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? 16TB SSD announced.

Cluster of machines?

• How many machines?

• Need to worry about machine and drive failure. Really?

• Need data backup, redundancy, recovery, etc.

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

Figure 2: Annualized failure rates broken down by age groups

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)
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-slave architecture, and a simple computation model called MapReduce (popularized by Google’s paper)

Simple explanation

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 machine ("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**  
   Machines ("reducers") *combines* results *independently* in parallel.
An 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 machine gets one line)

Each machine (mapper) outputs a key-value pair

Pairs sorted by key (automatically done)

Each machine (reducer) combines pairs into one

Input Files

Apple Orange Mango
Orange Grapes Plum

Apple Plum Mango
Apple Apple Plum

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:

- Input Files:
  - Apple Orange Mango
  - Orange Grapes Plum
  - Apple Plum Mango
  - Apple Apple Plum

- Each line passed to individual mapper instances:
  - Apple Orange Mango
  - Orange Grapes Plum
  - Apple Plum Mango

- Map Key Value Splitting:
  - Apple,1
  - Orange,1
  - Mango,1
  - Orange,1
  - Grapes,1
  - Plum,1
  - Apple,1
  - Mango,1
  - Plum,1

- Sort and Shuffle:
  - Apple,4
  - Apple,1
  - Apple,1
  - Apple,1
  - Mango,1
  - Mango,1
  - Orange,1

- Reduce Key Value Pairs:
  - Apple,4
  - Grapes,1
  - Mango,2
  - Orange,2

- Final Output:
  - Apple,4
  - Grapes,1
  - Mango,2
  - Orange,2
  - Plum,3
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 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)
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!
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)

- You only pay for what you use, e.g, compute time, storage
- You will use it in our next assignment (tentative)

http://aws.amazon.com/ec2/