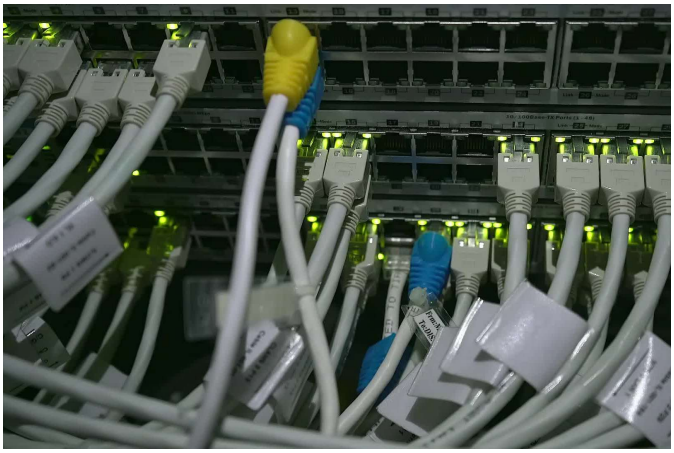
Data-Intensive Distributed Computing CS431/451/631/651

Winter 2023 – Dan Holtby



Today's Agenda

Who am I?

What is "Big Data?"

Why is it different than regular Data?

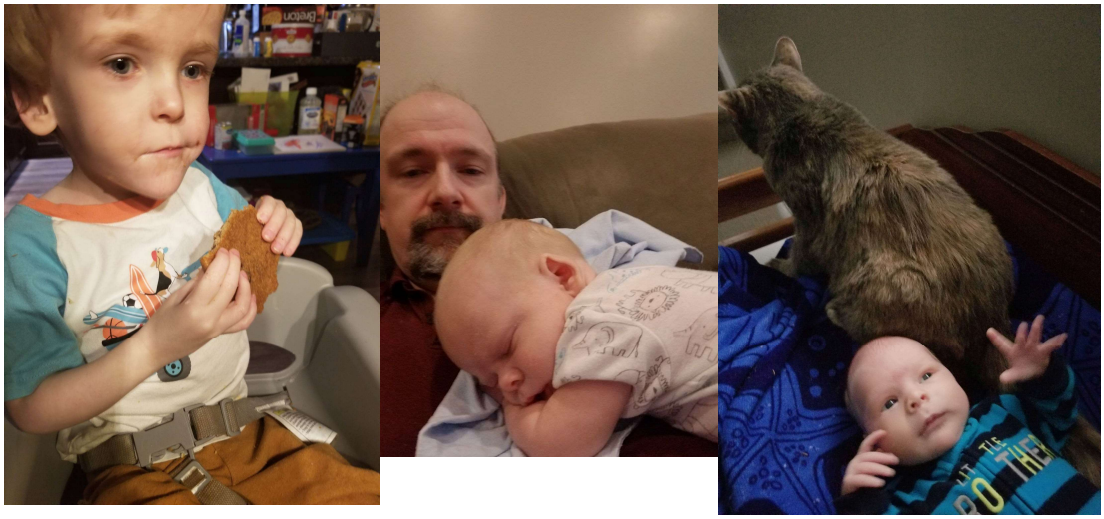
How is the course structured?

(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

My Family



Left to right: Charlie, Me and Ollie, Pixie and Ollie.

My Hobbies

Currently I'm addicted to using Stable Diffusion img2img to Anime-ify family photos.

I have a problem. Please help. There's so much work to do.

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)

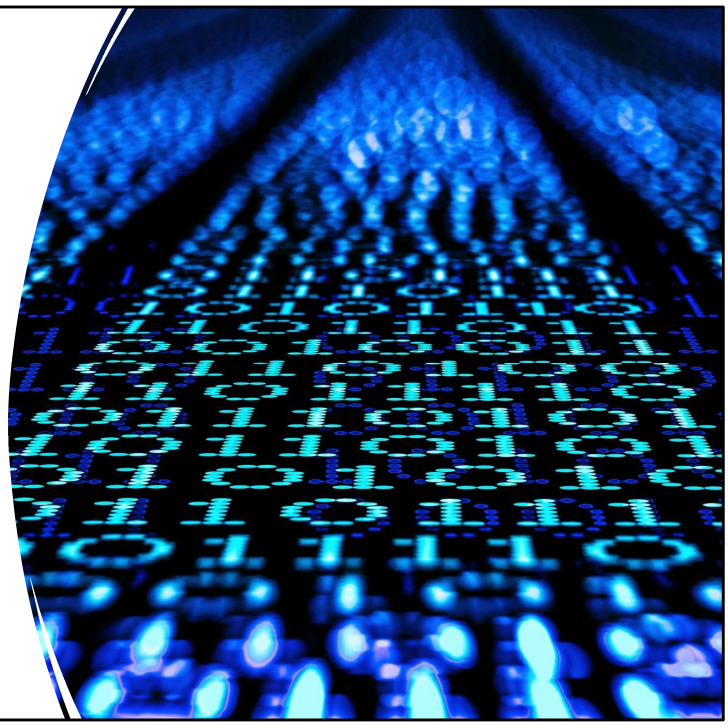
Everybody Should Be:

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

"Rapidly-Evolving" means "there might be version update issues and things might break – especially 431 where Python updates are my nemesis)

Big Data

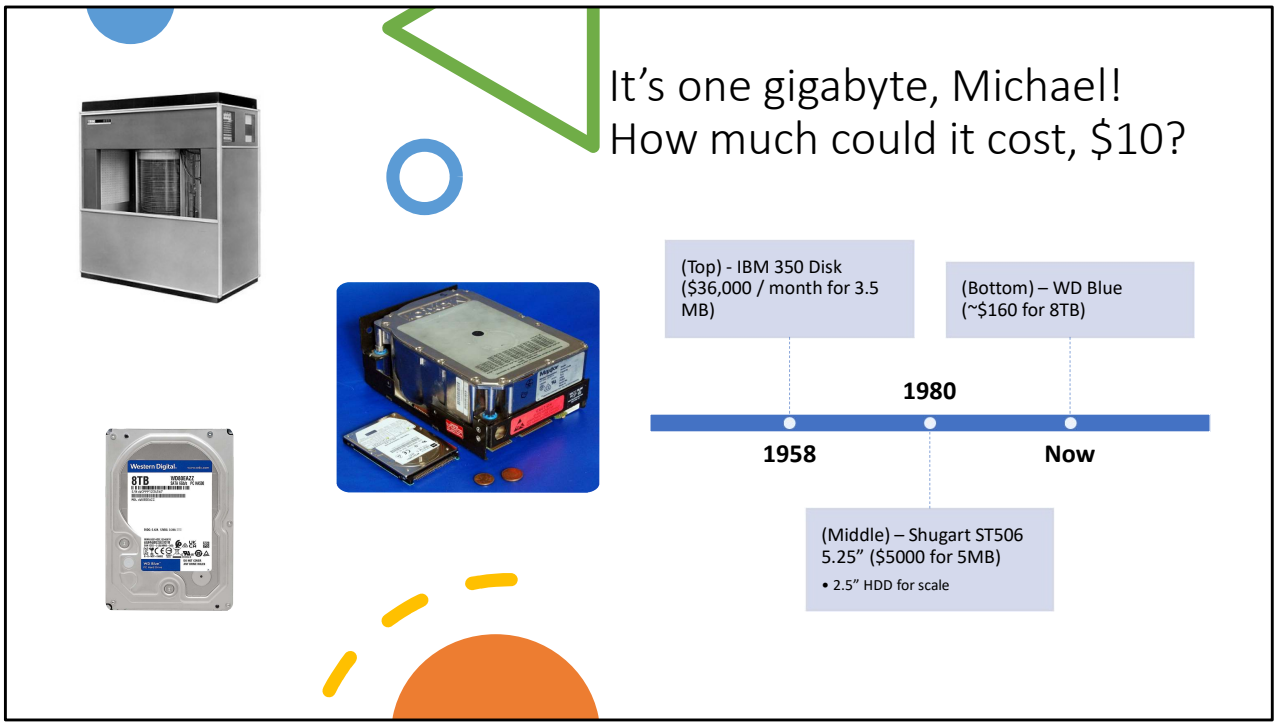
- Question: Why are data so big these days?
- Answer: It's complicated



After all, why not, why shouldn't I keep it?

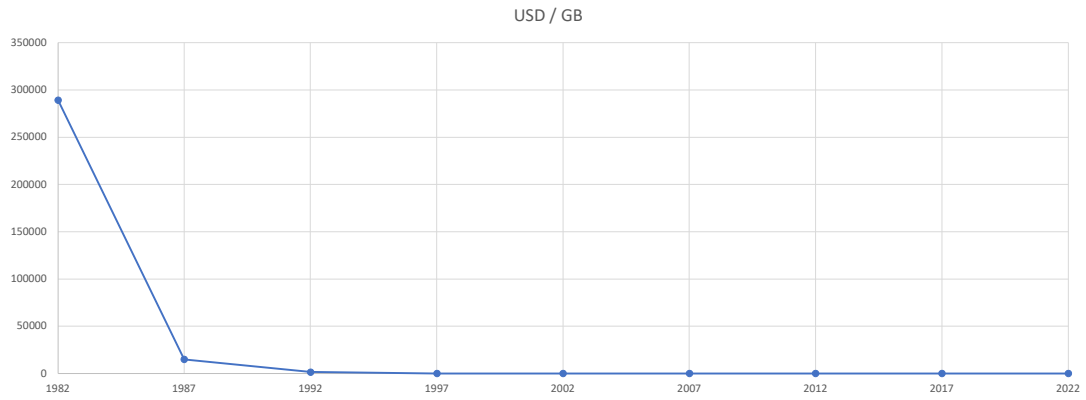
- The only reason to delete data is if the cost of keeping it is too high
- (Cost-Benefit Analysis)
  - (This is, of course, why Bilbo should not keep the One Ring)

What's going on here? The cheaper it is to store a GB, the most GB of data you'll find that are "worth it" to retain.
(In other words, data expands to fill its tank)



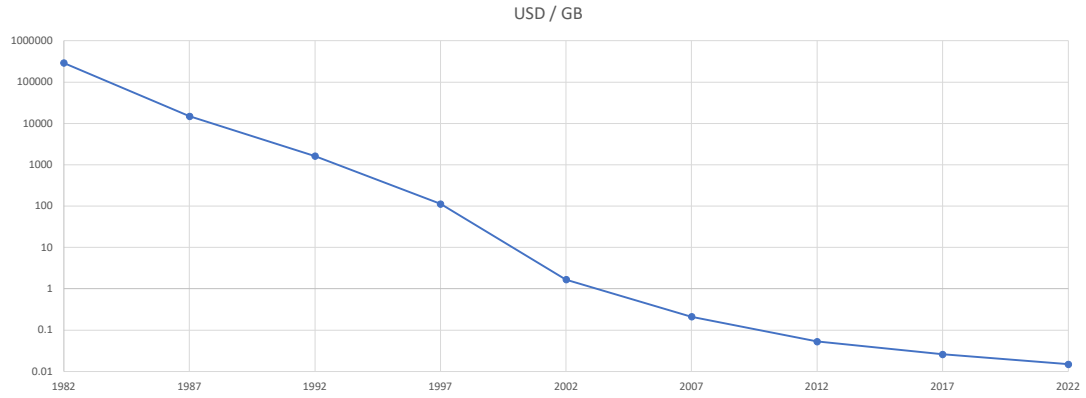
Right this moment (Aug 14) the WD Blue 8TB is the best GB/$ on amazon.ca if you exclude used. If you don’t, a 4TB WD enterprise grade Refurb is only $60!

Price per GB Over the Years



Never have a graph that looks like this. If you find that you do, use a log scale! Please!

Price per GB Over the Years (Log Scale)



That's more like it! The change in slope in the 1997-2002 is the "dot com boom" : economies of 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????

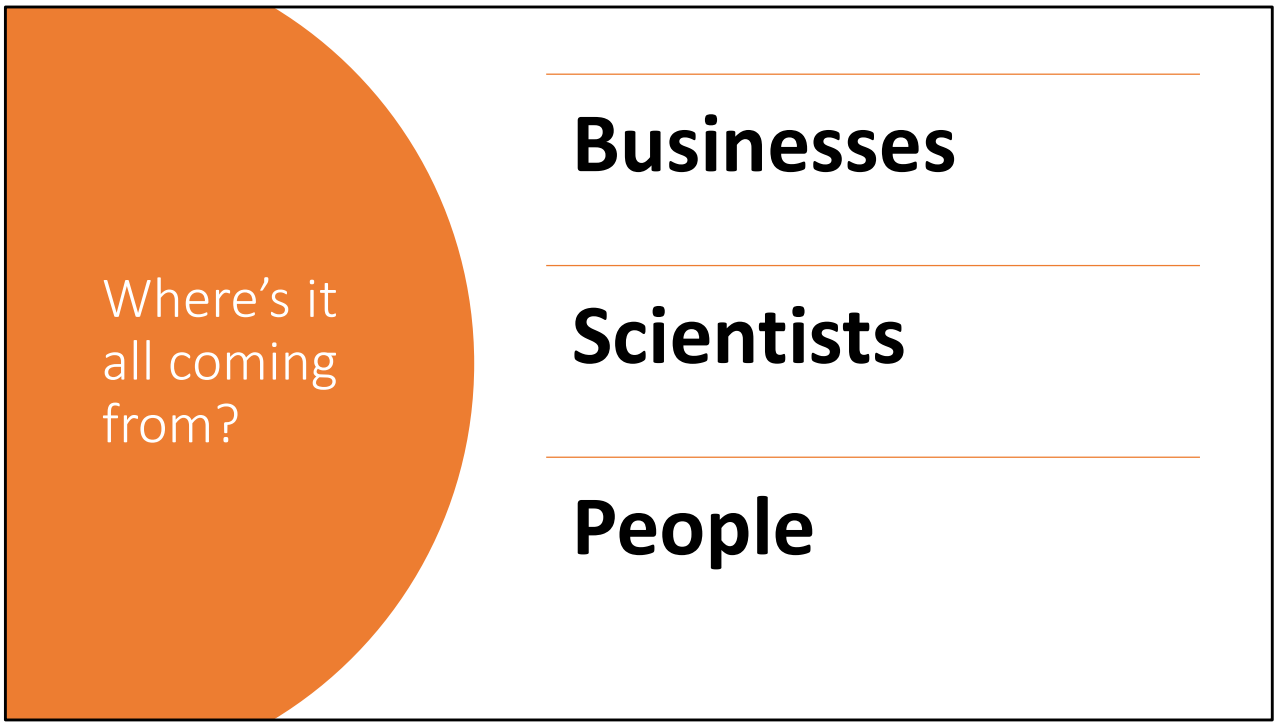
- Right now* we generate 2.5 exobytes (2,500,000 TB) per day
- That's ~2MB / person / second

* 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??? A DAY???

- 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)



That's not to say suits and scientists aren't people…

Business Data

DATA-DRIVEN DECISION-MAKING

DATA-DRIVEN PRODUCT DESIGN

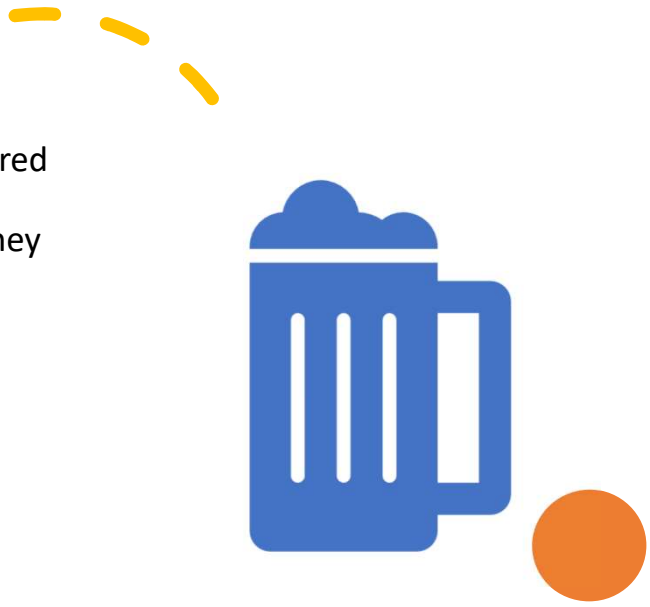
TARGETED ADVERTISING

Business Intelligence

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

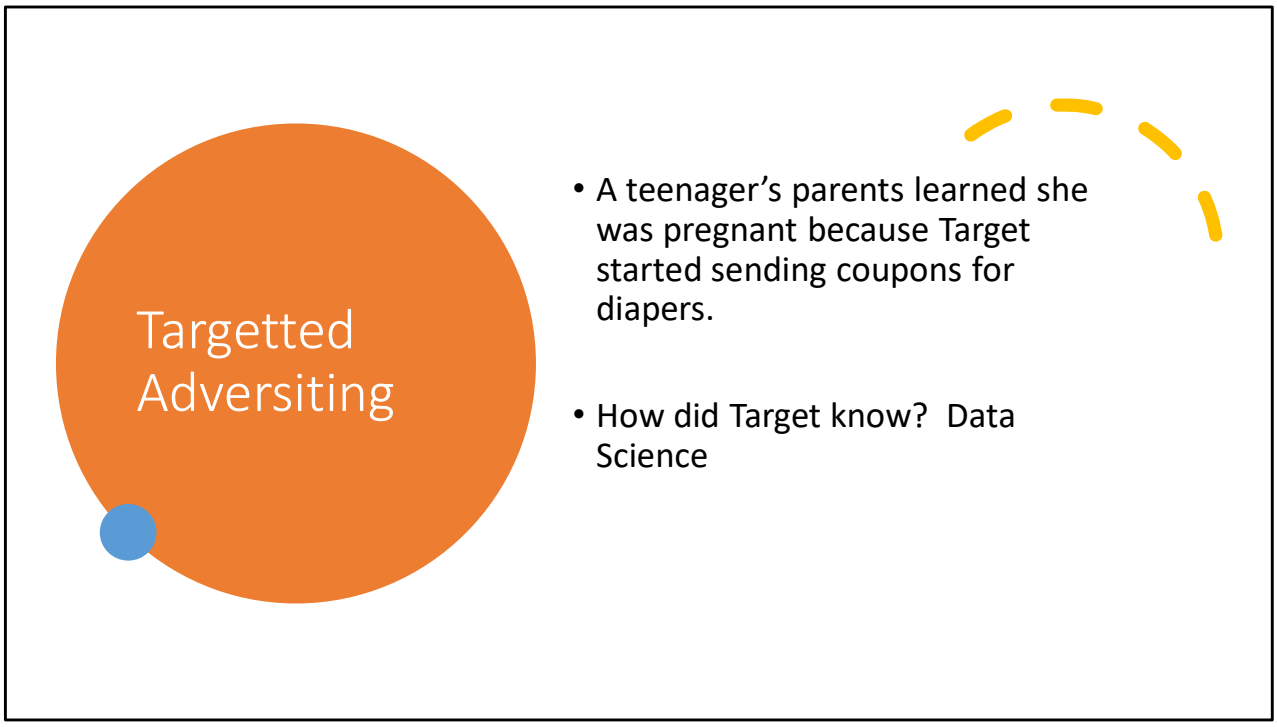
Anecdote!

- 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



Buying prenatal vitamins is somewhat a strong hint – less strong hint: switching to unscented soaps and lotions. Morning sickness is easily triggered by smells, or so my wife tells me.

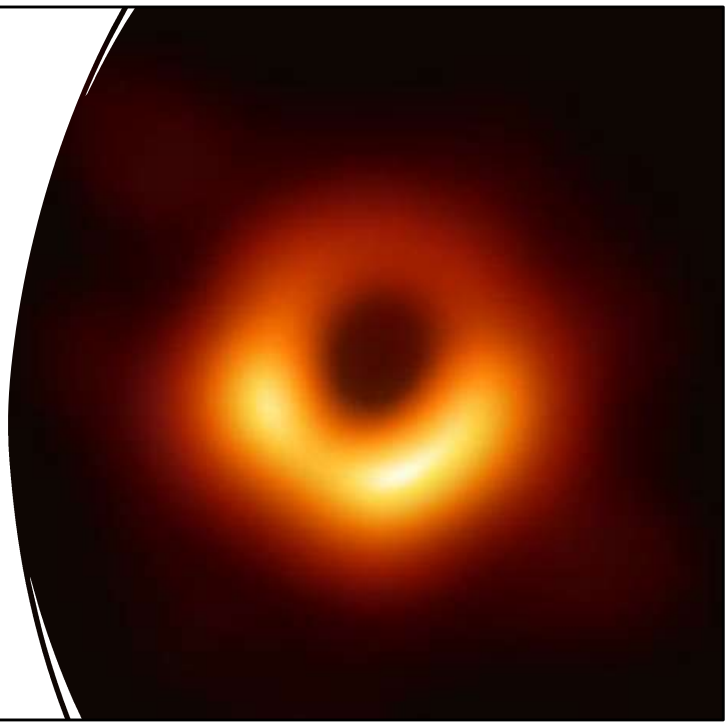
Dark Suspenseful Viral Plague Movies,

Science!

- Data-Intensive eScience
- Modern Experiments generate BIG DATA

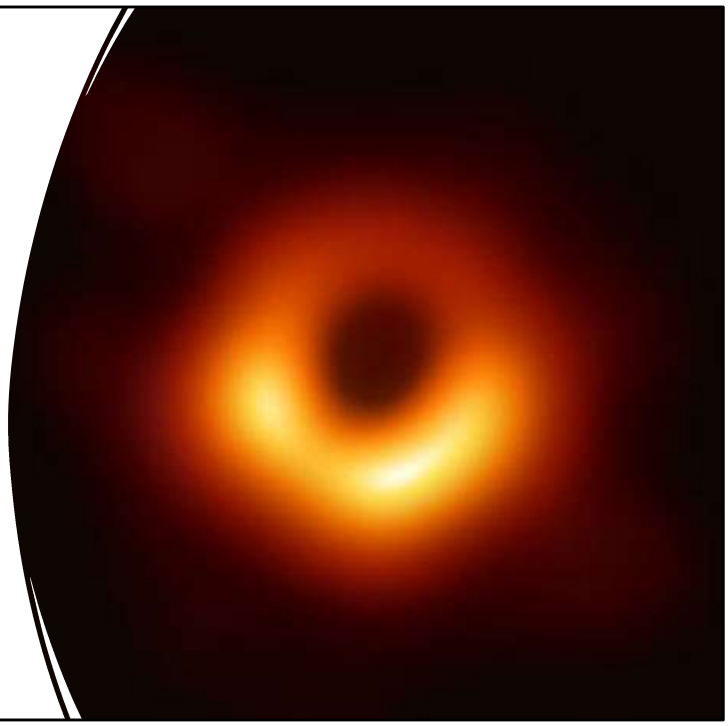
Black Hole

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



Black Hole

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

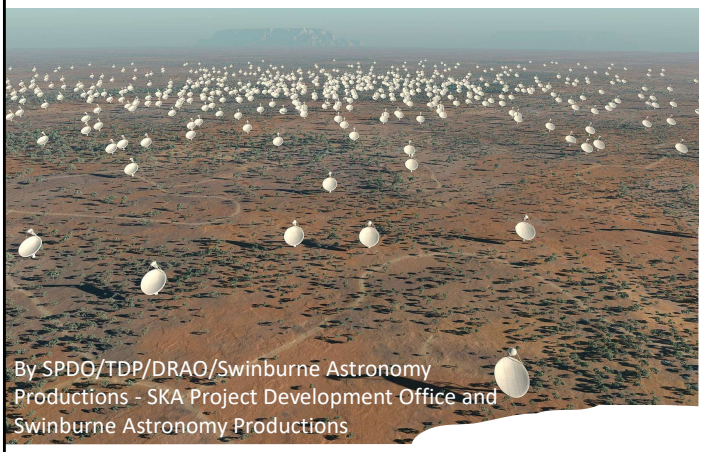


They shipped HDDs by plane, train, and automobile…err..truck. Would have taken years to send over the internet.

JAMES WEBB TELESCOPE

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

Square Kilometer Array (SKA)



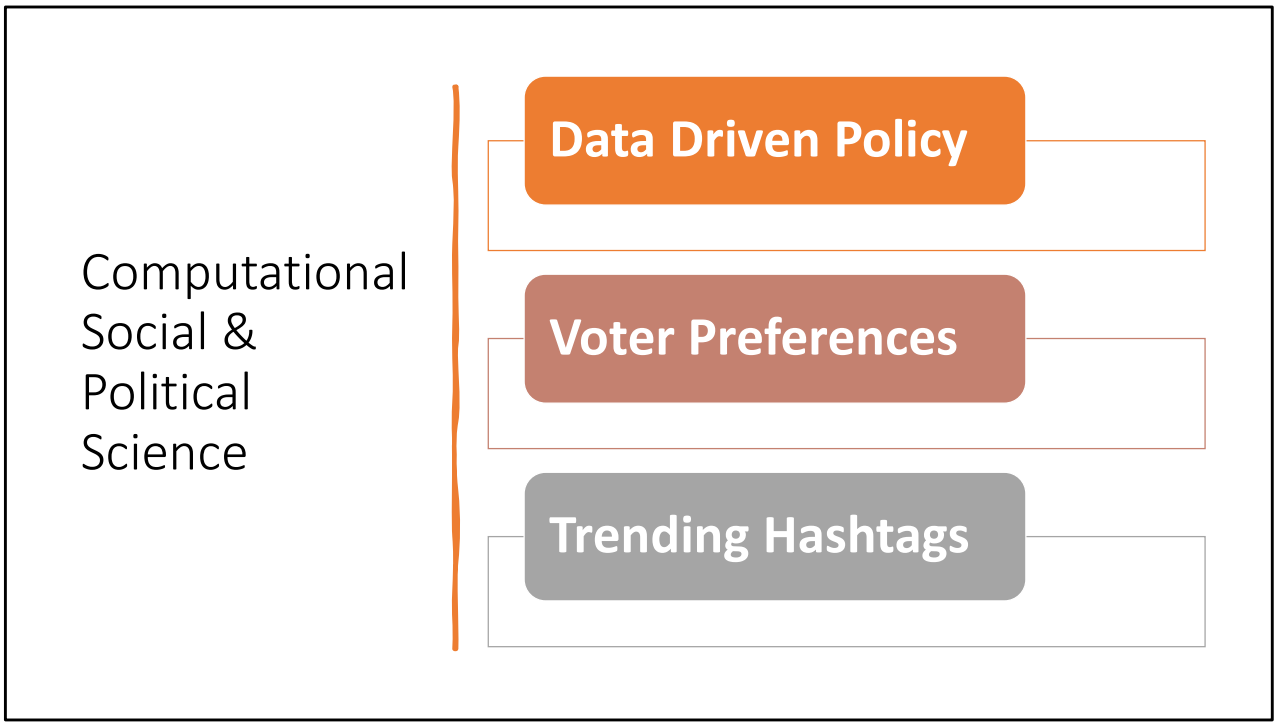
Estimated Completion Date – 2027

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
Data Driven Policy
Voter Preferences
Trending Hashtags

Humans as Sensors

Humans record their thoughts on social media.

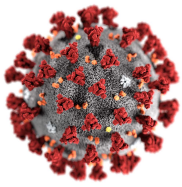
What can we do with all those data?

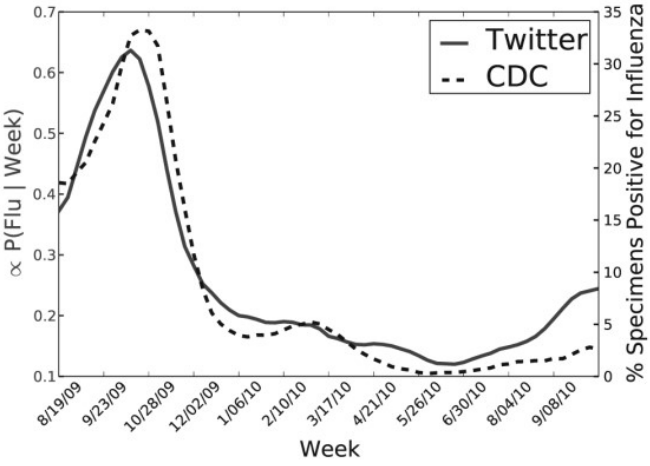
~~Twitter~~ 𝕏

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

Predicting *X* with ~~Twitter~~ 𝕏

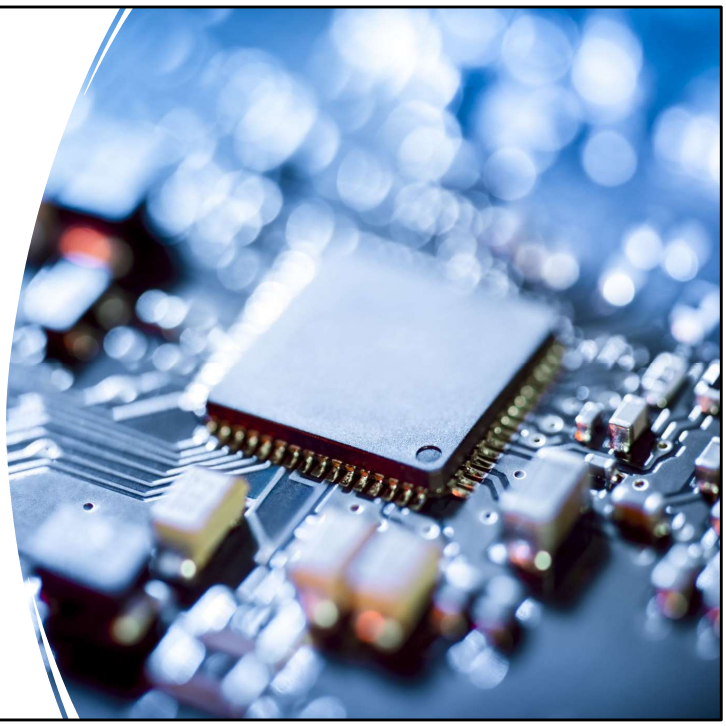
Fall 2020 Project : Predicting COVID with Twitter





Big Data, Big Computer?

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



Big Data, Big Network!

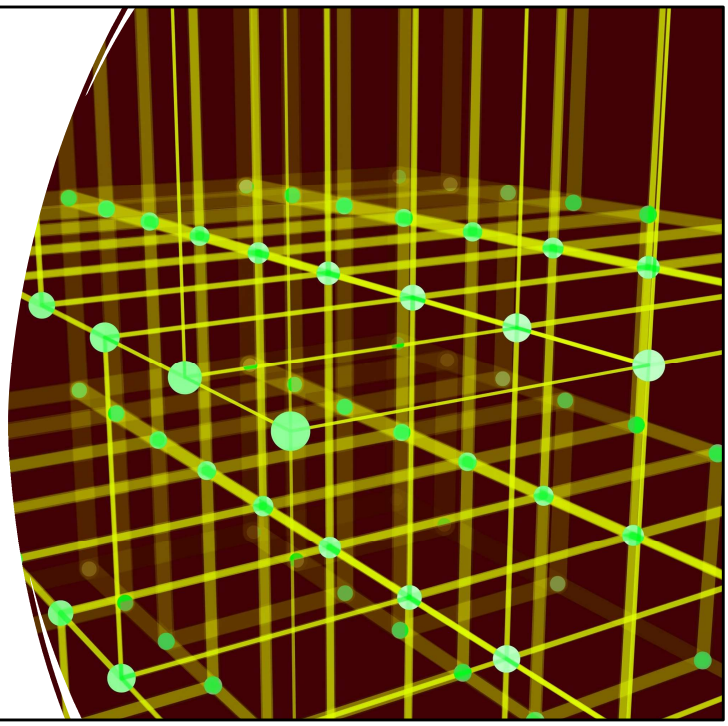
- Horizontal Scaling
- Cheap computers, just more of them

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?



Scaling Out!

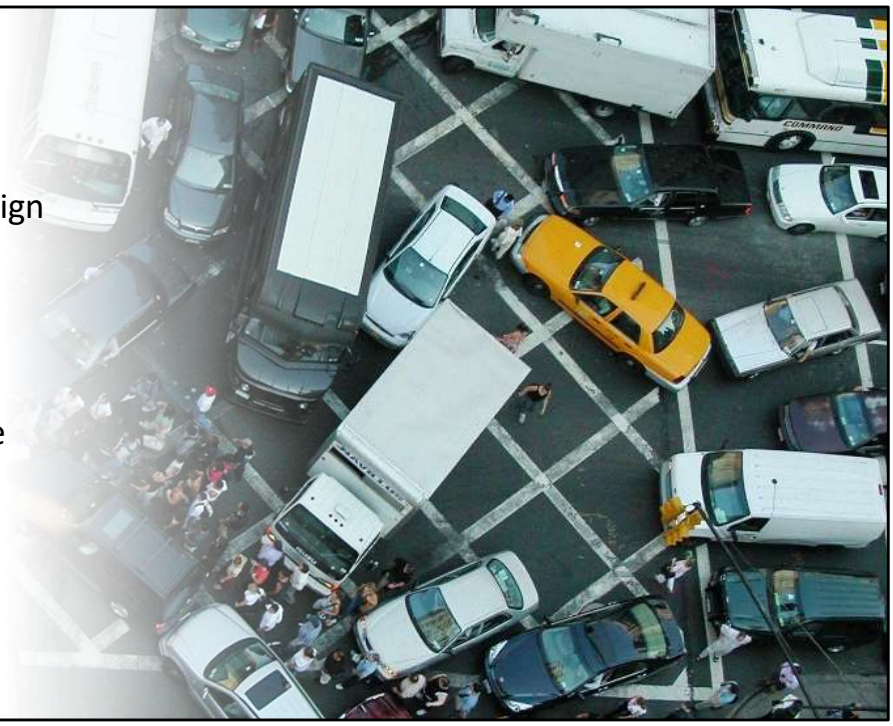
- A datacenter of many machines?
- Many datacenters???
- Fault tolerance

ALL HARDWARE FAILS

DIFFICULT

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

We're going to use one



Abstraction to the rescue

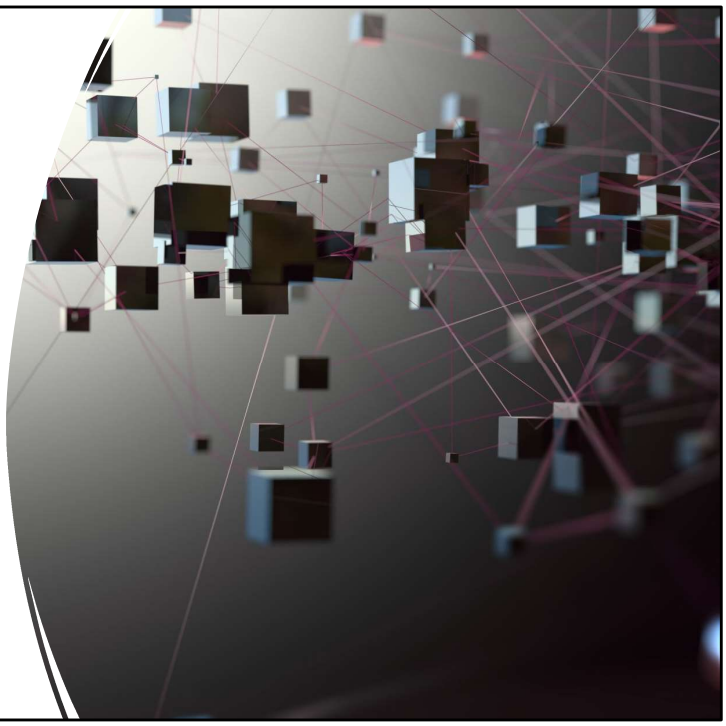
You didn't need to understand the hardware to use assembly

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?

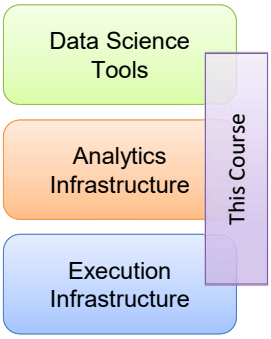
- How can we abstract a distributed network?
- (That's the topic of the next few lectures)



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

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Assignment Mechanics (CS431/631)

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

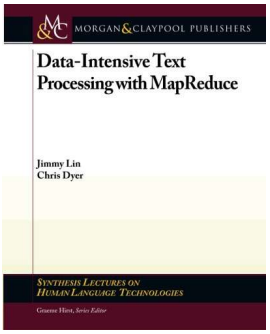
Assignments will be submitted using private Git repositories
Details are on the course website for the appropriate assignment

Python

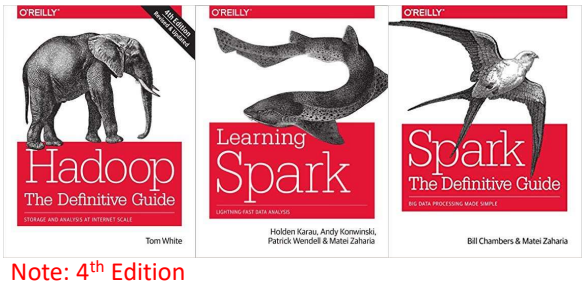
Late assignments will get 0

Course Materials

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



(optional but recommended)



Note: 4th Edition