## INTRO TO DATA SCIENCE LECTURE 15: MAP-REDUCE

#### **LAST TIME:**

- RELATIONAL DB'S (RDBMS)

#### **QUESTIONS?**

I. BIG DATA
II. PROGRAMMING MODEL
III. IMPLEMENTATION DETAILS

**EXERCISE:** 

V. MAP-REDUCE USING PIG

#### INTRO TO DATA SCIENCE

## I. BIG DATA

As you have probably heard, big data is a hot topic these days.

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

One approach would be to get a huge supercomputer.

#### **BIG DATA**

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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?

#### **BIG DATA**

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This has obvious benefits!

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

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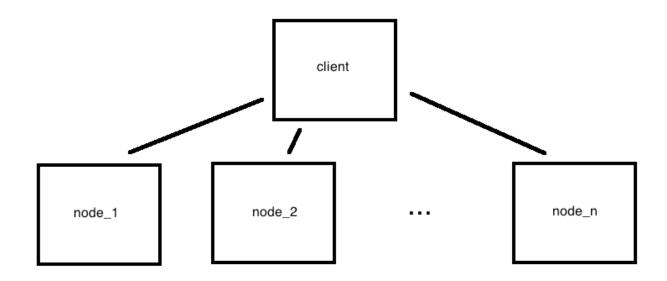
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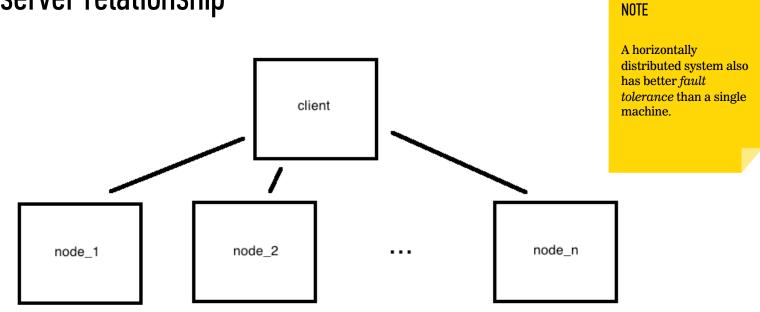
A: Scalability; in particular, storing & processing web-scale (multi-terabyte) datasets using clusters of multiple computing nodes.

"Scale out vs scale up!"

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



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How do we process data in a distributed architecture?

- move code to data
  - map-reduce → less overhead (network traffic, disk I/0)

"Computing nodes are the same as storage nodes."

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

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

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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.

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.

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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
- grep, sort, inverted index
- graph traversals, some ML algorithms

#### NOTE

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

### II. PROGRAMMING MODEL

#### MAP-REDUCE

As we've discussed, the map-reduce approach involves splitting a problem into subtasks and processing these subtasks in parallel.

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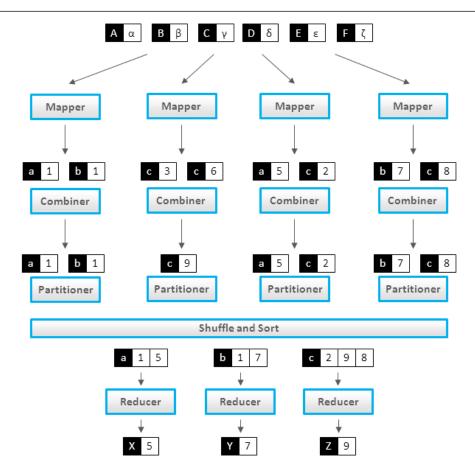
- 1) the **mapper** phase
- 2) the **reducer** phase

As we've discussed, the map-reduce approach involves splitting a problem into subtasks and processing these subtasks in parallel.

This takes place in (*approximately*) two phases:

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

#### **MAP-REDUCE**



#### MAP-REDUCE

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

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The functional paradigm is good at describing how to solve a problem, but not very good at describing data manipulations (eg, relational joins).

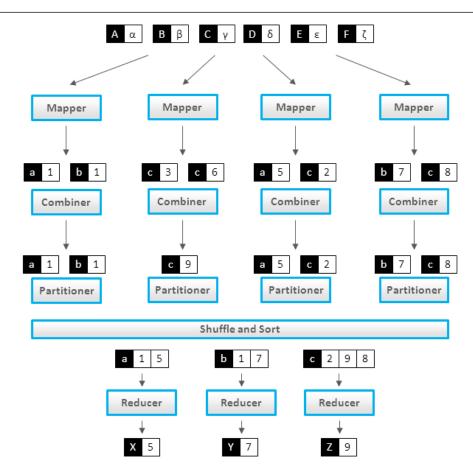
#### MAP-REDUCE

As our earlier diagram suggests, there are additional intermediate steps in a map-reduce workflow.

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#### **MAP-REDUCE**



# II. IMPLEMENTATION DETAILS

#### **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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- parallelization & distribution (eg, input splitting)
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- 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**

**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

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

#### **UNDER THE HOOD**

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

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.

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The Hadoop platform is bundled with an open-source implementation of this file system called *HDFS*.

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

```
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  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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# III. WORD COUNT EXAMPLE

## Map-reduce processes data in terms of *key-value pairs*:

```
input <k1, v1>

mapper <k1, v1> \rightarrow <k2, v2>

(partitioner) <k2, v2> \rightarrow <k2, [all k2 values]>

reducer <k2, [all k2 values]> \rightarrow <k3, v3>
```

#### MAP-REDUCE EXAMPLE

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

#### MAP-REDUCE EXAMPLE: MAPPER INPUT

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
```

#### MAP-REDUCE EXAMPLE: MAPPER

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)
```

#### MAP-REDUCE EXAMPLE: MAPPER OUTPUT

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

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

#### MAP-REDUCE EXAMPLE: PARTITIONER

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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```
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```

#### MAP-REDUCE EXAMPLE: REDUCER

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

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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)
```

#### MAP-REDUCE EXAMPLE: REDUCER OUTPUT

## Reducer output is aggregated...

```
where
in 6
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world 4
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sandiego 1
```

#### MAP-REDUCE EXAMPLE: REDUCER OUTPUT

## Reducer output is aggregated & sorted by key.

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