Hello! and Welcome

CS 744: BIG DATA SYSTEMS

Shivaram Venkataraman
Fall 2022
Assistant Professor in Computer Science

PhD at UC Berkeley: System Design for Large Scale Machine Learning

Industry: Google, Microsoft Research
Open source: Apache Spark committer

Call Me: Shivaram or Prof. Shivaram
COURSE LOGISTICS

Shivaram Venkataraman
Office hours: Monday 11-noon, CS 7367

TA: Roger Waleffe
Office hours: Monday 5-6pm and Thursday 5-6pm, CS 7372

Discussion, Questions: Use Piazza!
TODAYS AGENDA

What is this course about?

Why are we studying Big Data systems?

What will you do in this course?
BRIEF HISTORY OF BIG DATA
“…Storage space must be used efficiently to store indices and, optionally, the documents themselves. The indexing system must process hundreds of gigabytes of data efficiently…”

The Anatomy of a Large-Scale Hypertextual Web Search Engine

Sergey Brin and Lawrence Page
Google 2001

Commodity CPUs

Lots of disks → Large amounts of data

Low bandwidth network

Cheap! → Cost
Facebook’s daily logs: 60 TB

Google web index: 10+ PB
scientific breakthroughs will be powered by advanced computing capabilities that help researchers manipulate and explore massive datasets”

-- Jim Gray
GRAVITY WAVE DETECTION
Working with data from Solar Dynamics Observatory
[Brown et. al SDO Primer 2010]

Solar Flare Prediction Using Photospheric and Coronal Image Data.
[Jonas et. al American Geophysical Union, 2016]
Data Growth is Outpacing Computing Growth

Graph based on average growth

Source: More Data, More Science and... Moore’s Law  [Kathy Yellick]
Google data centers in The Dulles, Oregon
DATA CENTER EVOLUTION

Capacity:
~10000 machines

Bandwidth:
12-24 disks per node

Latency:
256GB RAM cache

Scale up
→ each machine is much more powerful

Scale out
→ larger number of machines
Reliability
Fault Tolerance

Outage in Dublin Knocks Amazon, Microsoft Data Centers Offline
By: Rich Miller
August 7th, 2011

A lightning strike has caused for Amazon and Microsoft, many sites using Amazon's BPOS (Business...)

More on today's Gmail issue
Posted: Tuesday, September 01, 2009

Posted by Ben Treynor, VP Engineering and Site Reliability

Gmail's web interface had a widespread outage today. We're currently investigating a problem with the service. Thus, right up front, I'd like to apologize and we're treating it as such. We've already taken a number of steps to fix or improve as a result of today's outage. We're committed to maintaining the reliability of our services and we're working hard to ensure that our efforts to restore the services, and what we are doing to prevent this sort of issue from happening again. As always, we will continue to keep you informed about our efforts to improve the service experience for all our users, and as with any significant service issue, our intention is to share the details of what happened.
The Joys of Real Hardware

Typical first year for a new cluster:

~0.5 overheating (power down most machines in <5 mins, ~1-2 days to recover)
~1 PDU failure (~500-1000 machines suddenly disappear, ~6 hours to come back)
~1 rack-move (plenty of warning, ~500-1000 machines powered down, ~6 hours)
~1 network rewiring (rolling ~5% of machines down over 2-day span)
~20 rack failures (40-80 machines instantly disappear, 1-6 hours to get back)
~5 racks go wonky (40-80 machines see 50% packetloss)
~8 network maintenances (4 might cause ~30-minute random connectivity losses)
~12 router reloads (takes out DNS and external vips for a couple minutes)
~3 router failures (have to immediately pull traffic for an hour)
~dozens of minor 30-second blips for dns
~1000 individual machine failures
~thousands of hard drive failures
slow disks, bad memory, misconfigured machines, flaky machines, etc.

Long distance links: wild dogs, sharks, dead horses, drunken hunters, etc.
How do we program this?
BIG DATA SYSTEMS
Big Data Landscape 2016 (Version 3.0)

Infrastructure
- Hadoop
- Data lakes
- NoSQL
- NewSQL
- Cloud
- MPP
- EDW
- Graph

Analytics
- Big Data Platforms
- Analytics Platforms
- Data Science Platforms
- Visualization
- AI

Applications
- Sales & Marketing
- Customer Service
- Security
- Vertical AI

Cross-Infrastructure/Analytics
- Hadoop
- Spark
- NoSQL Databases
- NewSQL Databases
- BI Platforms
- Statistical Computing
- Machine Learning
- Speech & NLP
- Data Integration
- Query/Data Flow
- Data Access

Open Source
- Google
- Microsoft
- IBM
- SAP
- Oracle
- NetApp
- Teradata

Data Sources & APIs
- Health
- Financial & Economic Data
- Air/Space/Sea
- Location/People/Entities

Incubators & Schools
- Jawbone
- Garmin
- Bloomberg
- Airspace
- Military
- Mapbox

Last Updated 3/23/2016
© Matt Turk (@matturck), Jim Hao (@jimhao), & FirstMark Capital (@firstmarkcap)
Scalable Storage Systems

Datacenter Architecture

Computational Engines

Resource Management

Applications

Machine Learning SQL Streaming Graph

General purpose systems that target application domains

How do design datacenter that can contain ~10,000 machines?
COURSE SYLLABUS
BACKGROUND SURVEY: PAPER READING

- 39.7%: I am new to this!
- 15.9%: I have evaluated a few papers before but I am still learning how to do this
- 42.9%: I have some experience in critically reading papers but I can learn more
- 0.5%: I have significant experience!
FAMILIARITY WITH TOOLS
PRIOR COURSES

- Operating Systems: 53 students (85.5%)
- Distributed Systems: 22 students (35.5%)
- Networking: 37 students (59.7%)
- Databases: 45 students (72.6%)
- Machine Learning: 41 students (66.1%)
- Optimization Algorithms: 15 students (24.2%)
What do you hope to learn from the course?

“In depth understanding of the architecture of data systems/ability to reason design choices”

“Ability to critically analyze big data and distributed systems, while also learning to apply those concepts in implementing new scalable systems”

“My research is in machine learning so I want to see how big data and machine learning interact since they are very intertwined.”

“To be familiar with all the breakthrough papers and latest advances in data science.”

“Have a fantastic project on my resume and GitHub; prepare me well to have related skills and find a related jobs in this field;...”
LEARNING OBJECTIVES

At the end of the course you will be able to

• Explain the design and architecture of big data systems
• Compare, contrast and evaluate research papers
• Develop and deploy applications on existing frameworks
• Design, articulate and report new research ideas
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CLASS FORMAT

Schedule: http://cs.wisc.edu/~shivaram/cs744-fa22
Reading: ~1 paper per class. We will create reading groups (Canvas)!

Review: Fill out review form (link posted on Piazza) by 12pm
Discussion: In-class group discussion, submit responses within 24 hours

What if you cannot attend?
   Best 15 responses (out of ~22)
COURSE FORMAT

Recordings released a few days after class session

- Yes, I plan to attend all the lectures synchronously.
- No, there maybe some weeks where I might not be able to attend in person

Important: In-class participation!
ABSTRACT

We have designed and implemented the Google File System, a scalable distributed file system for large distributed data-intensive applications. It provides fault tolerance while running on inexpensive commodity hardware, and it delivers high aggregate performance to a large number of clients.

While sharing many of the same goals as previous distributed file systems, our design has been driven by observations of our application workloads and technological environment, both current and anticipated, that reflect a marked departure from some earlier file system assumptions. This has led us to reexamine traditional choices and explore radically different points in the design space.

1. INTRODUCTION

We have designed and implemented the Google File System (GFS) to meet the rapidly growing demands of Google's data processing needs. GFS shares many of the same goals as previous distributed file systems such as performance, scalability, reliability, and availability. However, its design has been driven by key observations of our application workloads and technological environment, both current and anticipated, that reflect a marked departure from some earlier file system design assumptions. We have reexamined traditional choices and explored radically different points in the design space.
PRACTICE DISCUSSION!

https://forms.gle/3gkD6pGzib64zzt68

What are your goals in taking the Big Data Systems course?
How similar / different are goals among students in the group?

What were your main takeaways from "How to Read a Paper"?
Goals:
- Design, analyze big data systems
- Read research papers, state of the art
- Drawbacks of systems
- Big Data in Industry

Takeaways:
- How to optimize time spent / crux of the paper
ASSESSMENT

- Paper reviews: 10%
- Class Participation, Discussion: 10%
- Assignments (in groups): 20% (2 @ 10% each)
- Midterm exams: 30% (2 @15% each)
- Final Project (in groups): 30%
ASSIGNMENTS

Two homework assignments in Python using NSF CloudLab
- Assignment 0: Setup CloudLab account → TODAY
- Assignment 1: Data Processing
- Assignment 2: Machine Learning

Short coding based assignments. Preparation for course project
Work in groups of three
EXAMS

• Two midterm exams
• Open book, open notes
• Synchronous, in-class
• Focus on design, trade-offs

More details including sample papers soon
Explore new research ideas or significant implementation of Big Data systems

Research: Work towards workshop/conference paper
Implementation: Work towards open source contribution
Example: Research

*How do we scheduling distributed machine learning jobs while accounting for performance, efficiency, convergence?*

Example: Implementation

*Implement a new module in Apache YARN that allows GPUs to be allocated to machine learning jobs.*
COURSE PROJECT

Project Selection:
- Some course project ideas posted
- Form groups of three
- Bid for one or more ideas or propose your own!
- Instructor feedback/finalize idea

Assessment:
- Project introduction write up
- Mid-semester check-in
- Poster presentation
- Final project report
WAITLIST

- Class size is limited to ~80 for this semester
- Focus on research projects, discussion
- Limited undergraduate seats

If you are enrolled but don’t want to take, please drop ASAP!
If you are on the waitlist, we will admit students as spots open up
    Meet me in office hours (Monday) or next Tuesday after class if reqd.

If you want to audit the class:
BEFORE NEXT CLASS

Join Piazza: https://piazza.com/wisc/fall2022/cs744

Complete Assignment 0 (see website, Piazza)

Paper Reading: The Datacenter as a Computer