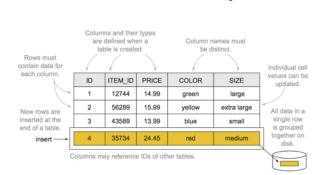
# INTRO TO DATA SCIENCE MAP REDUCE

## DATA SCIENCE IN THE NEWS

3 RECAP

#### **LAST TIME:**

- I. DATABASE EVOLUTION II. THE NOSQL MOVEMENT III. WORKING WITH STRUCTURED DATA (MYSQL, SQLITE)
- LAB: SQL (SQLITE)



From account:

To account:

Amount:

Savings

Checking

Transfer

1,000.00

Steps

Start

End

Begin transaction

Withdraw 1,000 from savings

Deposit 1,000 into checking

End transaction

INTRO TO DATA SCIENCE

## QUESTIONS?

WHAT WAS THE MOST INTERESTING THING YOU LEARNT?

WHAT WAS THE HARDEST TO GRASP?

I. BIG DATA
II. PROGRAMMING MODEL
III. IMPLEMENTATION DETAILS
IV. WORD COUNT EXAMPLE

#### **EXERCISE:**

V. MAP-REDUCE USING PYTHON

## I. BIG DATA



Q: What does "big data" actually refer to?

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A: Scalability; in particular, storing & processing web-scale (multi-terabyte) datasets...

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A: Scalability; in particular, storing & processing web-scale (multi-terabyte) datasets...

But this is only half of the story...how would you do this?

### One approach would be to get a huge supercomputer.



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#### But this has some obvious drawbacks:

- expensive
- difficult to maintain
- scalability is bounded



Instead of one huge machine, what if we got a bunch of regular (commodity) machines?



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This has obvious benefits!

- cheaper
- easier to maintain
- scalability is unbounded (just add more nodes to the cluster)

Now we can give a complete answer to our earlier question.

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Q: What does "big data" actually refer to?

A: Scalability; in particular, storing & processing web-scale (multi-terabyte) datasets <u>using clusters of multiple</u> <u>computing nodes</u>.

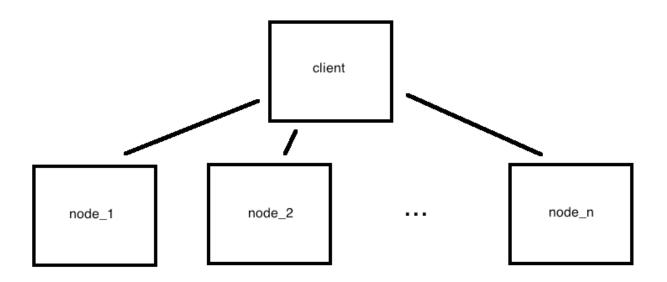
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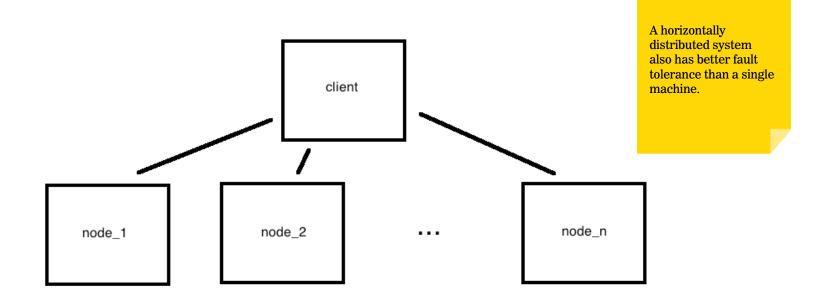
"Scale out vs scale up!"

We can visualize this horizontal cluster architecture as a single client-multiple server relationship



NOTE

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There are two ways to process data in a distributed architecture:

1) move data to code (& processing power)

2) move code to data

There are two ways to process data in a distributed architecture:

- 1) move data to code (& processing power)
  - SETI
- 2) move code to data
   map-reduce → less overhead (network traffic, disk
   I/O)
  - "Computing nodes are the same as storage nodes."

Divide and conquer is a fundamental algorithmic technique for solving a given task, whose steps include:

Divide and conquer is a fundamental algorithmic technique for solving a given task, whose steps include:

- 1) split task into subtasks
- 2) solve these subtasks independently
- 3) recombine the subtask results into a final result

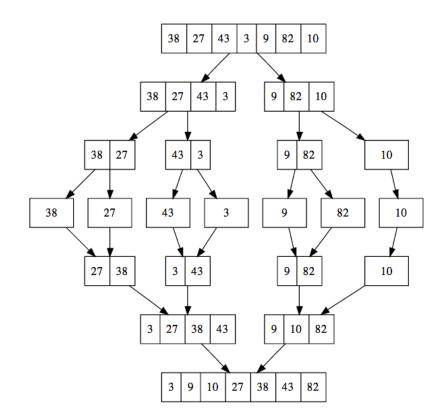
Divide and conquer is a fundamental algorithmic technique for solving a given task, whose steps include:

- 1) split task into subtasks
- 2) solve these subtasks independently
- 3) recombine the subtask results into a final result

This is how recursive algorithms work, for example.

#### One famous example of divide and conquer is merge sort.





Map-reduce leverages the divide and conquer approach by splitting a large dataset into several smaller datasets and performing a computation on each of these in parallel. Map-reduce leverages the divide and conquer approach by splitting a large dataset into several smaller datasets and performing a computation on each of these in parallel.

In fact, running a map-reduce job with identity (eg, donothing) mappers and reducers is similar to merge sort! Map-reduce leverages the divide and conquer approach by splitting a large dataset into several smaller datasets and performing a computation on each of these in parallel.

In fact, running a map-reduce job with identity (eg, donothing) mappers and reducers is similar to merge sort!

(The similarity is approximate, because results are output in multiple sets, and data is not broken down to singleelement subsets.) The defining characteristic of a problem that is suitable for the divide and conquer approach is that it can be broken down into independent subtasks. The defining characteristic of a problem that is suitable for the divide and conquer approach is that it can be broken down into independent subtasks.

Tasks that can be parallelized in this way include:

- count, sum, average
- grep, sort, inverted index
- graph traversals, some ML algorithms

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Tasks that can be parallelized in this way include

- count, sum, average
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- graph traversals, some ML algorithms

#### NOTE

Parallelizing an ML algorithm can be a non-trivial exercise!

## II. PROGRAMMING MODEL

This takes place in two phases:

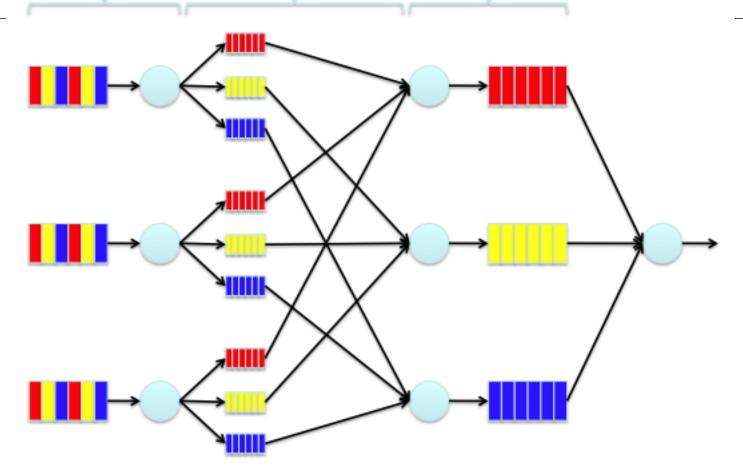
This takes place in two phases:

- 1) the mapper phase
- 2) the reducer phase

This takes place in (approximately) two phases:

- 1) the mapper phase
- 1.5) shuffle/sort
- 2) the reducer phase

Reduce



Map-reduce uses a functional programming paradigm. The data processing primitives are mappers and reducers, as we've seen.

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mappers – filter & transform data reducers – aggregate results

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mappers – filter & transform data reducers – aggregate results

The functional paradigm is good at describing how to solve a problem, but not very good at describing data manipulations (eg, relational joins). As our earlier diagram suggests, there are additional intermediate steps in a map-reduce workflow.

mappers – filter & transform data reducers – aggregate results

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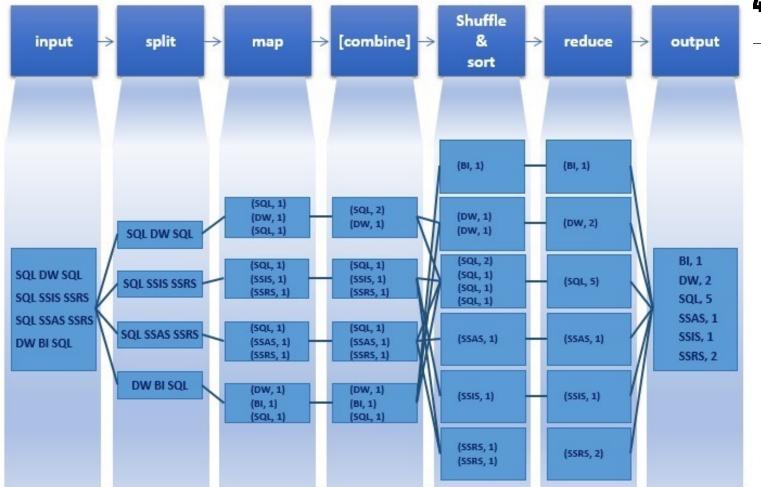
mappers – filter & transform data combiners – perform reducer operations on the mapper node (optional

step, to reduce network traffic and disk I/O).

partitioners – shuffle/sort/redirect mapper output
reducers – aggregate results

#### MapReduce - Word Count Example Flow





It's possible to overlay the map-reduce framework with an additional declarative syntax.

This makes operations like select & join easier to implement and less error prone.

Popular examples include Pig and Hive.

## Why Pig?

Because I bet you can read the following script.

### A Real Pig Script

```
top_5.pig
users = load 'users.csv' as (username: chararray, age: int); -
users 1825 = filter users by age >= 18 and age <= 25;
pages = load 'pages.csv' as (username: chararray, url: chararray); -
joined = join users_1825 by username, pages by username; -
grouped = group joined by url;
summed = foreach grouped generate group as url, COUNT(joined) AS views;
sorted = order summed by views desc;
top 5 = limit sorted 5;
    e top 5 into 'top 5 sites.csv';
```

Now, just for fun... the same calculation in vanilla Hadoop MapReduce.

### No, seriously.

```
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# II. IMPLEMENTATION DETAILS

The map-reduce framework handles a lot of messy details for you:

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- parallelization & distribution (eg, input splitting)
- partitioning (shuffle/sort/redirect)
- fault-tolerance (fact: tasks/nodes will fail!)
- I/O scheduling
- status and monitoring

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- partitioning (shuffle/sort/redirect)
- fault-tolerance (fact: tasks/nodes will fail!)
- I/O scheduling
- status and monitoring

This (along with the functional semantics) allows you to focus on solving the problem instead of accounting & housekeeping details.

Hadoop is a popular open-source Java-based implementation of the map-reduce framework (including file storage for input/output).

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You can download Hadoop and configure a set of machines to operate as a map-reduce cluster, or you can run it as a service via Amazon's Elastic Map-Reduce.

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Hadoop is written in Java, but the Hadoop Streaming utility allows client code to be supplied as executables (eg, written in any language).

Frequently when people say "map-reduce" they're referring to Hadoop, but there are some exceptions:

Frequently when people say "map-reduce" they're referring to Hadoop, but there are some exceptions:

- many NoSQL databases support native map-reduce queries
- commercial distributions (Cloudera, MapR, etc)
- Google's internal implementation

#### That said, Hadoop has a large user base.



source: http://www.hadoopwizard.com/which-big-data-company-has-the-worlds-biggest-hadoop-cluster/

Data is replicated in the (distributed) file system across several nodes.

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This permits locality optimization (and fault tolerance) by allowing the mapper tasks to run on the same nodes where the data resides.

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So we move code to data (instead of data to code), thus avoiding a lot of network traffic and disk I/O.

NOTE

nodes"

"Compute nodes are the same as storage

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The Google File System (GFS) was developed alongside map-reduce to serve as the native file system for this type of processing. The Google File System (GFS) was developed alongside map-reduce to serve as the native file system for this type of processing.

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If you use Amazon EMR, you can use their file system (Amazon S3) as well.

## III. WORD COUNT EXAMPLE

## Map-reduce processes data in terms of keyvalue pairs:

```
input <k1, v1> mapper <k1, v1> \rightarrow <k2, v2> <k2, [all k2 values]> reducer <k2, [all k2 values]> \rightarrow <k3, v3>
```

Using the following input, we can implement the "Hello World" of map-reduce: a word count.

# Using the following input, we can implement the "Hello World" of map-reduce: a word count.

```
where in where in the where in the world where in the world is where in the world is carmen where in the world is carmen sandiego
```

The first processing primitive is the mapper, which filters & transforms the input data, and emits transformed key-value pairs.

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```
mapper(k1, v1):
// k1 = line number
// v1 = line contents (eg, space-delimited string)

words = tokenize(v1) // split string into words
for word in words:
    emit (word, 1)
```

The mapper emits key-value pairs for each word encountered in the input data.

# The mapper emits key-value pairs for each word encountered in the input data.

```
where 1 in 1 where 1 in 1 the 1
```

The partitioner is internal to the map-reduce framework, so we don't have to write this ourselves. It shuffles & sorts the mapper output, and redirects all intermediate results for a given key to a single reducer.

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```
where
    [1, 1, 1, 1, 1, 1, 1]
in
    [1, 1, 1, 1, 1, 1]
the
    [1, 1, 1, 1, 1]
world
is
    [1, 1, 1, 1]
carmen
    [1, 1]
sandiego
[1]
```

Finally, the reducer receives all values for a given key and aggregates (in this case, sums) the results.

Finally, the reducer receives all values for a given key and aggregates (in this case, sums) the results.

```
reducer(k2, k2_vals):
// k2 = word
// k2_vals = word counts
emit k2, sum(k2_vals)
```

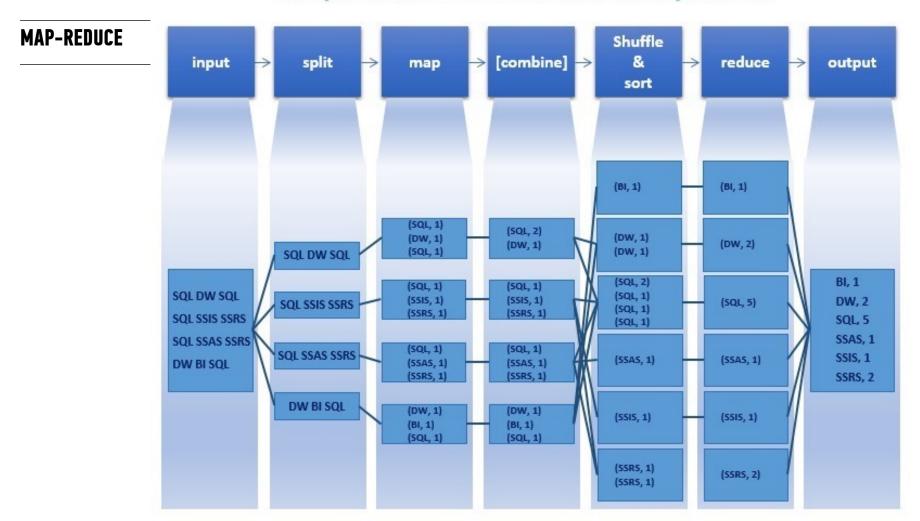
## Reducer output is aggregated...

```
where
in 6
the 5
world
is 3
carmen 2
sandiego 1
```

## Reducer output is aggregated & sorted by key.

```
carmen 2
is 3
in 6
the 5
sandiego 1
where 7
world 4
```

#### MapReduce - Word Count Example Flow



# EXERCISE & DISCUSSION