Scaling Up
Hadoop

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Partly based on materials by
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How to handle data that is really large?

Really big, as in...

- Petabytes (PB, about 1000 times of terabytes)
- Or beyond: exabyte, zettabyte, etc.

Do we really need to deal with such scale?

- Yes!
“Big Data” is Common…

Google processed **24 PB / day** (2009)

Facebook’s add **0.5 PB / day** to its data warehouses

CERN generated **200 PB** of data from “Higgs boson” experiments

Avatar’s 3D effects took **1 PB** to store

So, think **BIG**!

http://www.theregister.co.uk/2012/11/09/facebook_open_sources_corona/
http://thenextweb.com/2010/01/01/avatar-takes-1-petabyte-storage-space-equivalent-32-year-long-mp3/
http://dl.acm.org/citation.cfm?doid=1327452.1327492
How to analyze such large datasets?

First thing, how to **store** them?

Single machine? 60TB SSD announced. $$$$$…

**Cluster** of machines?

- How many machines?
- Need data backup, redundancy, recovery, etc.
- Need to worry about machine and drive failure.

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Really? Really???
How to analyze such large datasets?

3% of 100,000 hard drives fail within first 3 months

Failure Trends in a Large Disk Drive Population
How to analyze such large datasets?

How to analyze them?

• What software libraries to use?
• What programming languages to learn?
• Or more generally, what framework to use?
Lecture based on Hadoop: The Definitive Guide

Book covers Hadoop, some Pig, some HBase, and other things.

http://goo.gl/YNCWN
Open-source software for reliable, scalable, distributed computing

Written in Java

Scale to thousands of machines

- **Linear** scalability (with good algorithm design): if you have 2 machines, your job runs twice as fast

Uses **simple** programming model (MapReduce)

Fault tolerant (HDFS)

- Can recover from machine/disk failure (no need to restart computation)

http://hadoop.apache.org
Why learn Hadoop?

Fortune 500 companies use it

Many research groups/projects use it

Strong community support, and favored/backed by major companies, e.g., IBM, Google, Yahoo, eBay, Microsoft, etc.

It’s free, open-source

Low cost to set up (works on commodity machines)

Will be an “essential skill”, like SQL

http://strataconf.com/strata2012/public/schedule/detail/22497
Elephant in the room

Hadoop created by Doug Cutting and Michael Cafarella while at Yahoo

Hadoop named after Doug’s son’s toy elephant
How does Hadoop scales up computation?

Uses **master-worker** architecture, and a simple computation model called **MapReduce** (popularized by Google’s paper)

Simple way to think about it

1. **Divide** data and computation into smaller pieces; each machine works on one piece

2. **Combine** results to produce final results

MapReduce: Simplified Data Processing on Large Clusters
http://static.usenix.org/event/osdi04/tech/full_papers/dean/dean.pdf
How does Hadoop scales up computation?

More technically...

1. **Map phase**
   Master node *divides* data and computation into smaller pieces; each worker node ("mapper") works on one piece independently in parallel

2. **Shuffle phase** (automatically done for you)
   Master *sorts and moves* results to "reducers"

3. **Reduce phase**
   Worker nodes ("reducers") *combines* results independently in parallel
Example:
Find words’ frequencies among text documents

Input

- “Apple Orange Mango Orange Grapes Plum”
- “Apple Plum Mango Apple Apple Plum”

Output

- Apple, 4
  Grapes, 1
  Mango, 2
  Orange, 2
  Plum, 3

http://kickstarthadoop.blogspot.com/2011/04/word-count-hadoop-map-reduce-example.html
Master divides the data (each worker gets one line)

Each worker (mapper) outputs a **key-value pair**

Pairs sorted by key (automatically done)

Each worker (reducer) combines pairs into one

A machine can be **both** a mapper and a reducer
How to implement this?

```java
map(String key, String value):
    // key: document id
    // value: document contents
    for each word w in value:
        emit(w, "1");
```

[Diagram of the implementation process]
reduce(String key, Iterator values):
    // key: a word
    // values: a list of counts
    int result = 0;
    for each v in values:
        result += ParseInt(v);
    Emit(AsString(result));

How to implement this?
What if a machine dies?

Replace it!

- “map” and “reduce” jobs can be redistributed to other machines

Hadoop’s HDFS (Hadoop File System) enables this
HDFS: Hadoop File System

A distribute file system

Built on top of OS’s existing file system to provide redundancy and distribution

HSDF hides complexity of distributed storage and redundancy from the programmer

In short, you don’t need to worry much about this!
“History” of HDFS and Hadoop

Hadoop & HDFS based on...

• 2003 *Google File System* (GFS) paper

• 2004 Google *MapReduce* paper
What can you use Hadoop for?

As a “swiss knife”.

Works for many types of analyses/tasks (but not all of them).

What if you want to write less code?

- There are tools to make it easier to write MapReduce program (Pig), or to query results (Hive)
How to try Hadoop?

Hadoop can run on a single machine (e.g., your laptop)

• Takes < 30min from setup to running

Or a “home-brew” cluster

• Research groups often connect retired computers as a small cluster

Amazon EC2 (Amazon Elastic Compute Cloud), Microsoft Azure

• You only pay for what you use, e.g, compute time, storage

• You will use it in our next assignment