Hello!

CS 744: BIG DATA SYSTEMS

Shivaram Venkataraman

Fall 2021

WHO AM I ?

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: Thursday 11-noon, CS 7367 (or Zoom?)

TA: Yien Xu

Office hours: Mon 5-6pm, Zoom?

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

GOOGLE 1997

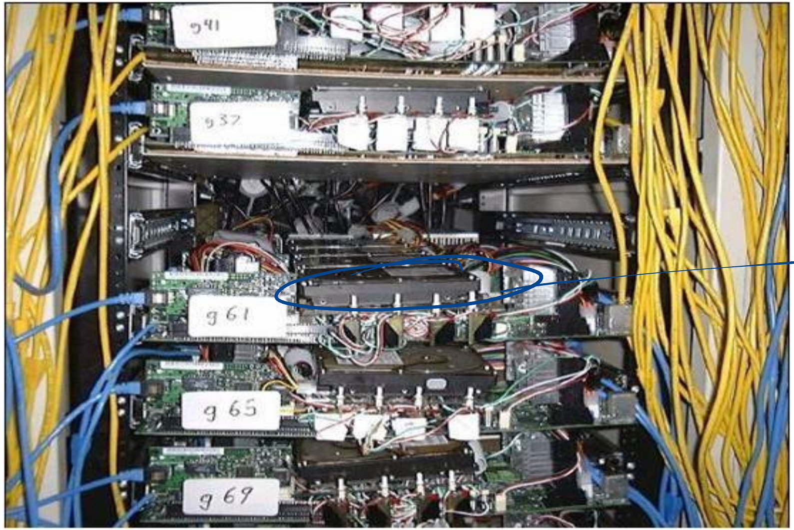
DATA, DATA, DATA

"…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



Hard disk

Commodity CPUs

Lots of disks

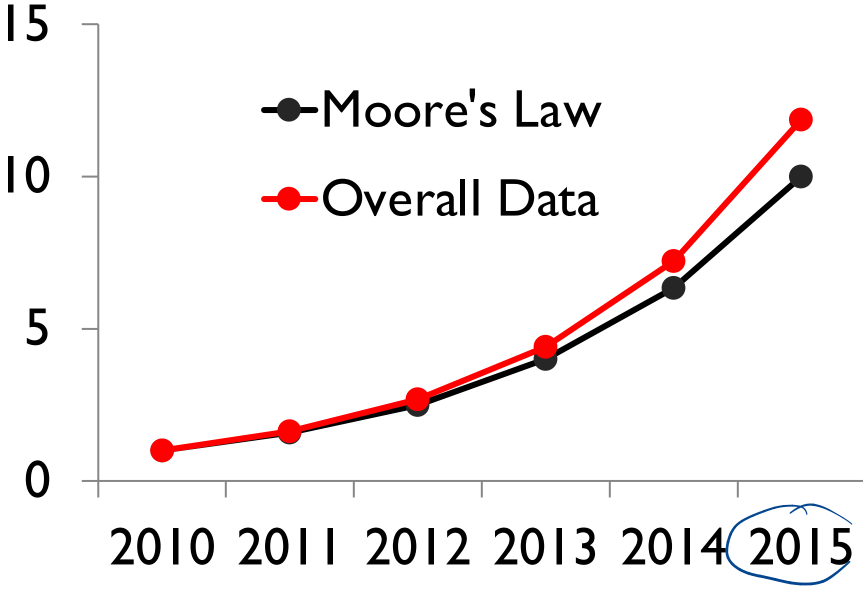
Low bandwidth network

Cheap !

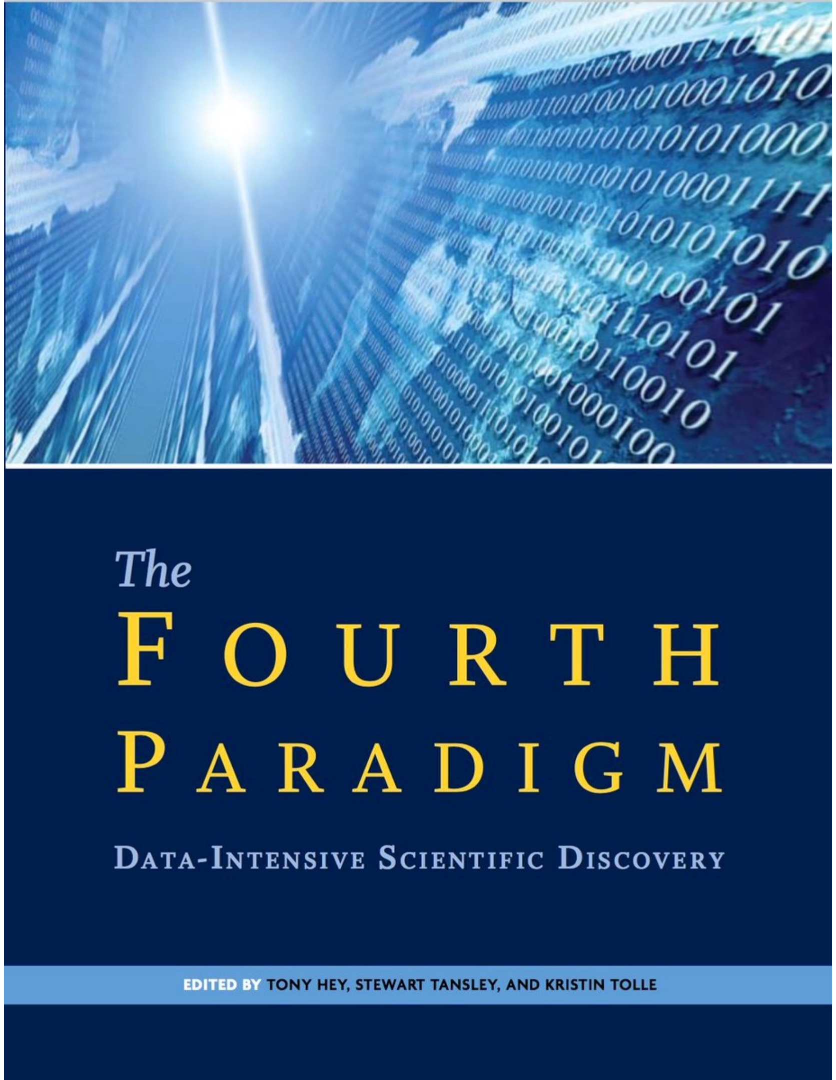
DATACENTER EVOLUTION

Facebook's daily logs: 60 TB

Google web index: 10+ PB



(IDC report*)

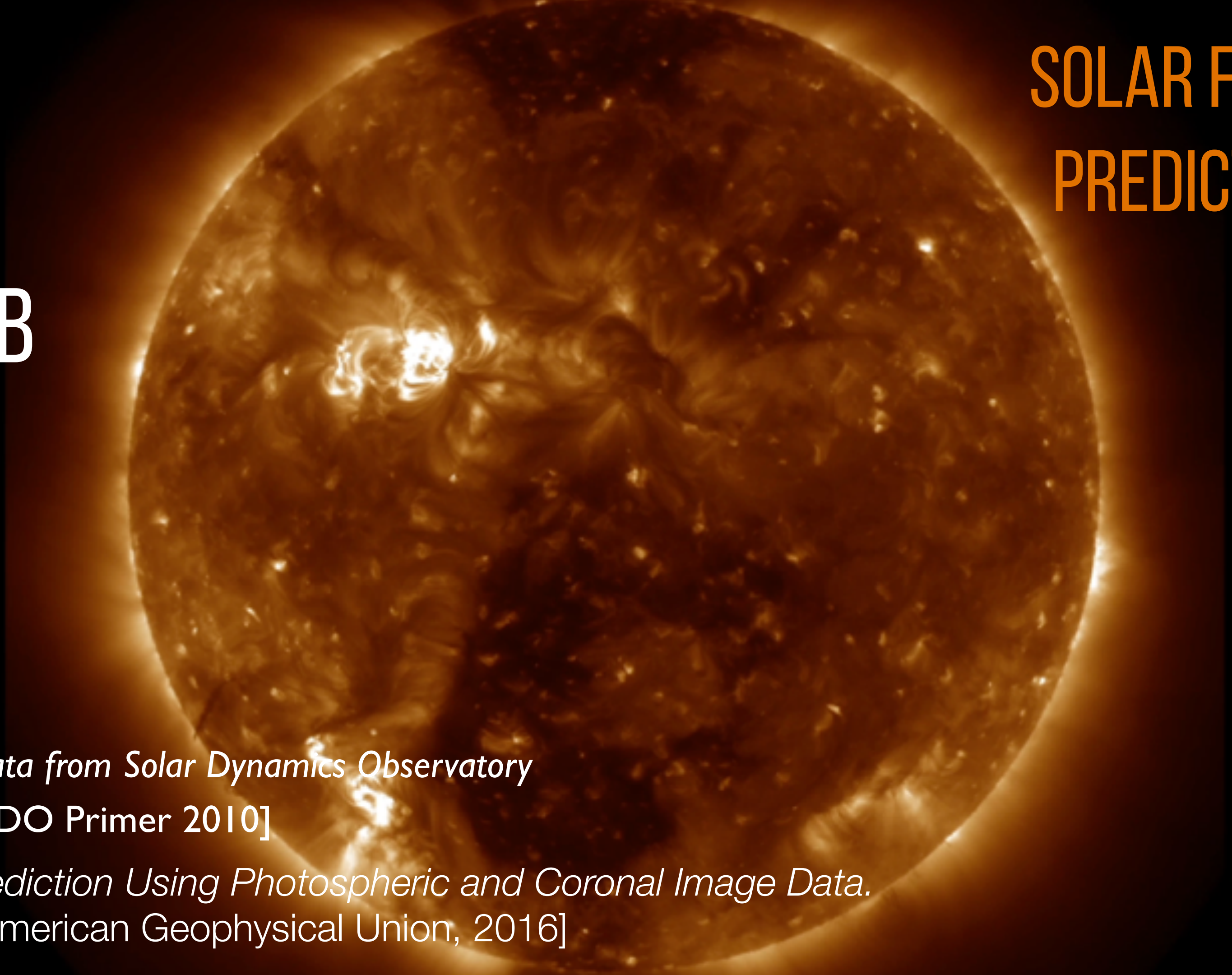


"scientific breakthroughs will be powered by advanced computing capabilities that help researchers manipulate and explore massive datasets"

-- Jim Gray

GRAVITY WAVE DETECTION

SOLAR FLARE PREDICTION



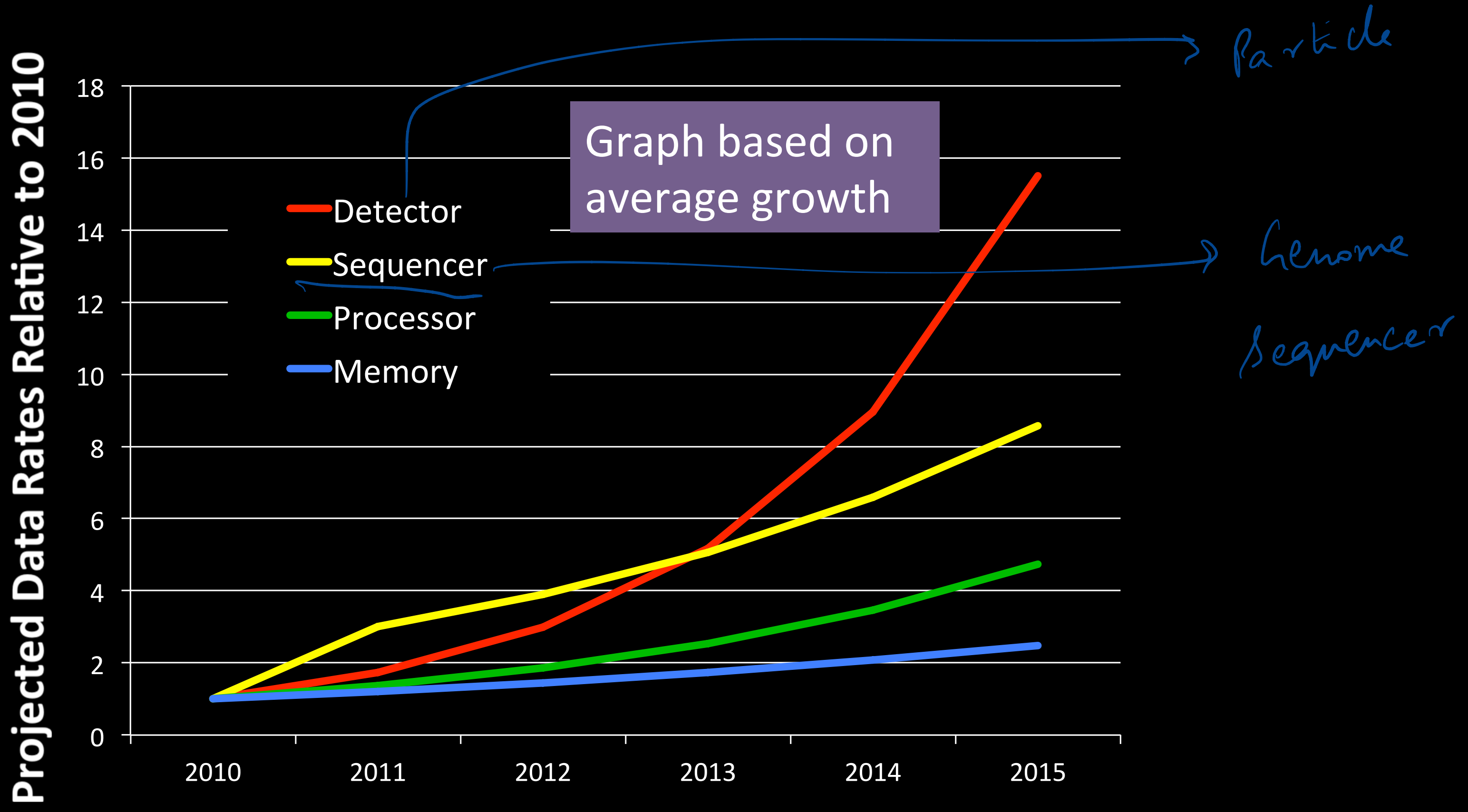
~ 2 PB

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]



Source: More Data, More Science and... Moore's Law [Kathy Yellick]

DATACENTER EVOLUTION

Google data centers in The Dulles, Oregon

DATACENTER EVOLUTION

Capacity:

~10000 machines

Bandwidth:

12-24 disks per node

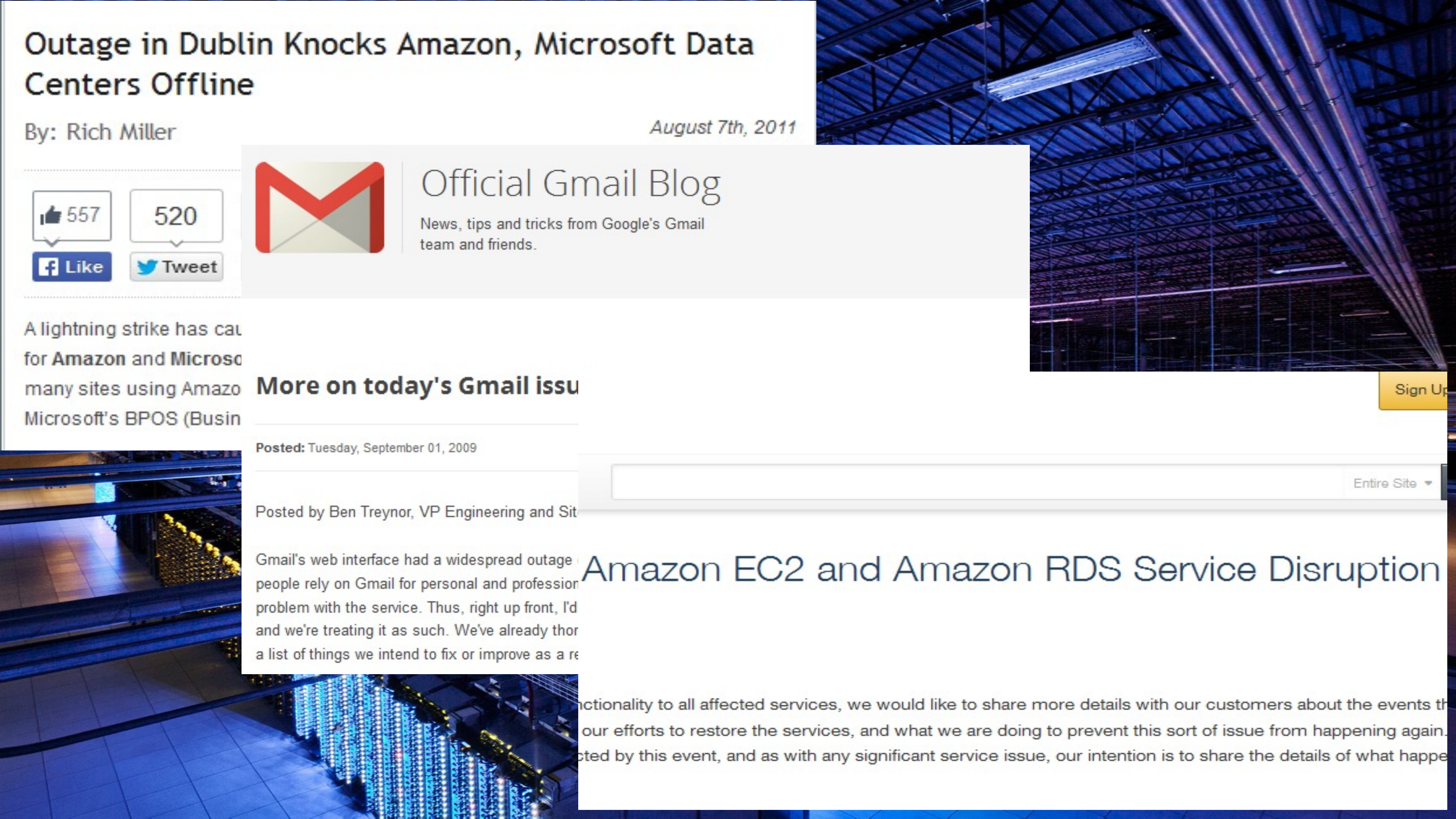
read or write data

1 TB of RAM

Latency:

256GB RAM "cache"

memory capacity


Outage in Dublin Knocks Amazon, Microsoft Data Centers Offline
By: Rich Miller
August 7th, 2011
557
520
Like
Tweet
A lightning strike has cau
for Amazon and Microso
many sites using Amazo
Microsoft's BPOS (Busin
Official Gmail Blog
News, tips and tricks from Google's Gmail team and friends.
More on today's Gmail issu
Posted: Tuesday, September 01, 2009
Posted by Ben Treynor, VP Engineering and Sit
Gmail's web interface had a widespread outage
people rely on Gmail for personal and profession
problem with the service. Thus, right up front, I'd
and we're treating it as such. We've already thor
a list of things we intend to fix or improve as a re
Sign Up
Entire Site
Amazon EC2 and Amazon RDS Service Disruption
ctionality to all affected services, we would like to share more details with our customers about the events th
our efforts to restore the services, and what we are doing to prevent this sort of issue from happening again.
cted by this event, and as with any significant service issue, our intention is to share the details of what happe

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)

Power failure

~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

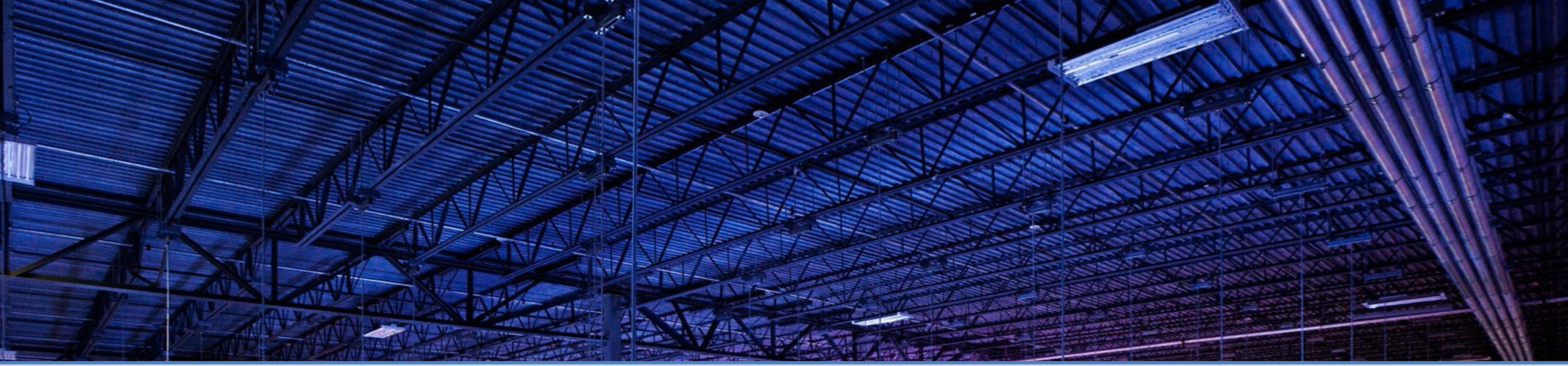
~1000 individual machine failures

~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.

JEFF DEAN @ GOOGLE



How do we program this ?

BIG DATA SYSTEMS

Cloud Computing Storage

- Hierarchy

NVMe → ↳ In memory Storage (Memcached / Redis)

↳ SSD storage

↳ Hard disk

↳ Tape

Optimizing data storage

↳ Compression

↳ Data Coding

↳ Density of storage

Software Systems that help process large datasets!

Big Data Landscape 2016 (Version 3.0)

Infrastructure

Hadoop On-Premise
cloudera, Hortonworks, MAPR, Pivotal, IBM InfoSphere, bluedata, jethro

Hadoop in the Cloud
amazon web services, Microsoft Azure, Google Cloud Platform, IBM InfoSphere, CAZENA, Treasure Data, altiscale, Qubole

Spark
databricks, GridGain, TACHYON NEXUS

Cluster Services
amazon web services, HPCC Systems, kubernetes, docker, Mesosphere, CoreOS, pepperdata, StackIQ

NoSQL Databases
amazon DynamoDB, Google Cloud Platform, ORACLE, Microsoft Azure, MarkLogic, mongoDB, DATASTAX, AEROSPIKE, Couchbase, SequoiaDB, redislabs, influxdata

NewSQL Databases
SAP HANA, Clustrix, Pivotal, paradigm4, NuoDB, memsql, splice machine, MariaDB, VoltDB, citusdata, deepdb, Trafodion, Cockroach Labs

Graph Databases
neo4j, Titan, GraphX, OrientDB, InfiniteGraph

MPP Databases
TERADATA, VERTICA, NETEZZA, Actian, kognitio, EXASOL, dremio

Cloud EDW
amazon web services, Google Cloud Platform, Microsoft Azure, Pivotal, snowflake, WATERLINE DATA, Infoworks

Data Transformation
alteryx, talend, TRIFACTA, tamr, Paxata, StreamSets, Alation

Data Integration
informatica, MuleSoft, snapLogic, Bedrock Data, xplenty

Management / Monitoring
New Relic, APPDYNAMICS, amazon web services, actifio, Numerify, splunk, DATADOG, Rocana, DRIVEN, Anodot

Security
TANIUM, illumio, CODE42, DataGravity, CipherCloud, VECTRA, sqrrl, BlueTalon

Storage
amazon web services, Google Cloud Platform, Microsoft Azure, panasas, nimblestorage, COHO DATA, Qumulo

App Dev
apigee, CASK, Keen IO, Typesafe, DRIVEN

Crowd-sourcing
amazon mechanical turk, CrowdFlower, WorkFusion

Analytics

Analyst Platforms
Palantir, AYASDI, Quid, enigma, Digital Reasoning, ORBITAL INSIGHT

Analytics Platforms
Microsoft, GUAVUS, Datameer, Bottlenose, interana

Data Science Platforms
context relevant, CONTINUUM ANALYTICS, DataRobot, Alpine, ARIMO, MODE, plotly, dataiku, Nutonian, DOMINO, sense, yhat, ALGORITHMIA

Visualization
tableau, Google Cloud Platform, Qlik, looker, Sisense, Roambi, ZoomData, datorama, CHARTIO

BI Platforms
Power BI, amazon web services, DOMO, salesforce Wave Analytics, GoodData, birst, kyvos insights, platfora, atscale, ARCADIA, SISENSE

Statistical Computing
sas, SPSS, MATLAB

Log Analytics
splunk, sumologic, kibana, CLOUD PHYSICS, loggly

Social Analytics
Hootsuite, NETBASE, DATASIFT, tracx, bitly, synthesio, simplereach

Real-Time
amazon web services, METAMARKETS, striim, confluent, DATATORRENT, dataArtisans

Machine Learning
Azure Machine Learning, H2O.ai, amazon web services, Dato, SKYTREE, rapidminer, DATARPM, deepsense.io, VISENZE, PredictionIO, glowfish

Speech & NLP
NarrativeScience, NUANCE, WolframAlpha, semantic machines, Gridspace, ARRIA, api.ai, cortical.io, maluuba, MindMeld, IDIBON, yseop

Horizontal AI
IBM Watson, Cortana, sentient, VIV, nervana, vicarious, nara, Numenta, HyperScience, Scaled Inference, Descartes Labs, clarifai, DEXTRO, MetaMind, Geometric Intelligence

Search
hp Autonomy, ORACLE ENDECA, EXALEAD, Lucidworks, elastic, ThoughtSpot, MAANA, swiftype, Algolia, SINEQUA

Data Services
Opera Solutions, Mu Sigma, EXL analytics, DATASCIENCE, Silicon Valley Data Science, kaggle, datascope, DataKind

For Business Analysts
OrigamiLogic, ClearStory Data, CIRRO, import.io

Web / Mobile / Commerce
Google Analytics, mixpanel, RJMetrics, BLUECORE, AMPLITUDE, granify, sumall, Airtable, retention science, custora

Applications

Sales & Marketing
RADIUS, Gainsight, bloomreach, Zeta, EVERSTRING, livefyre, blue yonder, Lattice, kahuna, infer, SAILTHRU, persado, AVISO, 6sense, QUANTIFIND, ACTIONIQ, fuse machines, NGAGIO

Customer Service
MEDALLIA, ATTENSITY, CLARABRIDGE, CLICKFOX, STELLAService, NGDATA, Preact, DigitalGenius, appuri, wise.io

Human Capital
gild, Connectifier, textio, entelo, hiQ

Legal
RAVEL, JUDICATA, Everlaw, eBrevia, PREMONITION

Ad Optimization
AppNexus, MediaMath, criteo, OpenX, rocketfuel, Integral Ad Science, theTradeDesk, Adgorithms, dstillery, LiveIntent, TAPAD, DataXu, Appier, MOAT

Security
CYLANCE, CounterTack, cybereason, AREA 1 SECURITY, ThreatMetrix, SentinelOne, Recorded Future, Guardian Analytics, FORTSCALE, sift science, Keybase, feedzai, SIGNIFYD

Vertical AI Applications
facebook, x.ai, Clara, KASISTO, lumiata

Publisher Tools
outbrain, Taboola, quantcast, Chartbeat, yieldbot, Yieldmo

Govt / Regulation
Socrata, OPENGOV, FiscalNote, enigma, PREDPOL, mark43, OpenDataSoft

Finance
Affirm, LendingClub, OnDeck, Kreditech, zestfinance, LendUp, Kabbage, tidemark, Payoff, INSIKT, Zuora, Dataminr, Lenddo, KENSHO, AIDYIA, iSENTIUM, Quantopian, sentient

Education/ Learning
KNEWTON, Clever, declara, PANORAMA EDUCATION, knowre

Life Sciences
23andMe, PATHWAY GENOMICS, Counsyl, deep genomics, Recombine, KYRUUS, FLATIRON, zymergen, HealthTap, METABIOTA, ZEPHYR HEALTH, ovia, Ginger.io, transcriptic, Glow, enlitic, AiCure, Atomwise

Industries
OPOWER, eHarmony, RetailNext, STITCH FIX, duetto, WorkFusion, BLUE RIVER, TACHYUS, SwiftKey, Seeq, FarmLogs, HowGood, celect, SIGHT MACHINE, statmuse, BOXEVER

Cross-Infrastructure/Analytics
amazon web services, Google, Microsoft, IBM, SAP, sas, 1010data, hp, Autonomy, VERTICA, vmware, TIBCO, TERADATA, ORACLE, NetApp

Open Source

Framework
hadoop HDFS, hadoop MapReduce, YARN, MESOS, Spark, TEZ, Apache Kylin, Flink, CDAP

Query / Data Flow
Pig, HIVE, SLAMDATA, APACHE DRILL, Google Cloud Dataflow

Data Access
cassandra, ACCUMULO, HBASE, mongoDB, kafka, SciDB, CouchDB, riak, OPENTSDB, nifi

Coordination
talend, oozie, Apache Zookeeper, Apache Ambari

Real-Time
STORM, Spark, APEX, Flink, TACHYON, druid

Stat Tools
R, ScalaLab, NumPy, SciPy

Machine Learning
mllib, mahout, Aerosolve, Apache SINGA, MADlib, torch, Caffe, scikit-learn, CNTK, TensorFlow, WEKA, FeatureFu, jupyter, VELES, DIMSUM, DL4J

Search
elasticsearch, Solr, Lucene

Security
Apache Ranger

Visualization
Zeppelin

Data Sources & APIs

Health
Apple, JAWBONE, GARMIN, practicefusion, fitbit, Withings, VALIDIC, netatmo, kinsa, Human API

IOT
UPTAKE, ThingWorx, helium, samsara, AUGURY, estimote

Financial & Economic Data
Bloomberg, DOW JONES, THOMSON REUTERS, S&P CAPITAL IQ, YODLEE, PREMISE, quandl, xignite, CB INSIGHTS, mattermark, StockTwits, estimize, PLAID

Air / Space / Sea
PLANET LABS, spire, WINDWARD, CRUISE, SKYCATCH, Airware, DroneDeploy

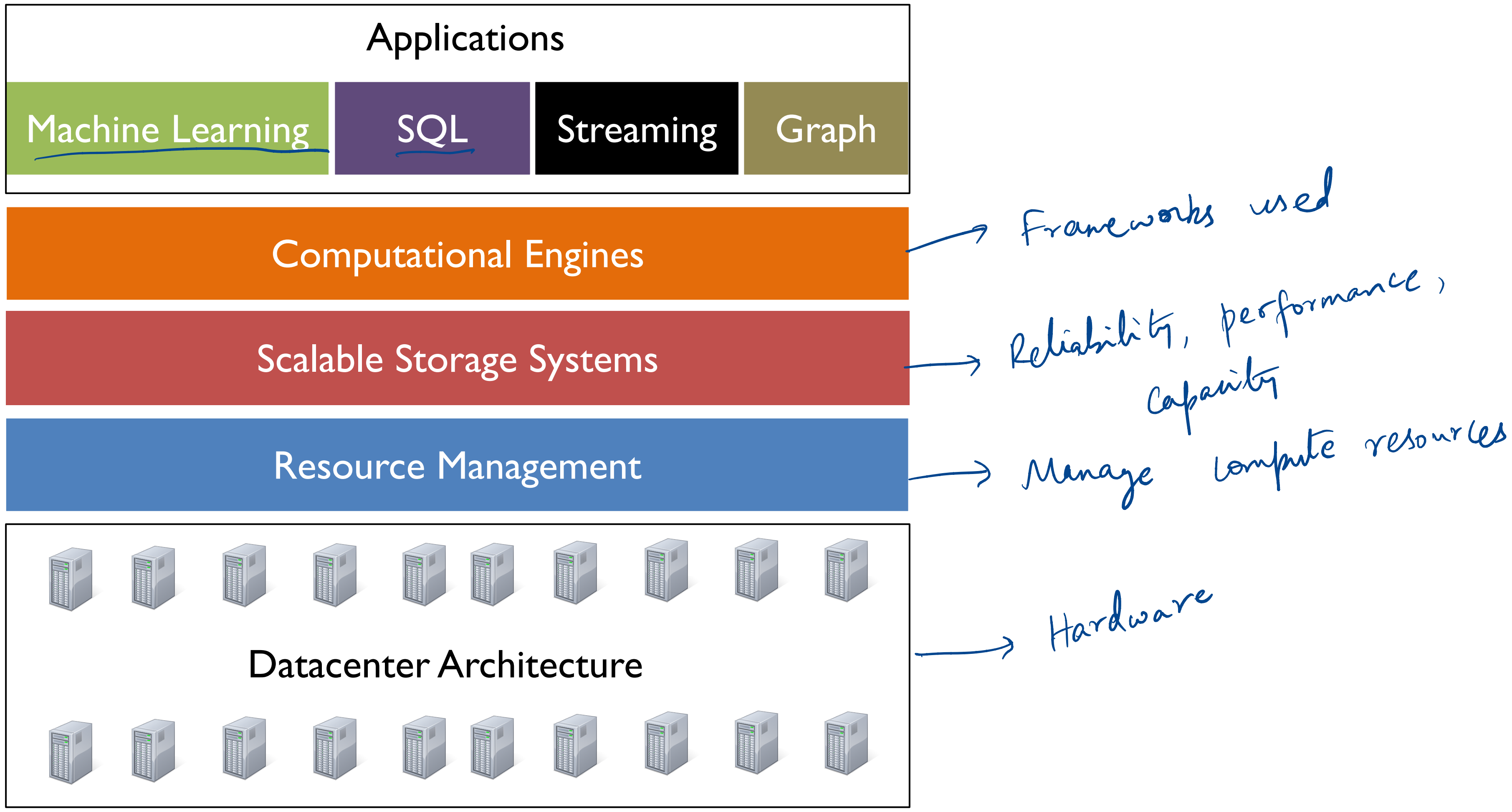
Location / People / Entities
acxiom, Experian, EPSILON, InsideView, GARMIN, foursquare, STREETLINE, esri, Crimson Hexagon, CARTODB, factual, PlaceIQ, CIRCULATE, placemeter, BASIS, Sense360

Other
qualtrics, panjiva, DATA.GOV

Incubators & Schools
GA, PLURALSIGHT, DataCamp, INSIGHT, DataElite, The Data Incubator, METIS

Last Updated 3/23/2016

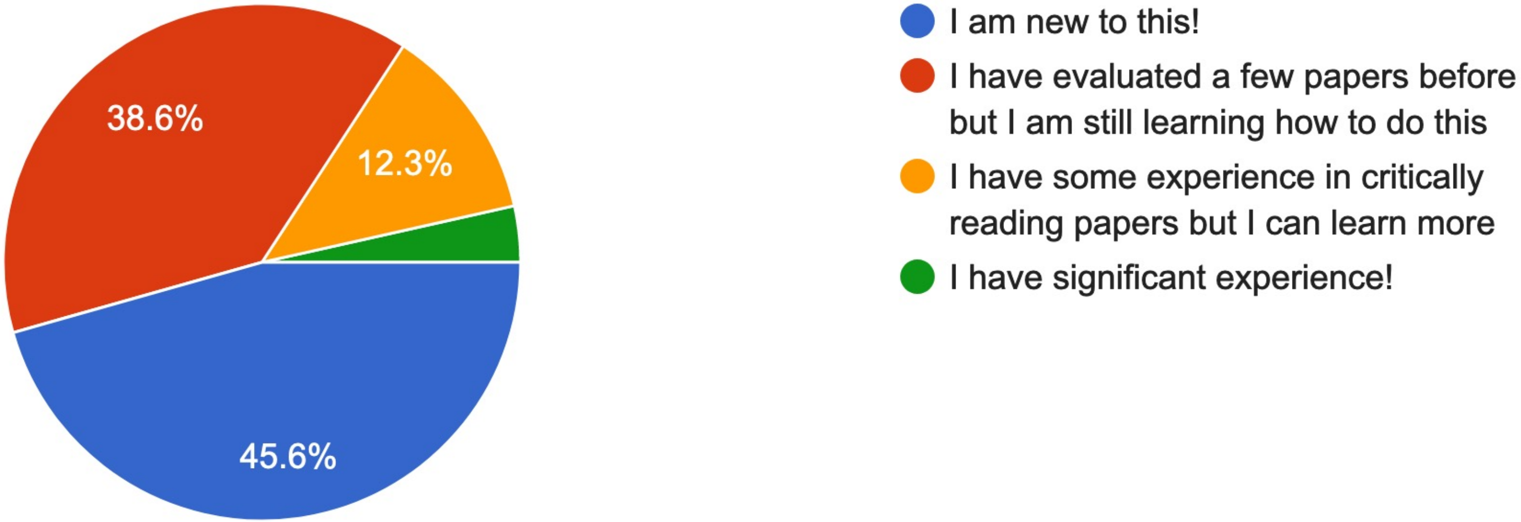
FIRSTMARK



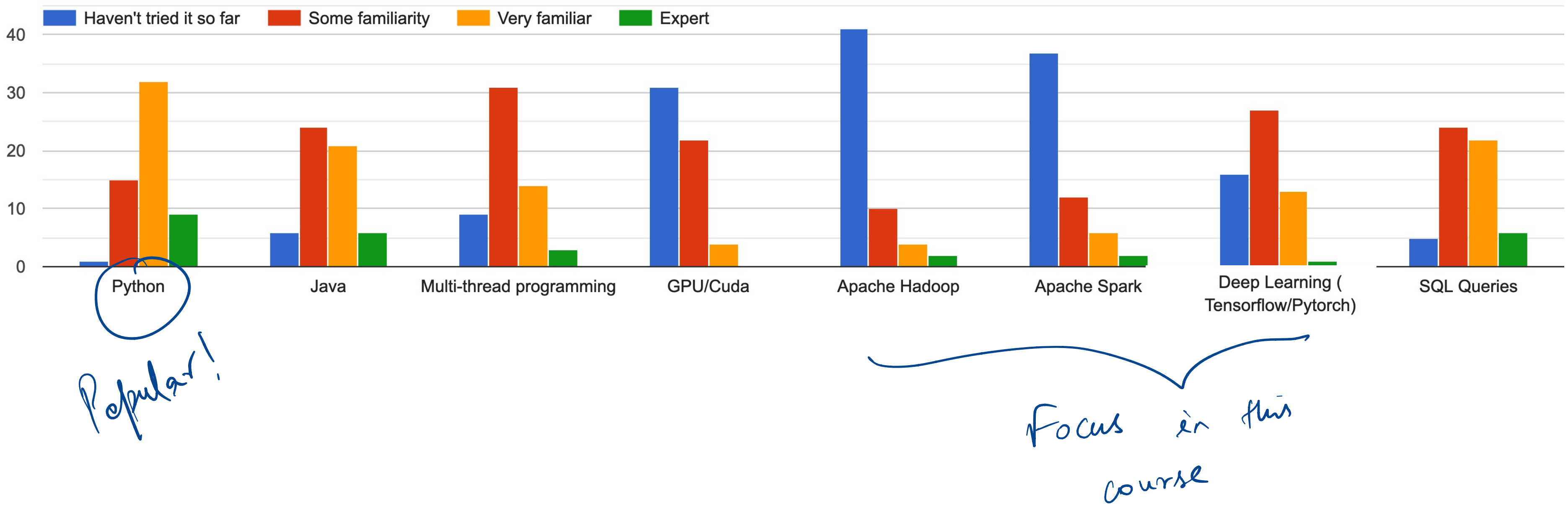
Applications
Machine Learning
SQL
Streaming
Graph
Computational Engines
Scalable Storage Systems
Resource Management
Datacenter Architecture
Frameworks used
Reliability, performance, capacity
Manage compute resources
Hardware

COURSE SYLLABUS

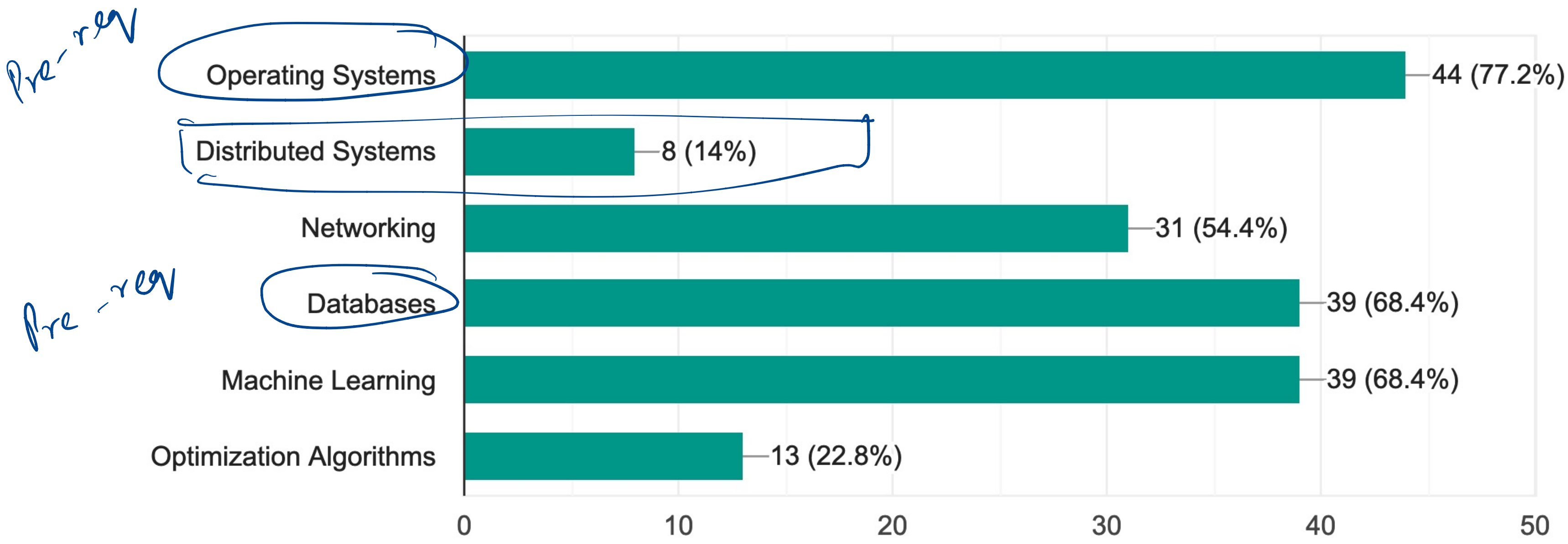
BACKGROUND SURVEY: PAPER READING



FAMILIARITY WITH TOOLS



PRIOR COURSES



WHAT DO YOU HOPE TO LEARN FROM THE COURSE?

Understanding of Big Data system architectures and approach towards their design

I hope to be able to design and deploy end to end machine learning pipelines that are designed keeping the tenets of low latency and high throughput in mind.

Tools and techniques to handle big data! My current research project has me handling large computations that I'm woefully unprepared for.

I want to learn about different systems and see if I can get a Data Science job.

I am interested in Systems research and would like to read and understand advanced papers related to it.

…

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

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
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Paper Review

Discussion

Assignment

Project

CLASS FORMAT

Schedule: http://cs.wisc.edu/~shivaram/cs744-fa21

Reading: ~1 paper per class

Review: Fill out review form (link posted on Piazza) by 9am

Discussion: In-class group discussion, submit responses within 24 hours

What if you cannot attend?

- Best 15 responses (out of ~22)
- Discussion: Student/TA/Prof (write their name!) and submit

HOW TO READ A PAPER: EXAMPLE

The Google File System

Sanjay Ghemawat, Howard Gobioff, and Shun-Tak Leung

Google*

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 rad-

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 assumptions. We have reexamined traditional choices and explored radically different points in the design space.

PRACTICE DISCUSSION!

https://forms.gle/KFG7Xd1CZm6bZcRp7 → Google Form

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"?

PRACTICE DISCUSSION SUMMARY

Takeaways

- Pass based approach is helpful filter
- Passes become progressively longer
- Literature survey as well!
- Google Scholar, Citeseer, Conference website

When do I stop nesting

- Time

References

- Which of these to read?

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
- 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 soon

COURSE PROJECT

Main grading component in the course!

Explore new research ideas or significant implementation of Big Data systems

Research: Work towards workshop/conference paper

Implementation: Work towards open source contribution

COURSE PROJECT EXAMPLES

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:

- List of 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 → feed back
- Mid-semester check-in
- Poster presentation
- Final project report

WAITLIST

- Class size is limited to ~75 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

If you want to audit the class:

↳ online videos, Piazza → review / → forms

→ assignment

BEFORE NEXT CLASS

Join Piazza: https://piazza.com/wisc/fall2021/cs744

Complete Assignment 0 (see website)

Paper Reading: The Datacenter as a Computer