

INTRO TO DATA SCIENCE LECTURE 10: MAP-REDUCE

Rob Hall DAT5 SF // April 9, 2014

LAST TIME:

- K-MEANS CLUSTERING
- K-MEANS IN PYTHON
- Q&A SESSION FOR HW4 ON LOGISTIC REGRESSION

QUESTIONS?

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

EXERCISE:

V. MAP-REDUCE USING PYTHON

I. BIG DATA

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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)

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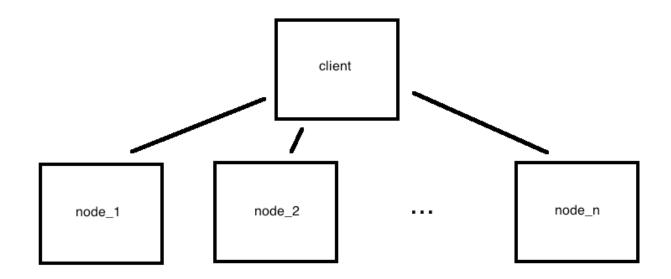
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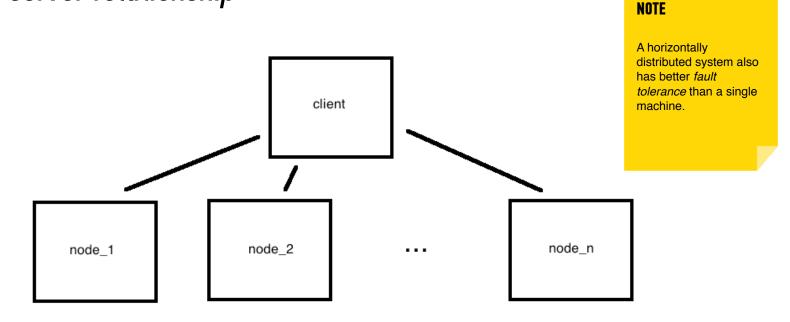
A: Scalability; in particular, storing & processing web-scale (multi-terabyte) datasets using clusters of multiple computing nodes.

"Scale out vs scale up!"

We can visualize this horizontal cluster architecture as a single clientmultiple server relationship



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1) move data to code (& processing power)

2) move code to data

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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:

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

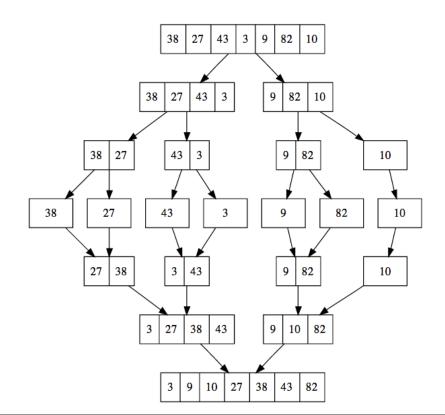
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- 2) solve these subtasks independently
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This is how recursive algorithms work, for example.

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.

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In fact, running a map-reduce job with identity (eg, do-nothing) 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 single-element 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.

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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
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NOTE

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

II. PROGRAMMING MODEL

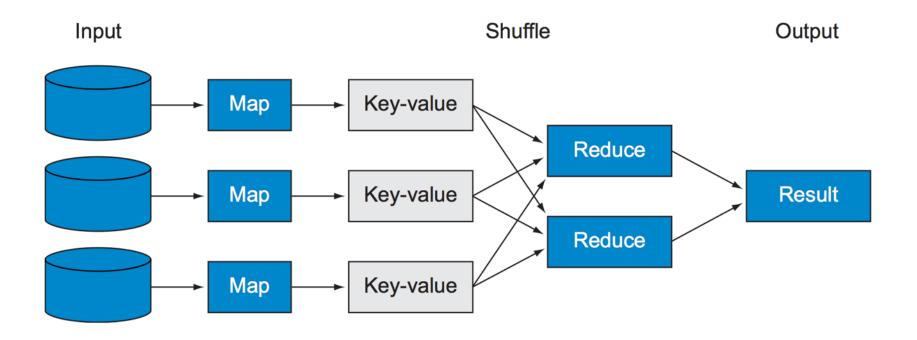
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- 1) the mapper phase
- 2) the reducer phase

This takes place in (approximately) two phases:

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



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).

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

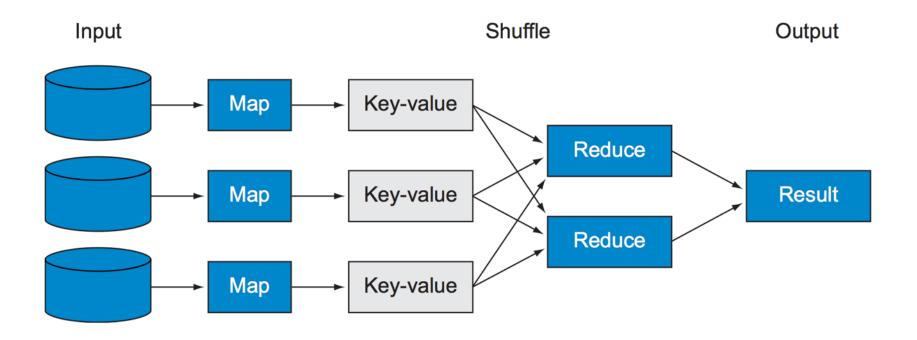
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As our earlier diagram suggests, there are additional intermediate steps in a map-reduce workflow.

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



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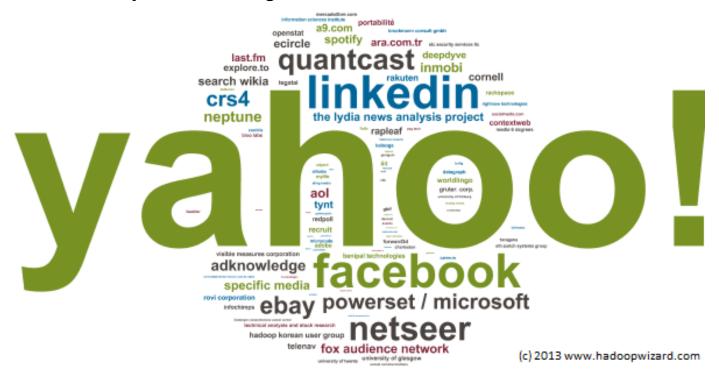
Hadoop is written in Java, but the Hadoop Streaming utility allows client code to be supplied as executables (eg, written in any language).

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

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- 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.



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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.

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UNDER THE HOOD

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

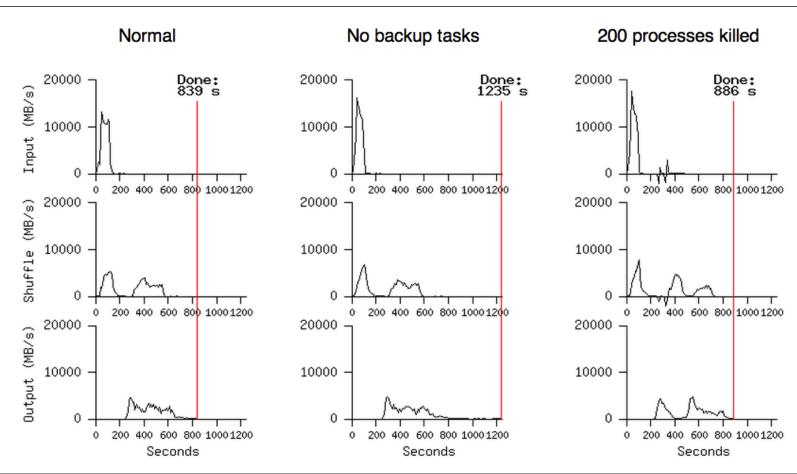
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If you use Amazon EMR, you can use their file system (Amazon S3) as well.



III. WORD COUNT EXAMPLE

Map-reduce processes data in terms of 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>
```

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

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where in 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.

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```
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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 4
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