

<http://poloclub.gatech.edu/cse6242>

CSE6242 / CX4242: Data & Visual Analytics

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...

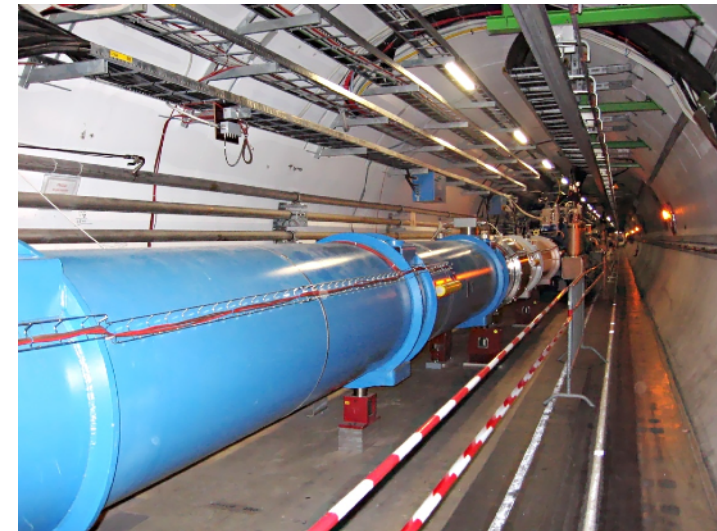
Google processed **24 PB / day** (2009)

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.

How to analyze such large datasets?

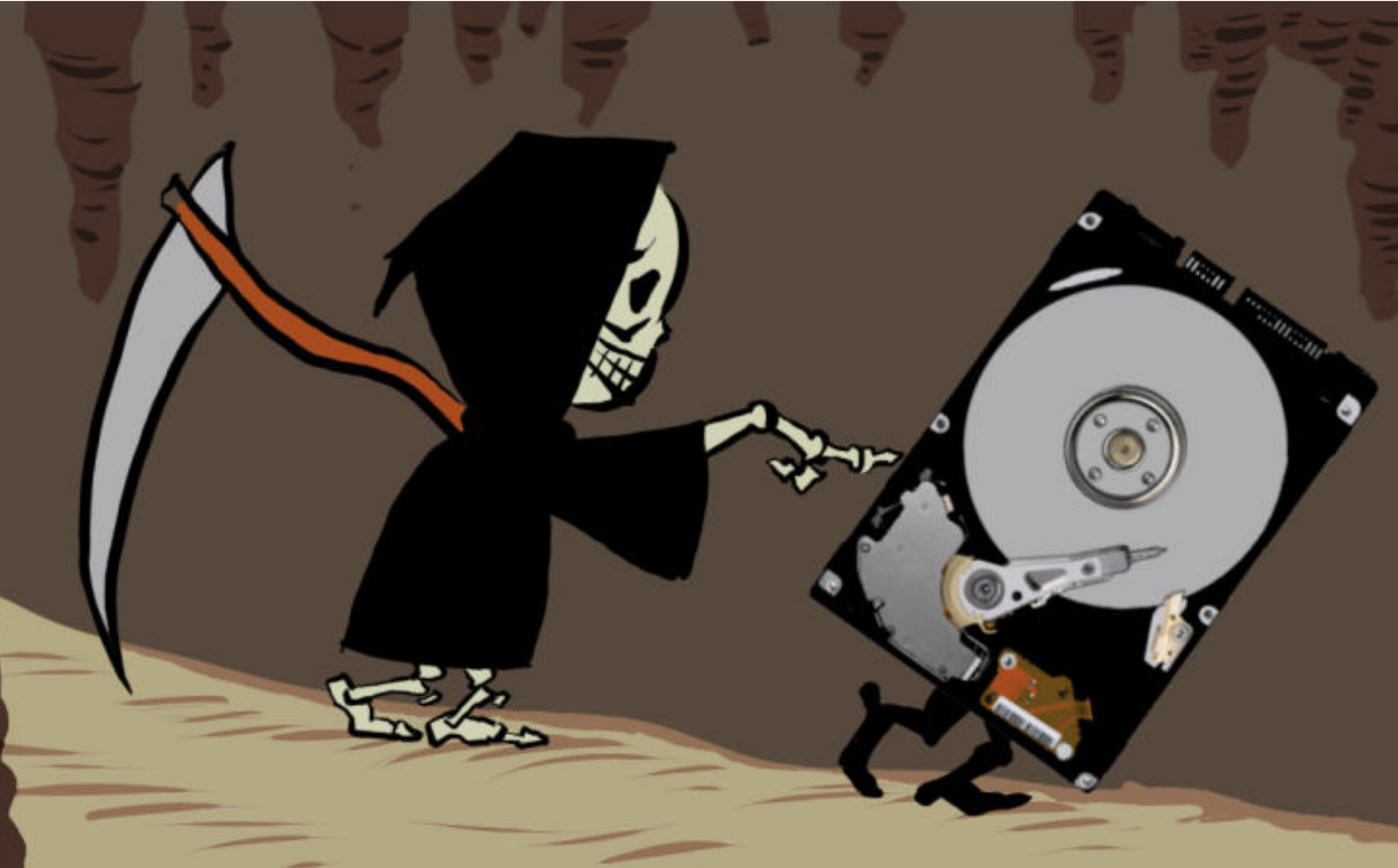
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Really? Really???



<http://lifehacker.com/how-long-will-my-hard-drives-really-last-1700405627>

How to analyze such large datasets?

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

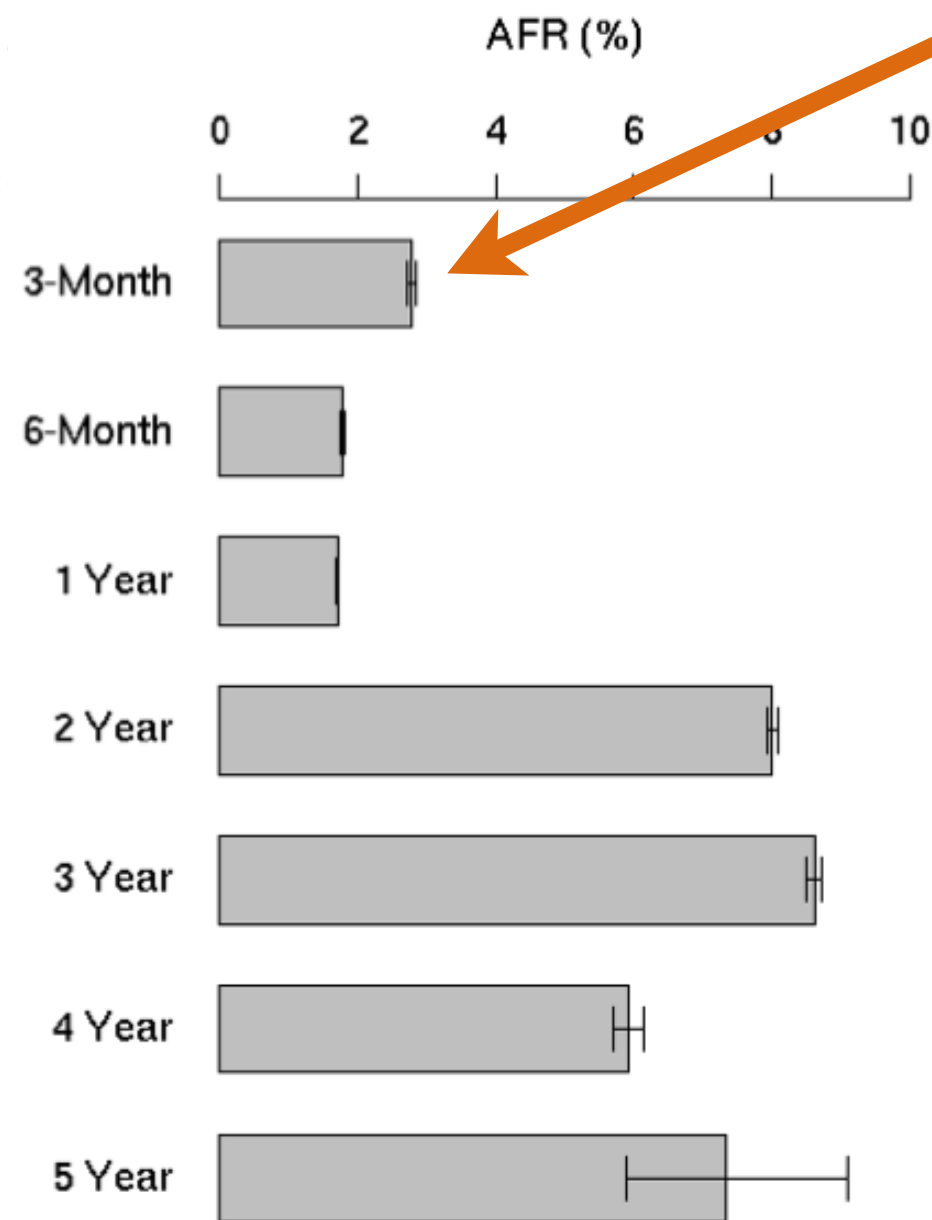


Figure 2: Annualized failure rates broken down by age groups

Failure Trends in a Large Disk Drive Population

http://static.googleusercontent.com/external_content/untrusted_dlcp/research.google.com/en/us/archive/disk_failures.pdf 6

<http://arstechnica.com/gadgets/2015/08/samsung-unveils-2-5-inch-16tb-ssd-the-worlds-largest-hard-drive/>

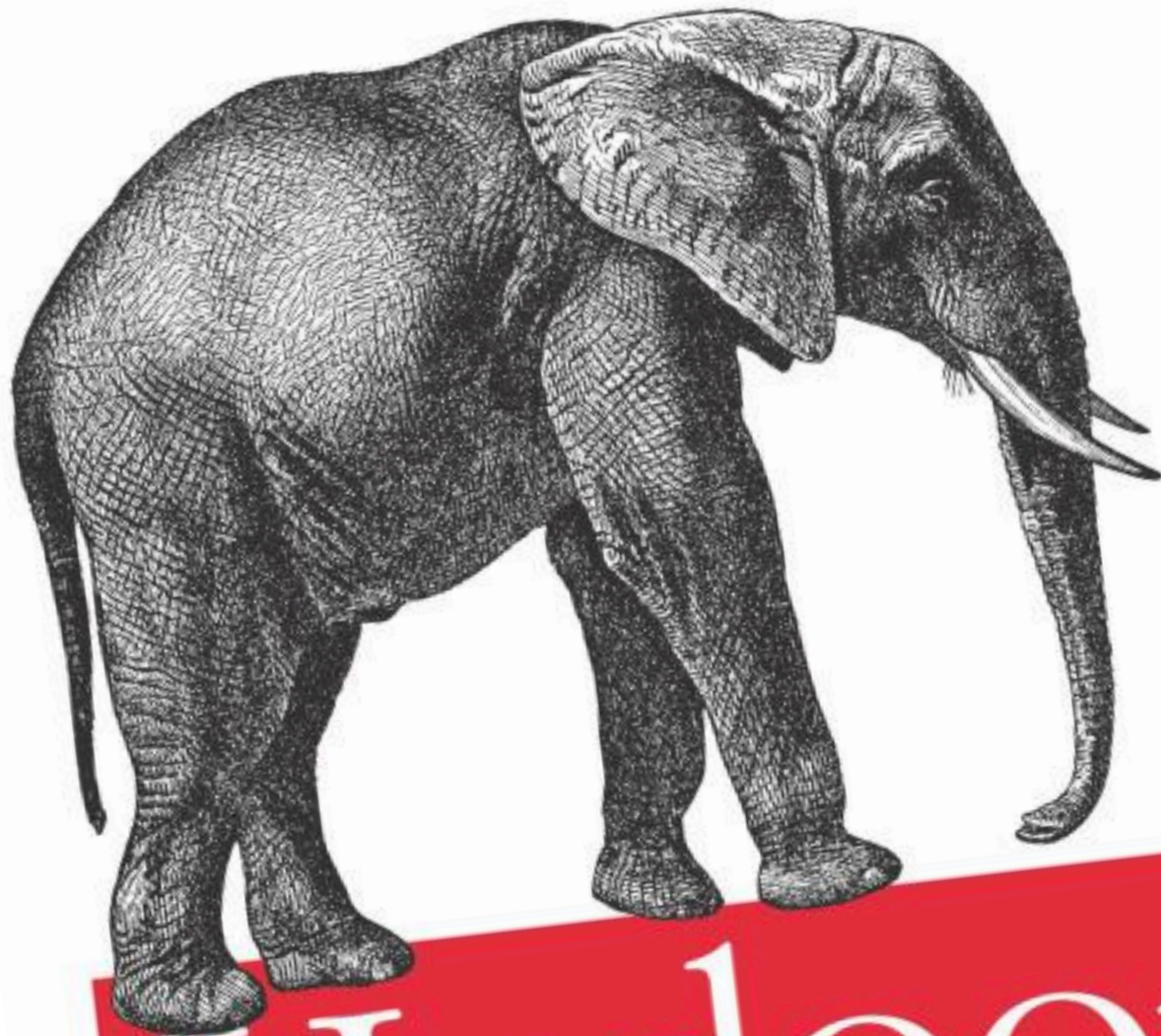
How to analyze such large datasets?

How to analyze them?

- What **software** libraries to use?
- What programming **languages** to learn?
- Or more generally, what **framework** to use?

Storage and Analysis at Internet Scale

3rd Edition
Revised & Updated



Hadoop

The Definitive Guide

O'REILLY®

Tom White

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 scale 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

How does Hadoop scale 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

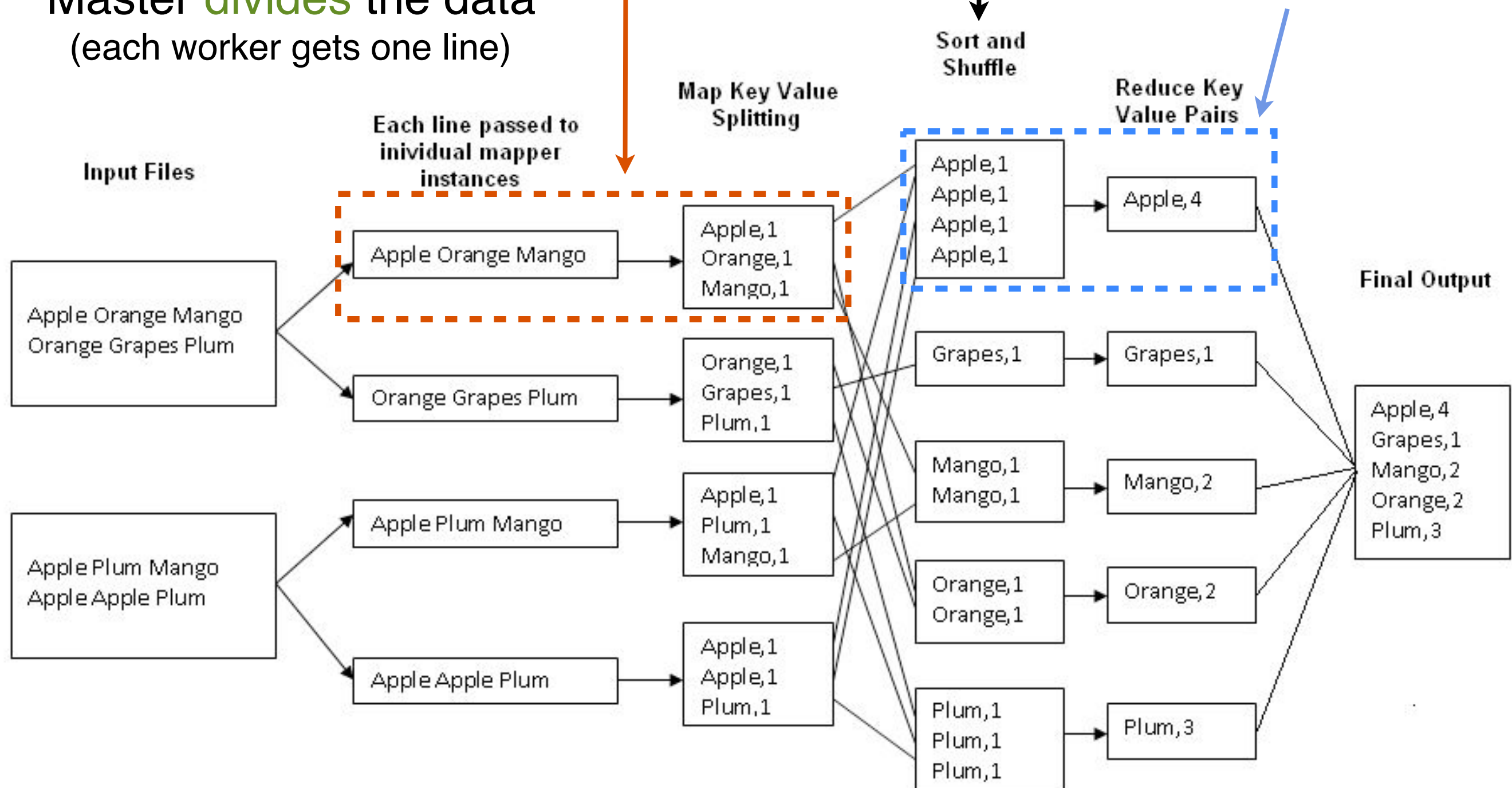
- Apple, 4
Grapes, 1
Mango, 2
Orange, 2
Plum, 3

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

Master **divides** the data
(each worker gets one line)

Pairs sorted by key
(automatically done)

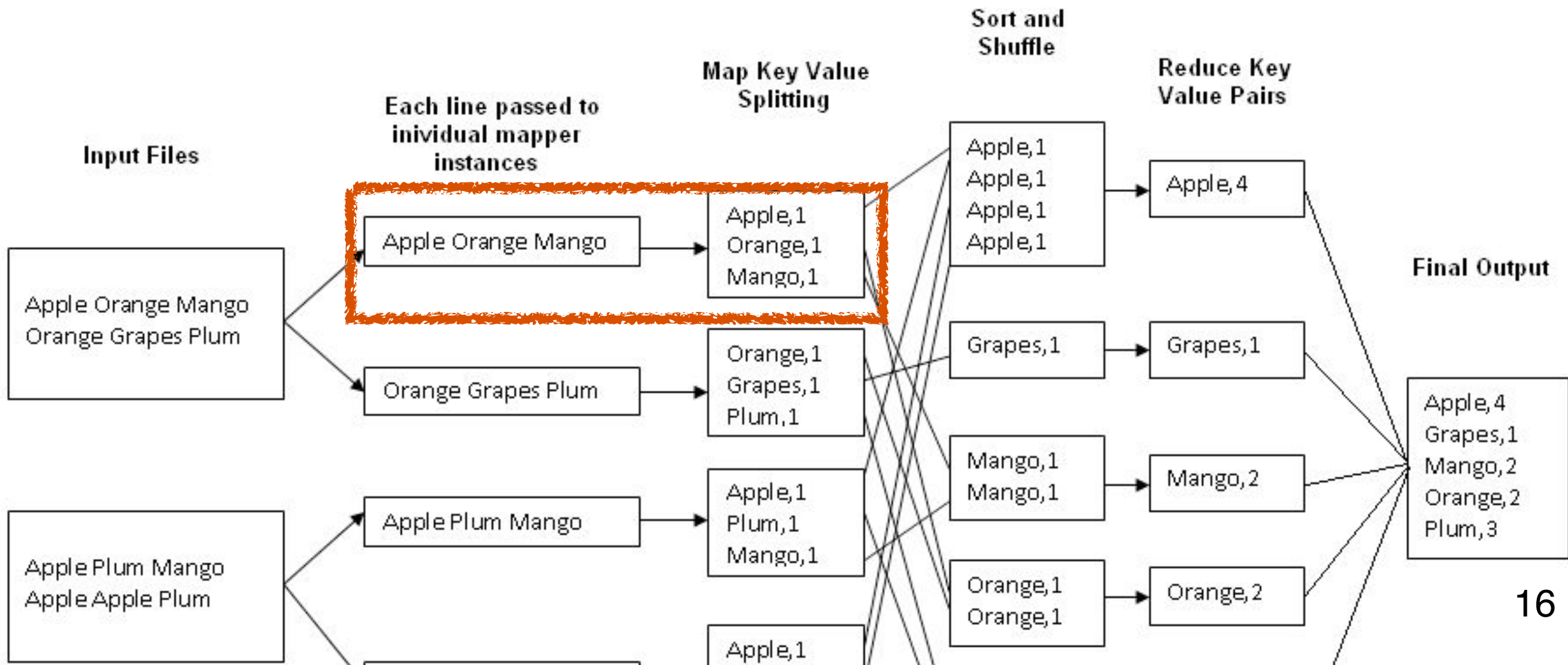
Each worker (**reducer**)
combines pairs into one



A machine can be **both** a mapper and a reducer

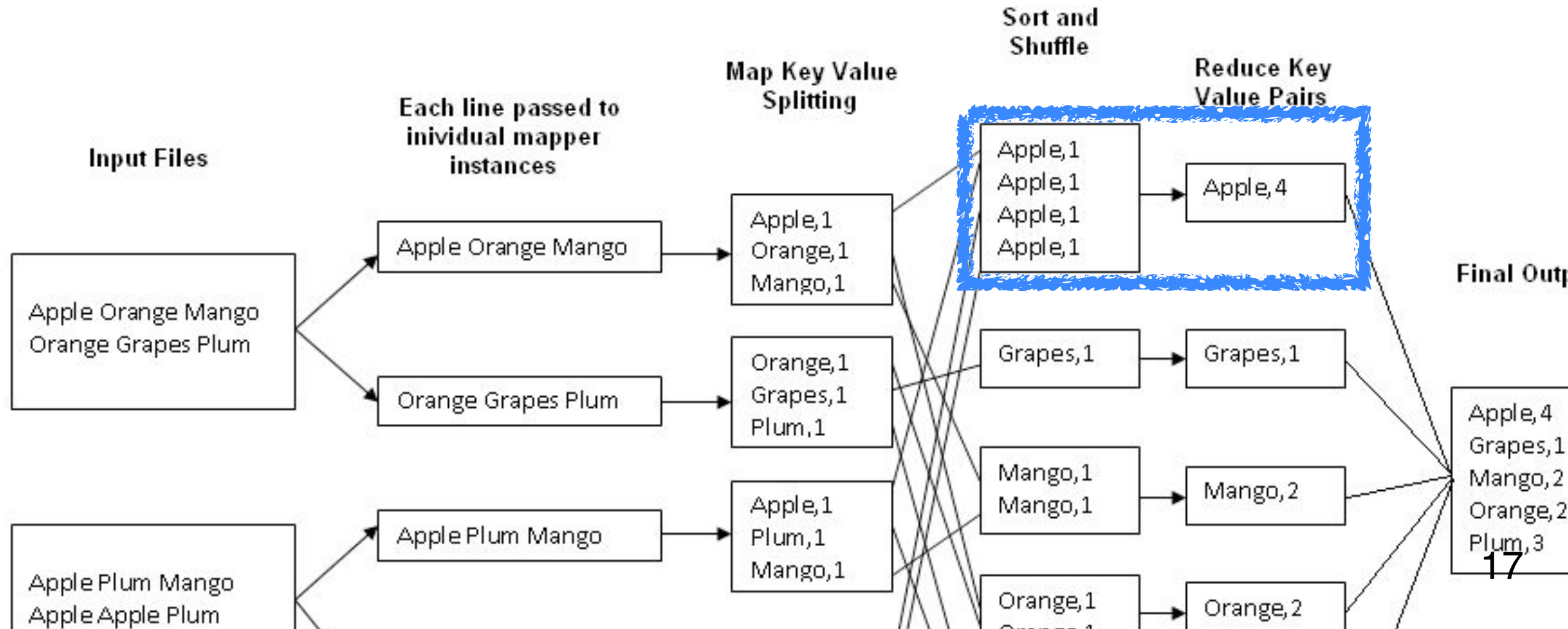
How to implement this?

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



How to implement this?

```
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));
```



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

HDFS 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

<http://cracking8hacking.com/cracking-hacking/Ebooks/Misc/pdf/The%20Google%20filesystem.pdf>

- 2004 Google *MapReduce* paper

<http://static.googleusercontent.com/media/research.google.com/en/us/archive/mapreduce-osdi04.pdf>

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-grown” 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