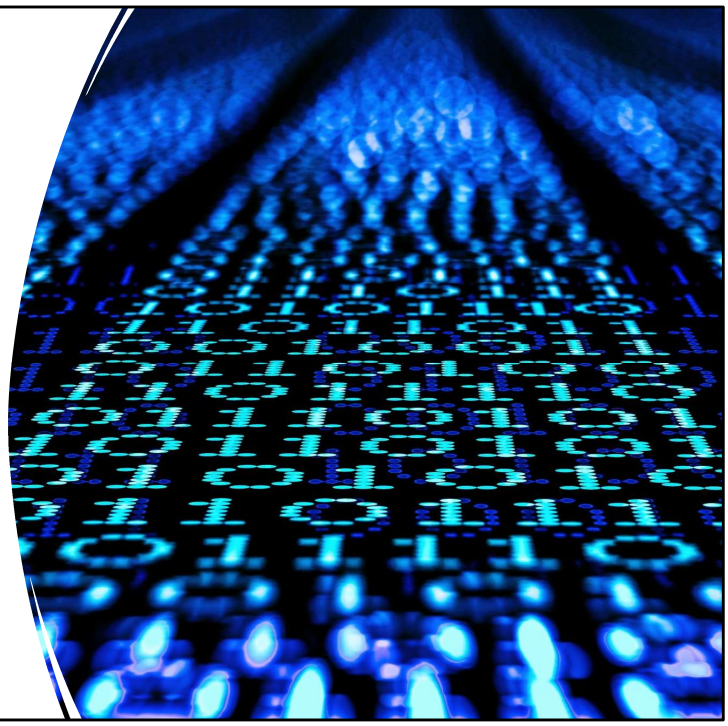
Expectations: Comfortable in Python (again, you'll be expected to pick it up **quickly** if not)

Everybody Should Be:

* Interested in the topic
* Comfortable with rapidly-evolving software

Big Data

- Question: Why are data so big these days?
- Answer: It's complicated



- The only reason to delete data is if the cost of keeping it is too high
  - (This is, of course, why Bilbo should not keep the One Ring)

It’s one gigabyte, Michael! How much could it cost, $10?

(Top) - IBM 350 Disk ($36,000 / month for 3.5 MB)

(Bottom) – WD Green (~$60 for 2TB)

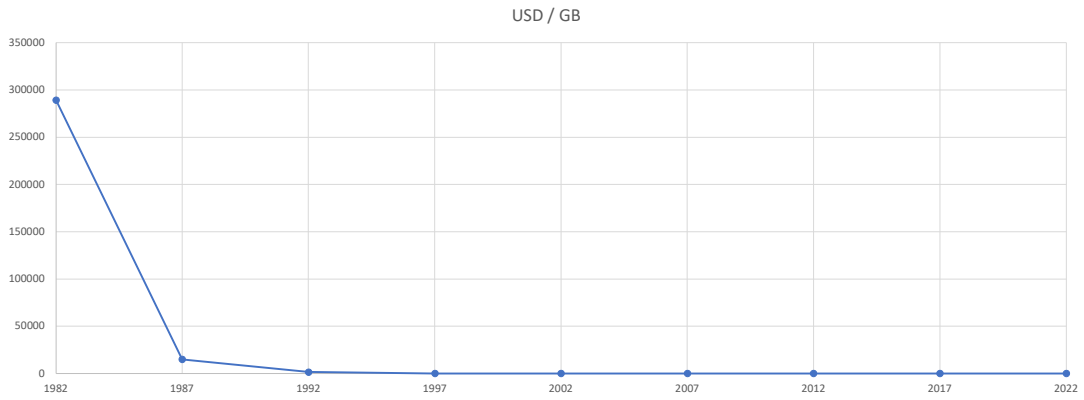
1980

1958 **Now**

(Middle) – Shugart ST506 5.25” ($5000 for 5MB)

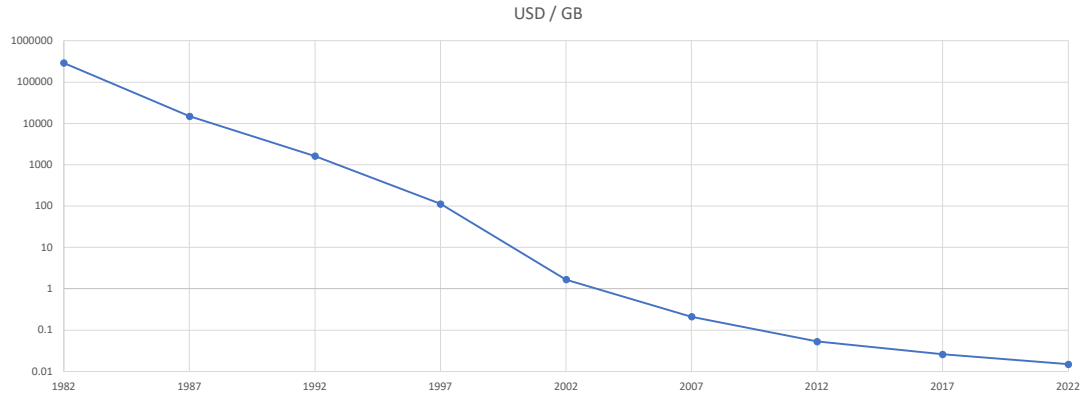
- 2.5” HDD for scale

Price per GB Over the Years



PRO-TIP: never make a graph that looks like this, use a log scale

Price per GB Over the Years (Log Scale)



Where are all these data coming from?

- Facebook generates 4PB / day (that's 4 million GB)
- There are 500 million new tweets per day (~60 GB just for the text)
- 720,000 hours of new YouTube videos per day. (It would take 90,000 full time employees just to review uploads)
- Every "smart" device you own is sending telemetry back to corporate to be packaged and sold.

How much????

- Right now* we generate 2.5 exobytes (2,500,000 TB) per day
- That's ~2MB / person / second

* The number is from 2020, it's probably bigger now but I can't find a good source

A lot of that is video so it's all about averages

2.5 EXObytes???

- That might seem like a lot, but it's nothing compared to what it's going to be
- Will be up to 500 exobytes / day in 2025 (125 million 4TB HDDs filled per day)

But Why?

Businesses

Scientists

People

Business Data

DATA-DRIVEN DECISION-MAKING

DATA-DRIVEN PRODUCT DESIGN

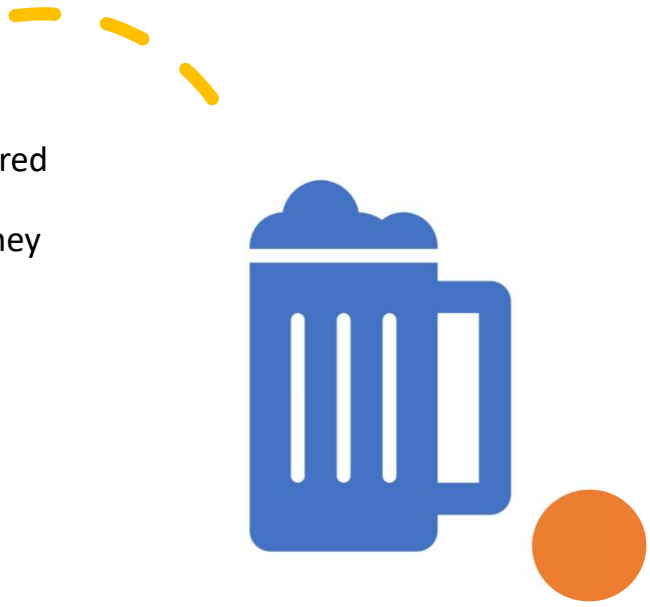
TARGETED ADVERTISING

Business Intelligence

- "What worked? What didn't?"
- This isn't a new concept.

Anecdote!

- In the 1990s, Walmart Discovered people tend to buy beer and diapers at the same time, so they put them together.
- PS this isn't true. Anecdotes rarely are.



What Would Walmart Do?

- Stores actually want items that are bought together to be FAR APART.
- So if Walmart did put beer and diapers close, it's because they're NOT bought together.
- Costco puts the rotisserie chicken at the back so you have to walk past everything else to grab one

- A teenager's parents learned she was pregnant because Target started sending coupons for diapers.
- How did Target know? Data Science

Preferences

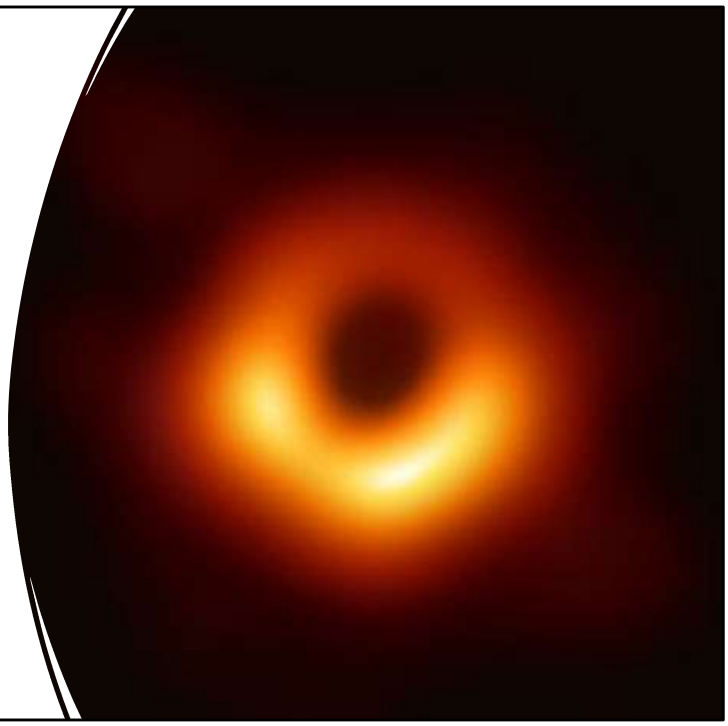
- “Customers like you bought…”
- “People who liked X watch Y”
- Oddly specific Netflix categories

Science!

- Data-Intensive eScience
- Modern Experiments generate BIG DATA

Black Hole

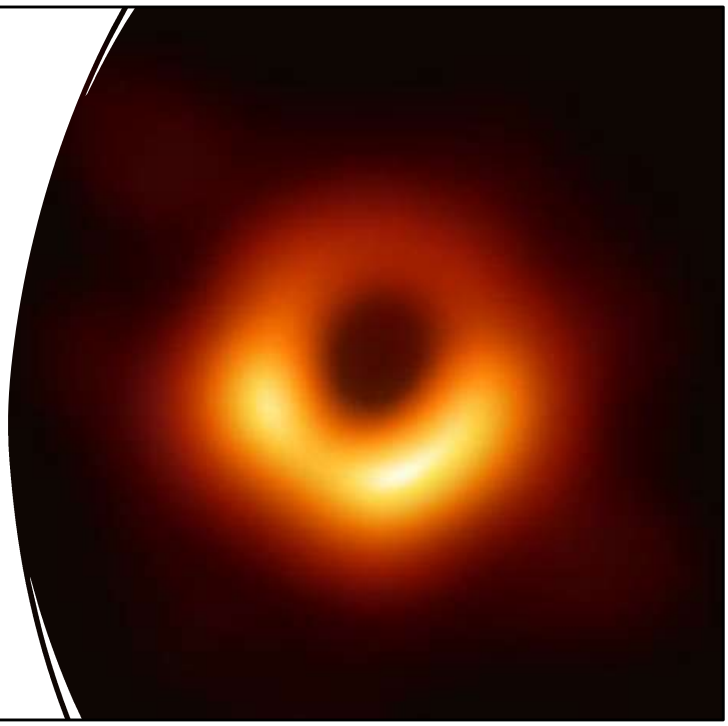
- First Image of a Black Hole (2019)
- 4.5PB of data from 8 telescopes



They flew and drove trucks full of HDD. Would have taken years to send over the internet.

Black Hole

- They shipped HDDs
- *Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway.* –Andrew Tanenbaum

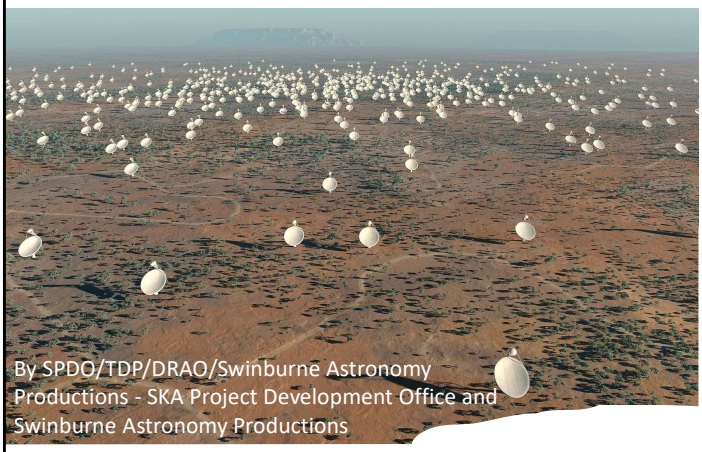


Because infereometry doesn't parallelize well, not a good candidate for MapReduce (or other data-intensive distributed techniques). Getting all the data in one place was mandatory

JAMES WEBB TELESCOPE

- JWST sends 57GB / day back to Earth
- One pretty picture requires MANY images stitched together

Square Kilometer Array (SKA)


By SPDO/TDP/DRAO/Swinburne Astronomy Productions - SKA Project Development Office and Swinburne Astronomy Productions

Estimated Completion Date – 2027

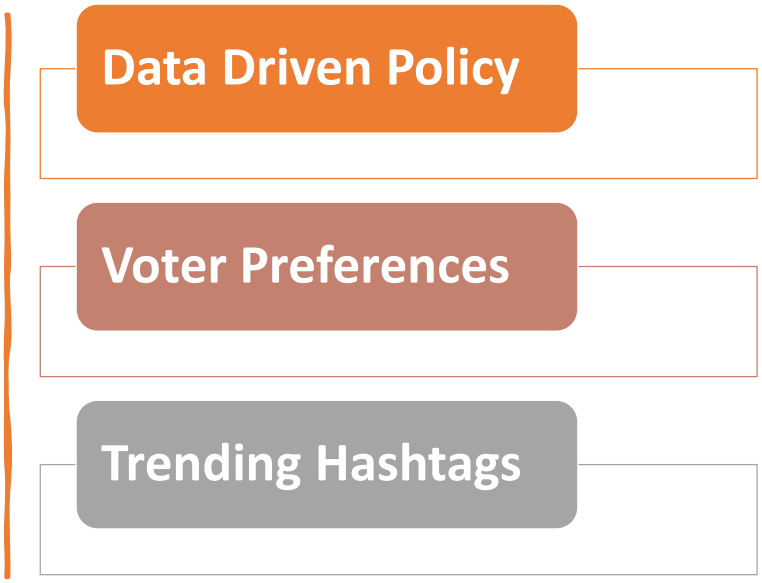
Will generate too much data to handle today (5 Tb/sec)

They're crossing that bridge when they come to it.

Large Hadron Collider

- Generates 1 PB / sec during an experiment
- That's more than the SKA, but it's not constantly running

Computational Social & Political Science



Humans as Sensors

Humans record their thoughts on social media.

What can we do with all those data?

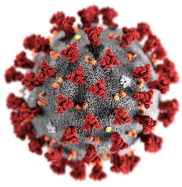
Twitter

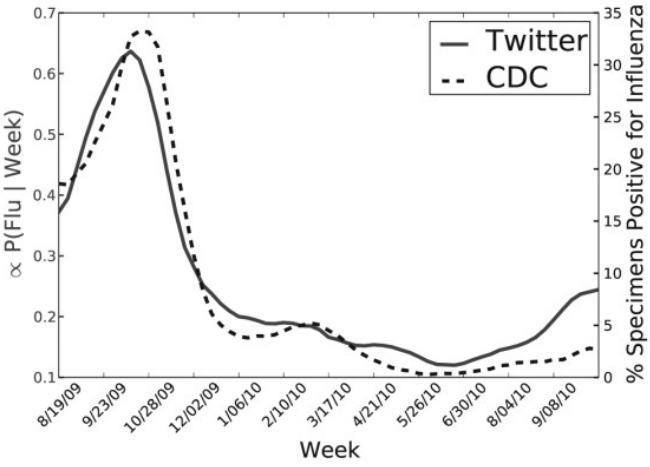
- Can Tweets tell us anything?
- Sentiment Analysis + Social Science

Sentiment Analysis – Figuring out the tone of a tweet. Harder than it sounds. People are sarcastic, might use memes.
Fortunately people also tend to label their own sentences with emojis. Eyeroll emoji = sarcastic. Angry face = mad post.

Predicting *X* with Twitter

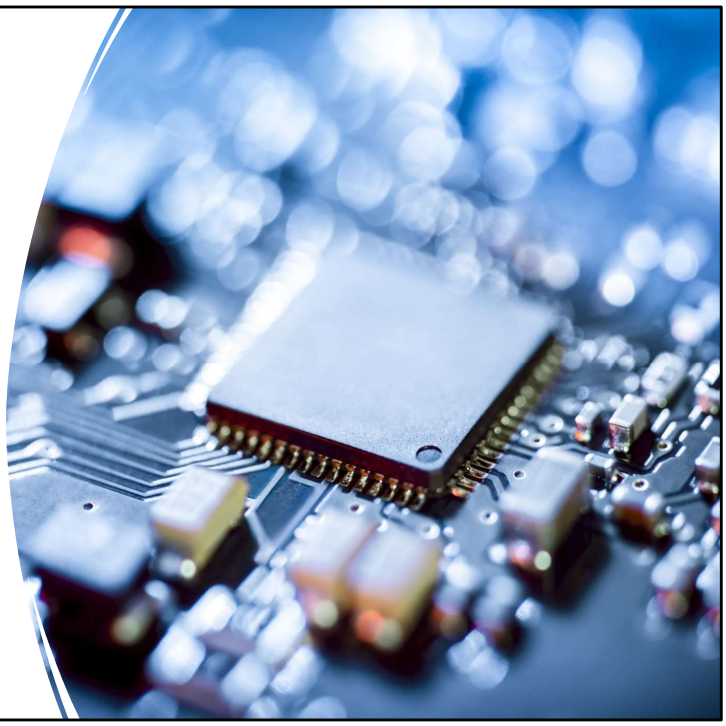
Fall 2020 Project : Predicting COVID with Twitter





Big Data, Big Computer?

- Vertical Scaling – More RAM, Disk, CPU
- Return of the Mainframe?
- Expensive!
- Limited!



Big Data, Big Network!

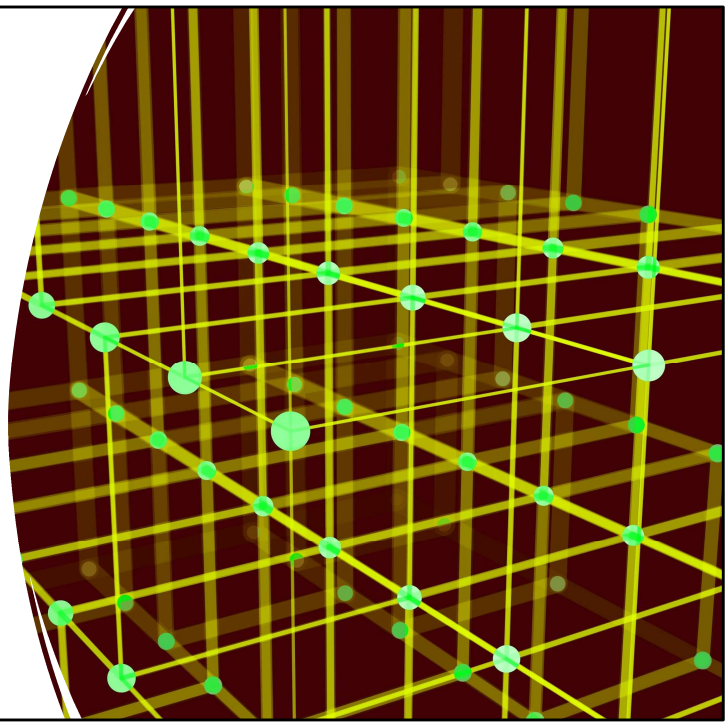
- Horizontal Scaling
- Cheap computers, just more of them

Distributed Computing

- Many inexpensive computers working together
- Just like it says on the course

Parallelization is hard

- Deadlocks, Livelocks, Race Conditions, oh my!
- That's just on one computer. What if they're remote?



If you haven't taken OS, parallel programming, etc. you'll just have to take my word for it

Scaling Out!

- A datacenter of many machines?
- Many datacenters???
- Fault tolerance

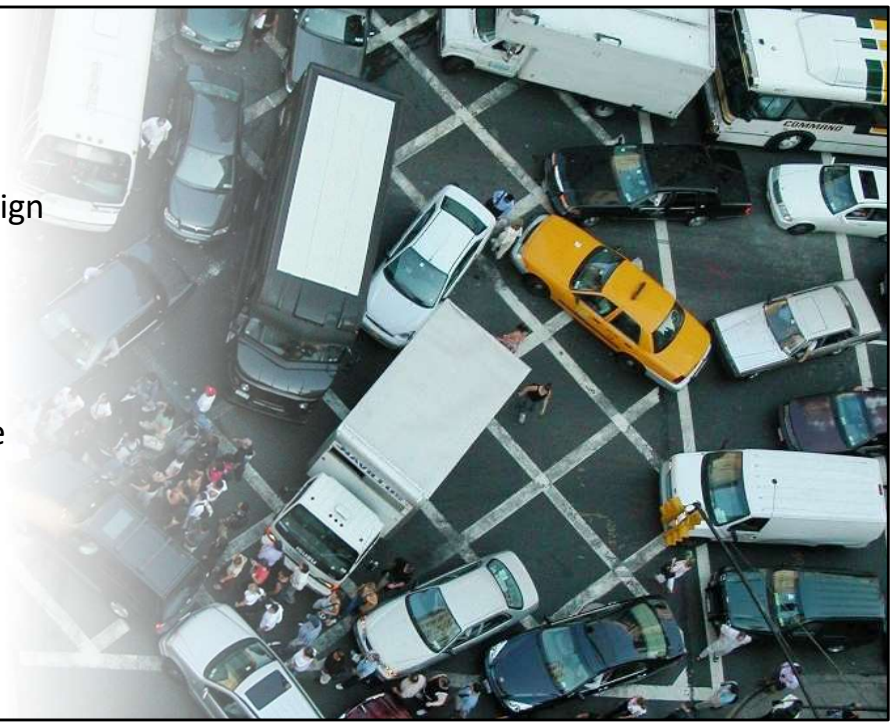
ALL HARDWARE FAILS

Over the years I've lost 2 video cards, 1 stick of RAM, several HDD, though none with data loss…a mother board I think? 1 power supply, 2 if you count obnoxious coil whine as failure. Oh, a monitor, if that counts. Went all yellow unless you beat it senseless (the IT term for this is "percussive maintenance")

DIFFICULT

We're not going to design a fault-tolerant distributed computer network

We're going to use one



Abstraction to the rescue

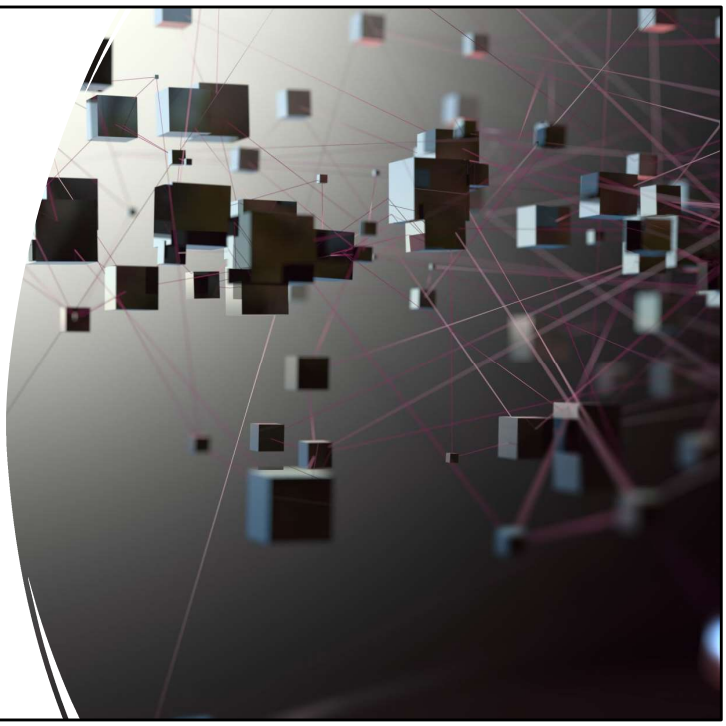
You didn't need to understand the hardware to use assembly

You didn't need to understand assembly to use C++

You didn't need to understand a hash table to use std::UnorderedMap

What's the Next Layer?

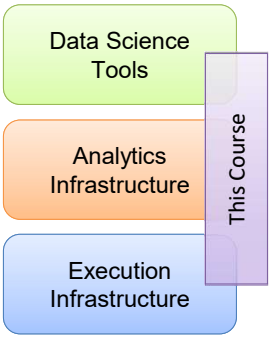
- How can we abstract a distributed network?
- (That's the topic of the next few lectures)



What's CS431/CS451?

A little helping of

- **Data Science**
- **Distributed Analytics**
- **Distributed Execution**



More Buzzwords Please!

You got it!

- Analytics
- Business intelligence
- Data warehousing
- MapReduce, Hadoop, Spark, Pig, Hive, NoSQL, Pregel, Giraph, Storm/Heron
- Thinking at scale

HOW HARD IS THE COURSE?

- Based on course surveys –
- CS431 - ~8 hours a week
- CS451 - ~10 hours a week (That's a heavy course)

- UWFlow seems to think they're both relatively easy though

Grading

Undergrads

Assignments – 70%

Final Exam – 30%

Grad Students

Assignments – 60%

Final Exam – 20%

Project – 20%

Course Info and Help

Course Website: https://www.student.cs.uwaterloo.ca/~cs451

(Yes, even if you're in CS431)

Piazza (you should have been emailed an invite)

Online Office Hours: Microsoft Teams

In-Person Office Hours: See website.

Academic Integrity

All assignments will be checked for plagiarism / unauthorized collaboration! (See the course syllabus for more details)

One term, 23% of the class was under investigation for plagiarism.

If caught: 0 on the assignment, -5% on your course grade

Assignment Mechanics (CS451/651)

Java

Scala 

We'll be using <u>private</u> Git repos for assignments

Complete your assignments, push to GitLab
We'll pull your repos at the deadline and grade

Late assignments will get 0

45

Assignment Mechanics (CS431/631)

Assignments will use Python and Jupyter (Google Colab)
Everything you need to know is in the assignment itself

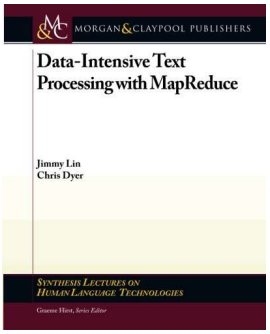
Assignments will be submitted using Git
Details are on the course website for the appropriate assignment

Python

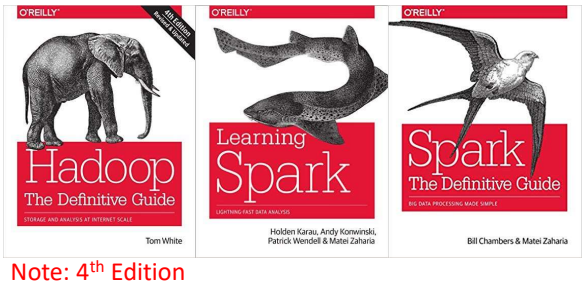
Late assignments will get 0

Course Materials

One (required) textbook +
Three (optional but recommended) books +
Additional readings from other sources as appropriate



(optional but recommended)



Note: 4th Edition