Introduction to Database Systems
CSE 414

Lecture 27: Map Reduce and Pig Latin

Announcements

- Last(!) web quiz due tonight
- HW8 out now, due last day of the qtr (next Friday)
  - **No Late Days** (will post solutions over the weekend)
  - You should have received AWS credit code via email. Send mail to cse414-staff@cs if problems.
  - Start setting up account now(!). Takes time.
    - And ***follow instructions!!*** Usually the biggest problem.
- Final exam:
  - Mon. 6/8, 2:30-4:20, this room
  - Review Sun. 12/7, 2 pm, SAV 260
  - Comprehensive, biased towards things since midterm
  - Closed book; reference notes included in test

Outline

- Example of a large MapReduce job
- Whirlwind tour of Pig Latin for HW8
  - You'll need to learn from slides, starter code, Hadoop and related web pages; will not do details in class like we did for SQL

Executing a Large MapReduce Job

Anatomy of a Query Execution

- Running problem #4
- 20 nodes = 1 master + 19 workers
- Using PARALLEL 50

March 2013

Hadoop job_201303091944_0001 on domU-12-31-39-06-75-A1

User: hadoop
Job Name: PigLatin:DefaultJobName
Job File: hdfs://10.208.122.79:9000/mnt/var/lib/hadoop/tmp/mapred/staging/hadoop/.staging/job_201303091944_0001/job.xml
Submit Host: domU-12-31-39-06-75-A1.compute-1.internal
Submit Host Address: 10.208.122.79
Job-ACLs: All users are allowed
Job Setup: Successful
Status: Succeeded
Started at: Sat Mar 09 19:49:21 UTC 2013
Finished at: Sat Mar 09 23:33:14 UTC 2013
Finished in: 3hrs, 43mins, 52sec
Job Cleanup: Successful
Black-listed TaskTrackers: 1

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	7908	0	0	7908	0	14 / 16
reduce	100.00%	50	0	0	50	0	0 / 8

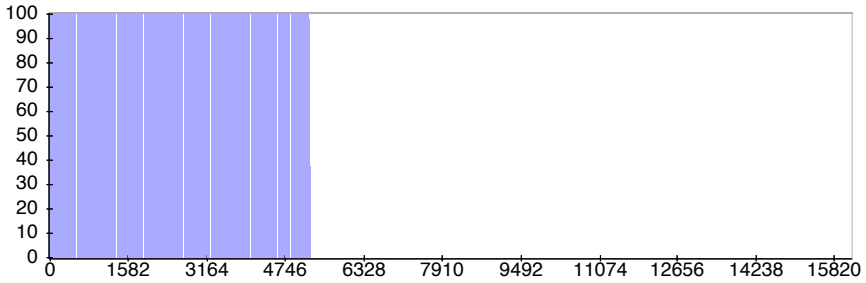
	Counter	Map	Reduce	Total
Job Counters	SLOTS_MILLIS_MAPS	0	0	454,162,761
	Launched reduce tasks	0	0	58
	Total time spent by all reduces waiting after reserving slots (ms)	0	0	0
	Rack-local map tasks	0	0	7,938
	Total time spent by all maps waiting after reserving slots	0	0	0

Some other time (March 2012)

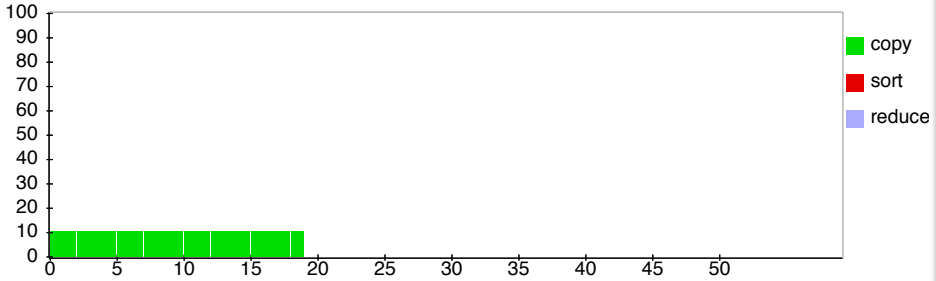
- Let's see what happened…

1h 16min

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	33.17%	15816	10549	38	5229	0	0 / 0
reduce	4.17%	50	31	19	0	0	0 / 0



luce Completion Graph - close



1h 16min

Only 19 reducers active, out of 50. Why?

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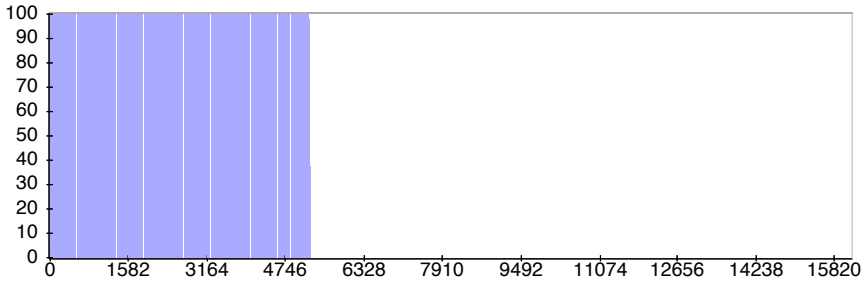

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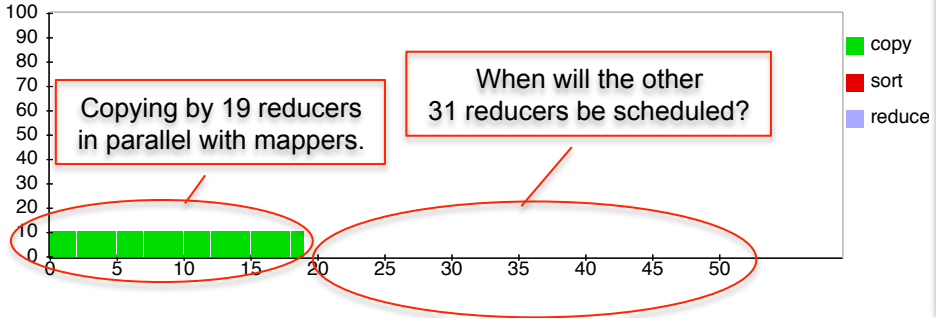

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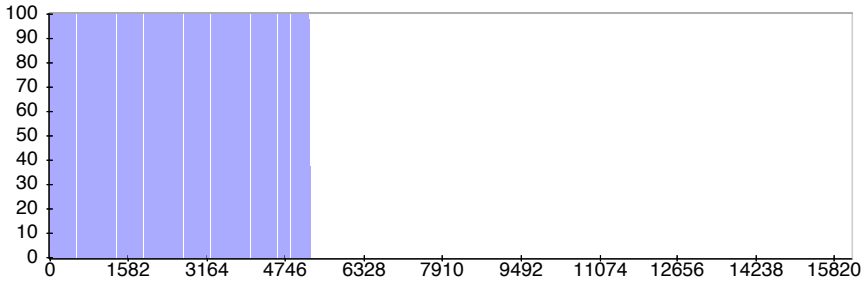
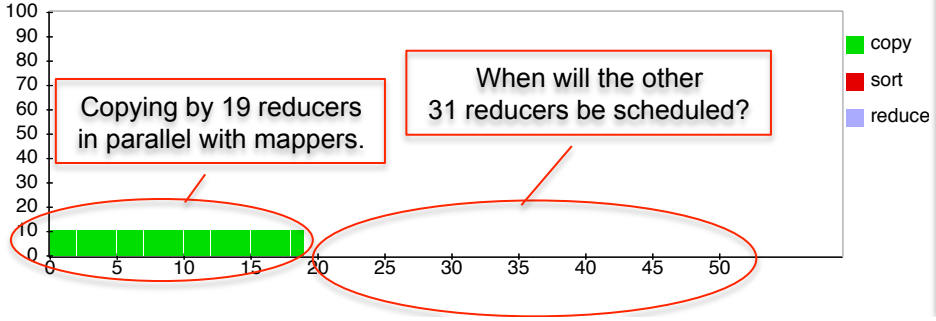
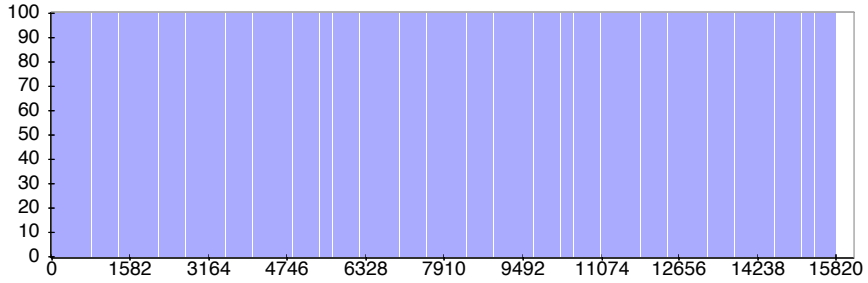


luce Completion Graph - close



3h 50min

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	15816	0	0	15816	0	0 / 18
reduce	32.42%	50	31	19	0	0	0 / 0



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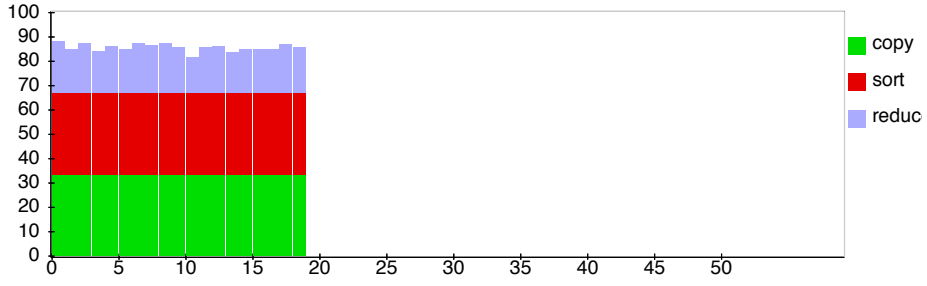

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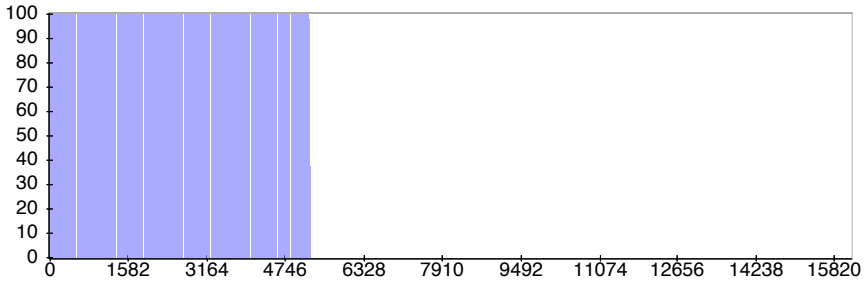

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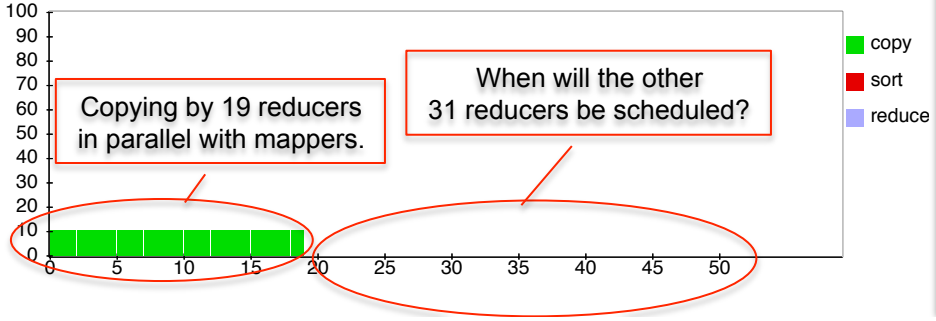

3h 50min

Speculative Execution

Completed. Sorting, and the rest of Reduce may proceed now

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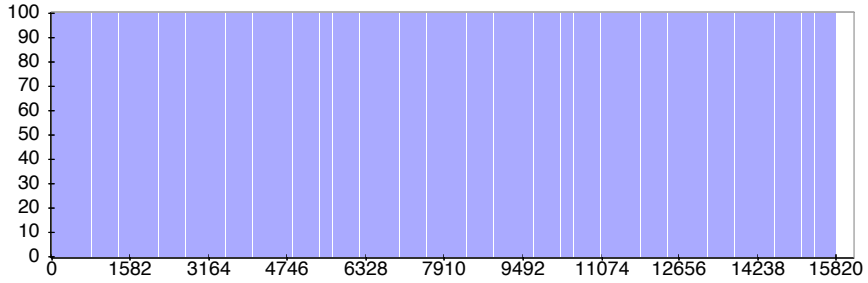

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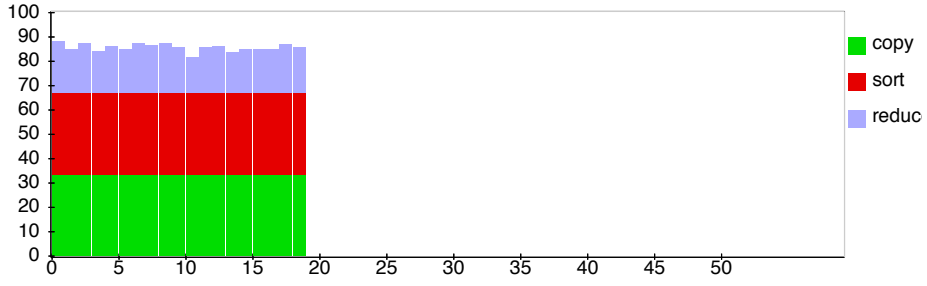
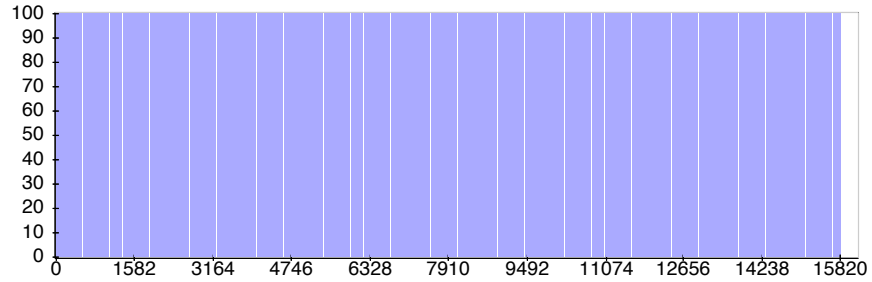


3h 51min

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	15816	0	0	15816	0	0 / 18
reduce	37.72%	50	19	22	9	0	0 / 0

ɔ Completion Graph - close



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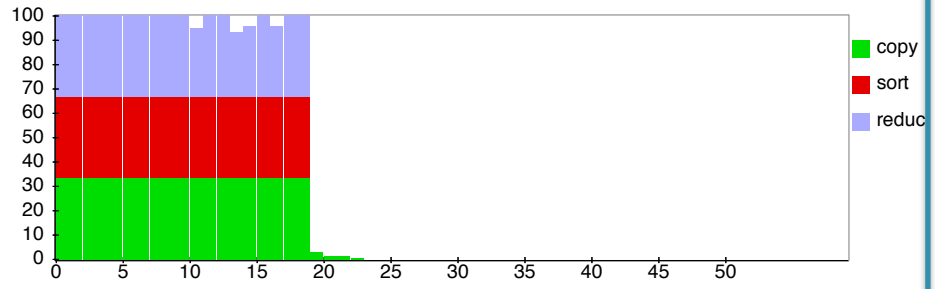

3h 51min

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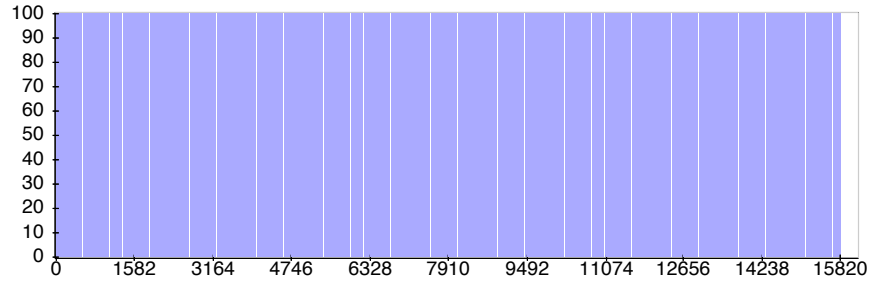

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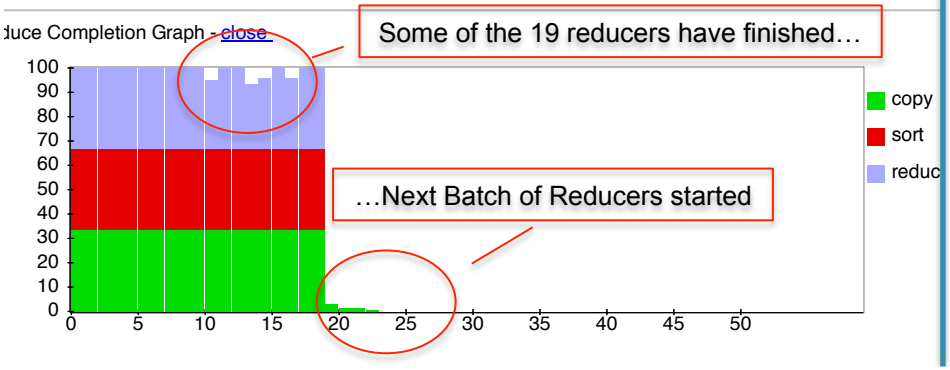

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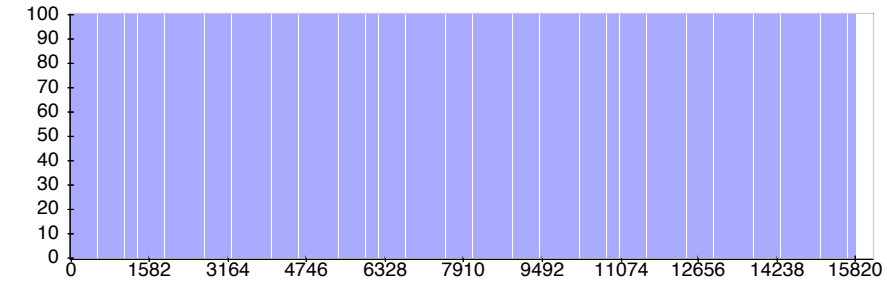

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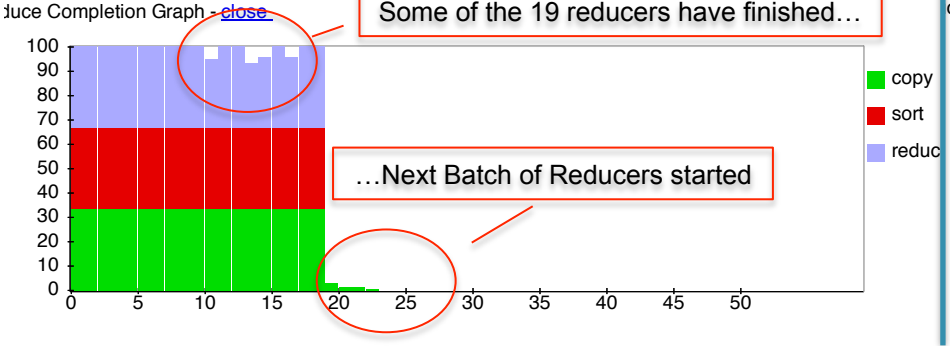
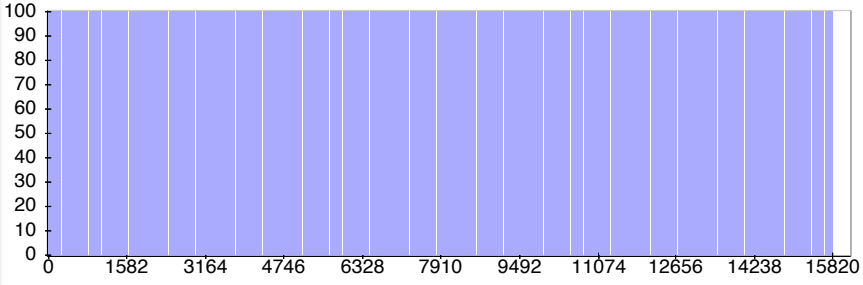


3h 52min

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	15816	0	0	15816	0	0 / 18
reduce	42.35%	50	11	20	19	0	0 / 0



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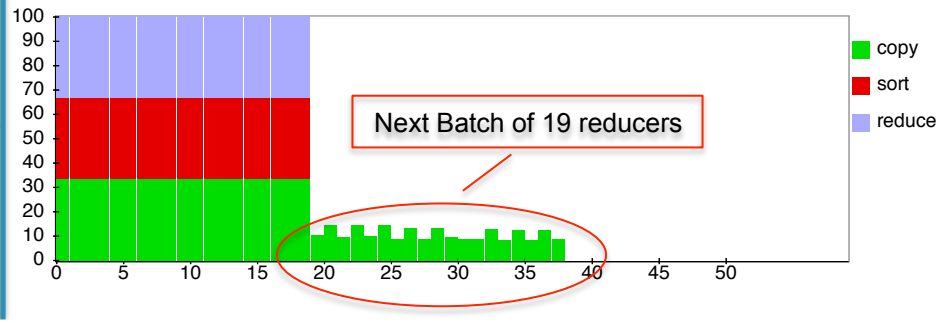
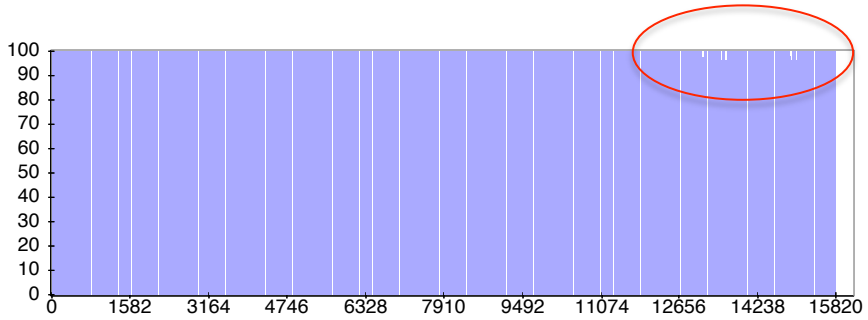


4h 18min

Several servers failed: “fetch error”. Their map tasks need to be rerun. All reducers are waiting….

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	99.88%	15816	2638	30	13148	0	15 / 3337
reduce	48.42%	50	15	16	19	0	0 / 0



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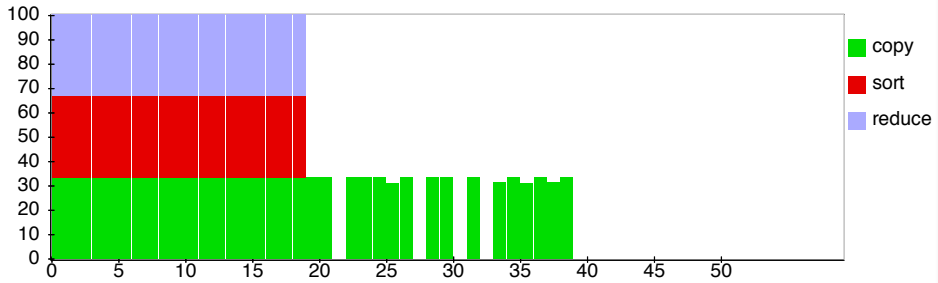

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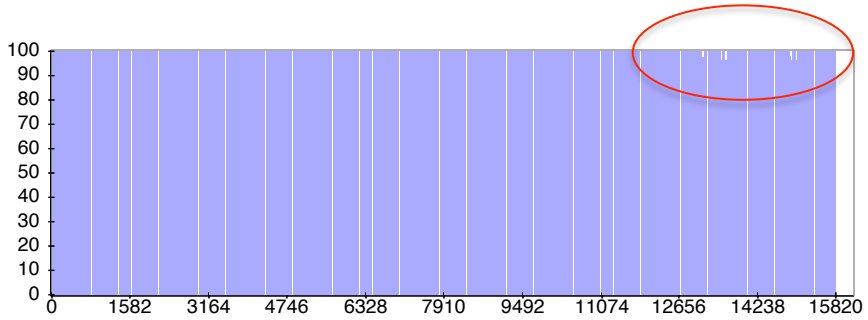

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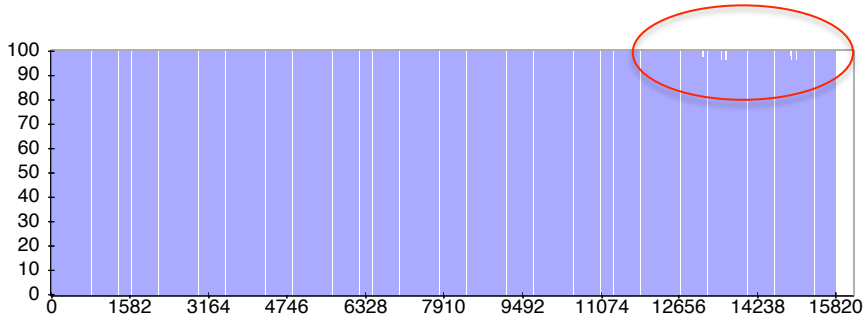

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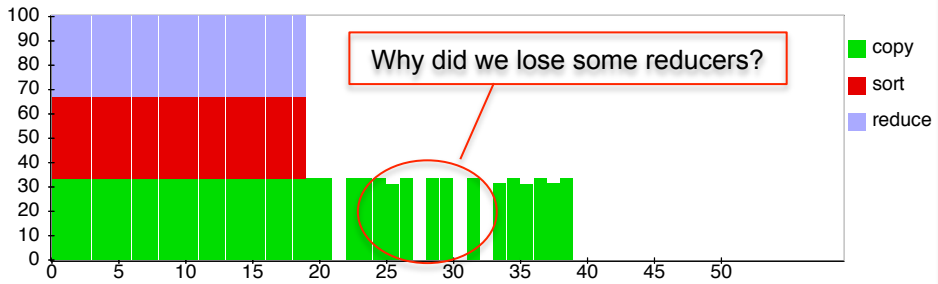
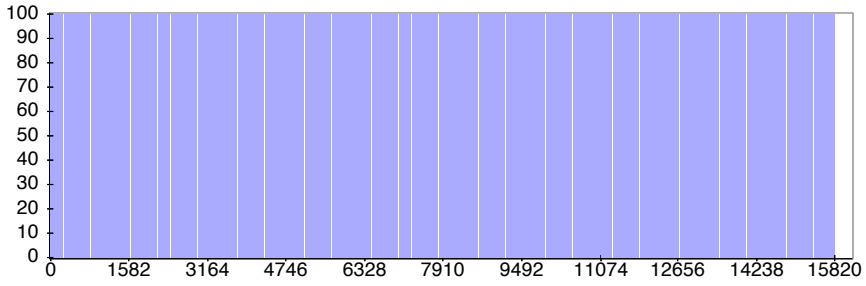


7h 10min

Mappers finished, reducers resumed.

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	15816	0	0	15816	0	26 / 5968
reduce	94.15%	50	0	6	44	0	0 / 8



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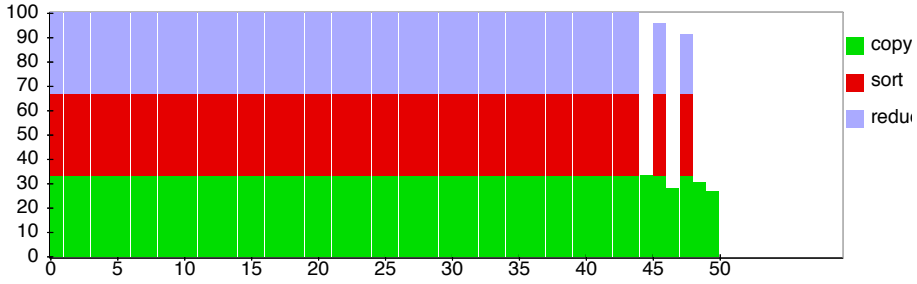


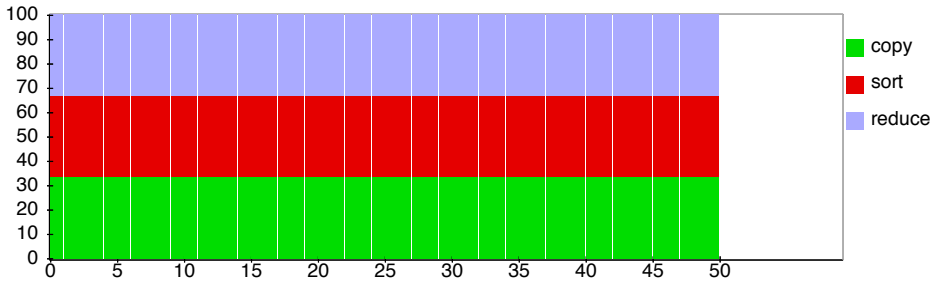
7h 20min

Success! 7hrs, 20mins.

Hadoop job_201203041905_0001 on ip-10-203-30-146

User: hadoop
Job Name: PigLatin:DefaultJobName
Job File: hdfs://10.203.30.146:9000/mnt/var/lib/hadoop/tmp/mapred/staging/hadoop/.staging/job_201203041905_0001/job.xml
Submit Host: ip-10-203-30-146.ec2.internal
Submit Host Address: 10.203.30.146
Job-ACLs: All users are allowed
Job Setup: Successful
Status: Succeeded
Started at: Sun Mar 04 19:08:29 UTC 2012
Finished at: Mon Mar 05 02:28:39 UTC 2012
Finished in: 7hrs, 20mins, 10sec
Job Cleanup: Successful
Black-listed TaskTrackers: 3

Kind	% Complete	Num Tasks	Pending	Running	Complete	Killed	Failed/Killed Task Attempts
map	100.00%	15816	0	0	15816	0	26 / 5968
reduce	100.00%	50	0	0	50	0	0 / 14



Pig Latin Mini-Tutorial

(will not discuss in detail in class; please read in order to do homework 8)

Pig Latin Overview

- Data model = loosely typed *nested relations*
- Query model = a SQL-like, dataflow language

- Execution model:
  - Option 1: run locally on your machine; e.g. to debug
  - Option 2: compile into graph of MapReduce jobs, run on a cluster supporting Hadoop

Example

- Input: a table of urls:
  (url, category, pagerank)
- Compute the average pagerank of all sufficiently high pageranks, for each category
- Return the answers only for categories with sufficiently many such pages

Page(url, category, pagerank)

First in SQL…

```
SELECT category, AVG(pagerank)
FROM Page
WHERE pagerank > 0.2
GROUP BY category
HAVING COUNT(*) > 10^6
```

Page(url, category, pagerank)

…then in Pig-Latin

```
good_urls = FILTER urls BY pagerank > 0.2
groups = GROUP good_urls BY category
big_groups = FILTER groups
                    BY COUNT(good_urls) > 10^6
output = FOREACH big_groups GENERATE
                    category, AVG(good_urls.pagerank)
```

Types in Pig-Latin

- Atomic: string or number, e.g. ‘Alice’ or 55
- Tuple: (‘Alice’, 55, ‘salesperson’)
- Bag: {(‘Alice’, 55, ‘salesperson’),
  (‘Betty’,44, ‘manager’), …}
- Maps: we will try not to use these

Types in Pig-Latin

Tuple components can be referenced by number

- $0, $1, $2, …

Bags can be nested ! Non 1st Normal Form

- {(‘a’, {1,4,3}), (‘c’,{ }), (‘d’, {2,2,5,3,2})}

[Olston'2008]

$$t = \left('alice', \left\{ \begin{array}{c} ('lakers', 1) \\ ('iPod', 2) \end{array} \right\}, ['age' \rightarrow 20] \right)$$

Let fields of tuple t be called f1, f2, f3

Expression Type	Example	Value for t
Constant	'bob'	Independent of t
Field by position	$0	'alice'
Field by name	f3	'age' → 20
Projection	f2.$0	{('lakers'), ('iPod')}
Map Lookup	f3#'age'	20
Function Evaluation	SUM(f2.$1)	1 + 2 = 3
Conditional Expression	f3#'age'>18? 'adult':'minor'	'adult'
Flattening	FLATTEN(f2)	'lakers', 1 'iPod', 2

[Olston'2008]

Loading data

- Input data = FILES !
  - Heard that before ?

- The LOAD command parses an input file into a bag of records
- Both parser (="deserializer") and output type are provided by user

For HW8: simply use the code provided

[Olston'2008]

Loading data

```
queries = LOAD 'query_log.txt'
          USING userLoadFcn( )
          AS (userID, queryString, timeStamp)
```

Pig provides a set of built-in load/store functions

A = LOAD 'student' USING PigStorage('\t') AS (name: chararray, age:int, gpa: float);

same as

A = LOAD 'student' AS (name: chararray, age:int, gpa: float);

[Olston'2008]

Loading data

- USING userfuction( ) -- is optional
  - Default deserializer expects tab-delimited file
- AS type – is optional
  - Default is a record with unnamed fields; refer to them as $0, $1, …
- The return value of LOAD is just a handle to a bag
  - The actual reading is done in pull mode, or parallelized

[Olston'2008]

FOREACH

```
expanded_queries =
   FOREACH queries
   GENERATE userId, expandQuery(queryString)
```

expandQuery( ) is a UDF that produces likely expansions
Note: it returns a bag, hence expanded_queries is a nested bag

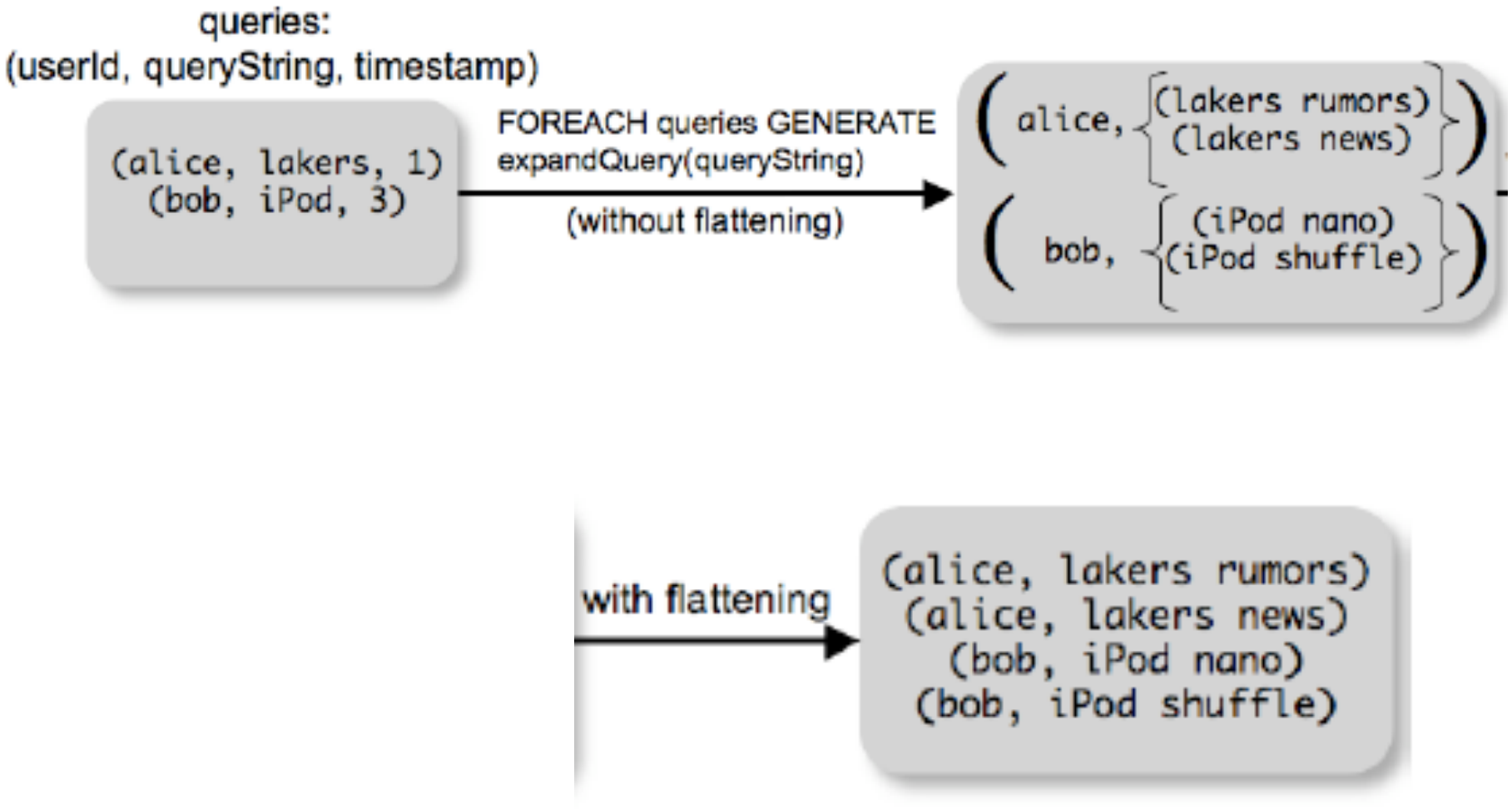
[Olston'2008]

FOREACH

```
expanded_queries =
   FOREACH queries
   GENERATE userId,
                    flatten(expandQuery(queryString))
```

Now we get a flat collection

[Olston'2008]


queries:
(userId, queryString, timestamp)
(alice, lakers, 1)
(bob, iPod, 3)
FOREACH queries GENERATE
expandQuery(queryString)
(without flattening)
alice, {(lakers rumors) (lakers news)}
bob, {(iPod nano) (iPod shuffle)}
with flattening
(alice, lakers rumors)
(alice, lakers news)
(bob, iPod nano)
(bob, iPod shuffle)

[Olston'2008]

FLATTEN

Note that it is NOT a normal function !

(some folks don't like this about Pig-latin)

- A normal FLATTEN would do this:
  - FLATTEN({{2,3},{5},{},{4,5,6}}) = {2,3,5,4,5,6}
  - Its type is: {{T}} → {T}
- The Pig Latin FLATTEN does this:
  - FLATTEN({4,5,6}) = 4, 5, 6
  - What is its Type? {T} → T, T, T, …, T ?????

[Olston'2008]

FILTER

Remove all queries from Web bots:

```
real_queries =  FILTER queries BY userId neq 'bot'
```

Better: use a complex UDF to detect Web bots:

```
real_queries =  FILTER queries
                BY NOT isBot(userId)
```

[Olston'2008]

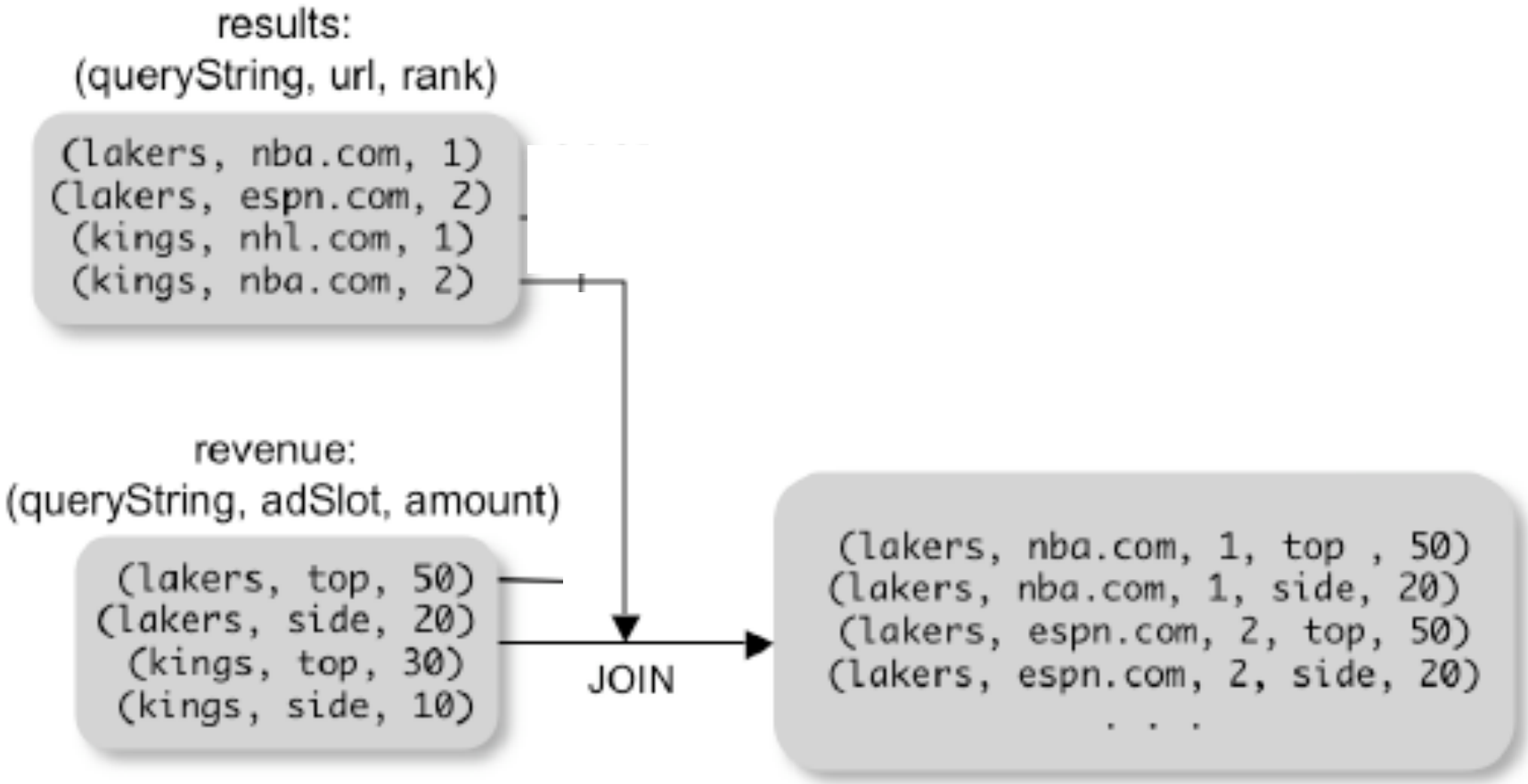
JOIN

results: {(queryString, url, position)}
revenue: {(queryString, adSlot, amount)}

```
join_result = JOIN results BY queryString
                   revenue BY queryString
```

join_result : {(queryString, url, position, adSlot, amount)}

[Olston'2008]


results:
(queryString, url, rank)
(lakers, nba.com, 1)
(lakers, espn.com, 2)
(kings, nhl.com, 1)
(kings, nba.com, 2)
revenue:
(queryString, adSlot, amount)
(lakers, top, 50)
(lakers, side, 20)
(kings, top, 30)
(kings, side, 10)
JOIN
(lakers, nba.com, 1, top , 50)
(lakers, nba.com, 1, side, 20)
(lakers, espn.com, 2, top, 50)
(lakers, espn.com, 2, side, 20)
. . .

[Olston'2008]

GROUP BY

revenue: {(queryString, adSlot, amount)}

```
grouped_revenue = GROUP revenue BY queryString
query_revenues =
    FOREACH grouped_revenue
    GENERATE queryString,
                SUM(revenue.amount) AS totalRevenue
```

grouped_revenue: {(queryString, {(adSlot, amount)})}
query_revenues: {(queryString, totalRevenue)}

[Olston'2008]

Simple MapReduce

input : {(field1, field2, field3, ...)}

```
map_result = FOREACH input
                 GENERATE FLATTEN(map(*))
key_groups = GROUP map_result BY $0
output = FOREACH key_groups
         GENERATE $0, reduce($1)
```

map_result : {(a1, a2, a3, . . .)}
key_groups : {(a1, {(a2, a3, . . .)})}

[Olston'2008]

Co-Group

results: {(queryString, url, position)}
revenue: {(queryString, adSlot, amount)}

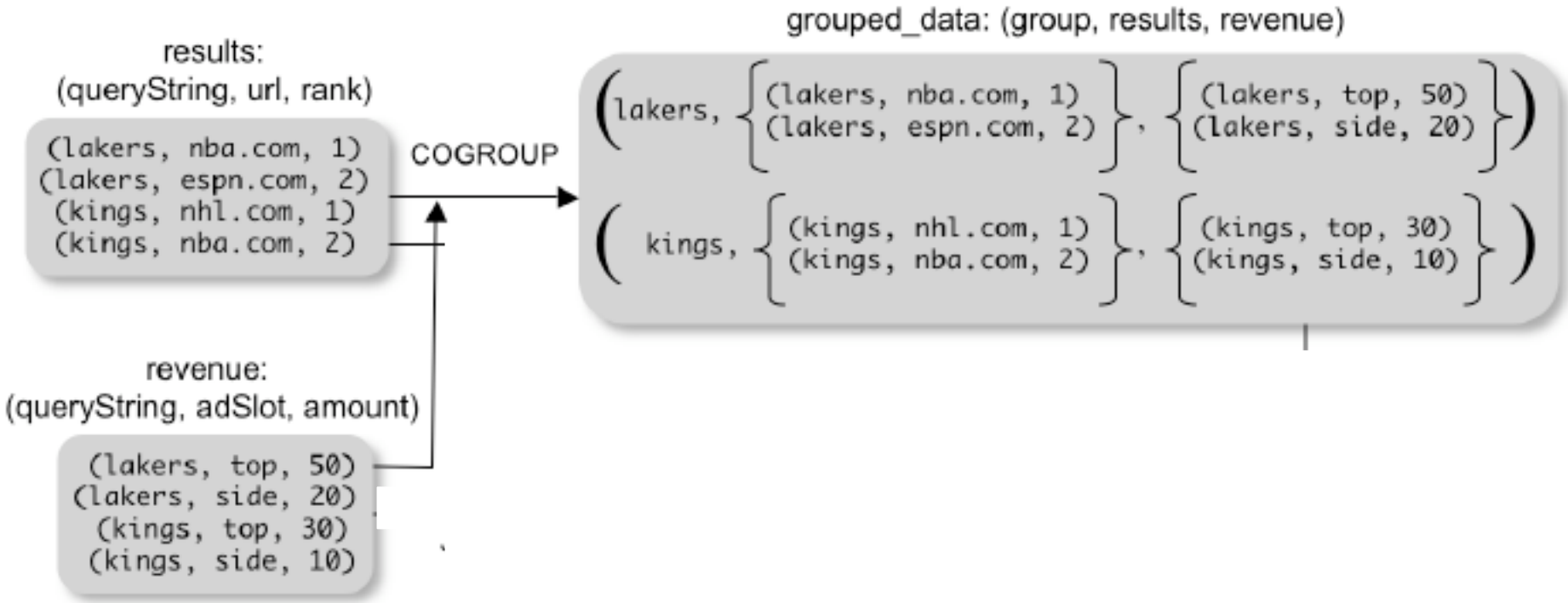
```
grouped_data =
      COGROUP results BY queryString,
              revenue BY queryString;
```

grouped_data: {(queryString, results:{(url, position)},
revenue:{(adSlot, amount)})}

What is the output type in general ?

[Olston'2008]

Co-Group



Is this an inner join, or an outer join ?

[Olston'2008]

Co-Group

grouped_data: {(queryString, results:{(url, position)},
revenue:{(adSlot, amount)})}

```
url_revenues = FOREACH grouped_data
               GENERATE
               FLATTEN(distributeRevenue(results, revenue));
```

distributeRevenue is a UDF that accepts search results and revenue information for a query string at a time, and outputs a bag of urls and the revenue attributed to them.

[Olston'2008]

Co-Group v.s. Join

grouped_data: {(queryString, results:{(url, position)},
revenue:{(adSlot, amount)})}

```
grouped_data = COGROUP results BY queryString,
                       revenue BY queryString;
join_result = FOREACH grouped_data
              GENERATE FLATTEN(results),
                       FLATTEN(revenue);
```

Result is the same as JOIN

[Olston'2008]

Asking for Output: STORE

```
STORE query_revenues INTO `theoutput'
        USING userStoreFcn();
```

Meaning: write query_revenues to the file 'theoutput'

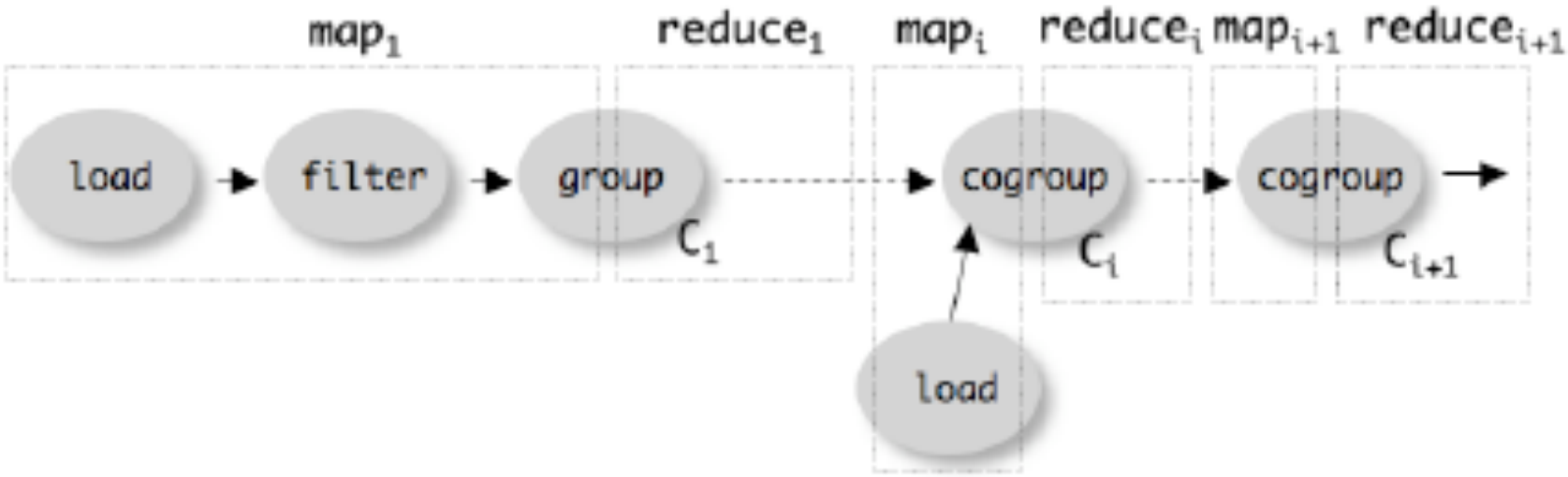
[Olston'2008]

Implementation

- Over Hadoop !
- Parse query:
  - Everything between LOAD and STORE → one logical plan
- Logical plan → graph of MapReduce ops
- All statements between two (CO)GROUPs → one MapReduce job

[Olston'2008]

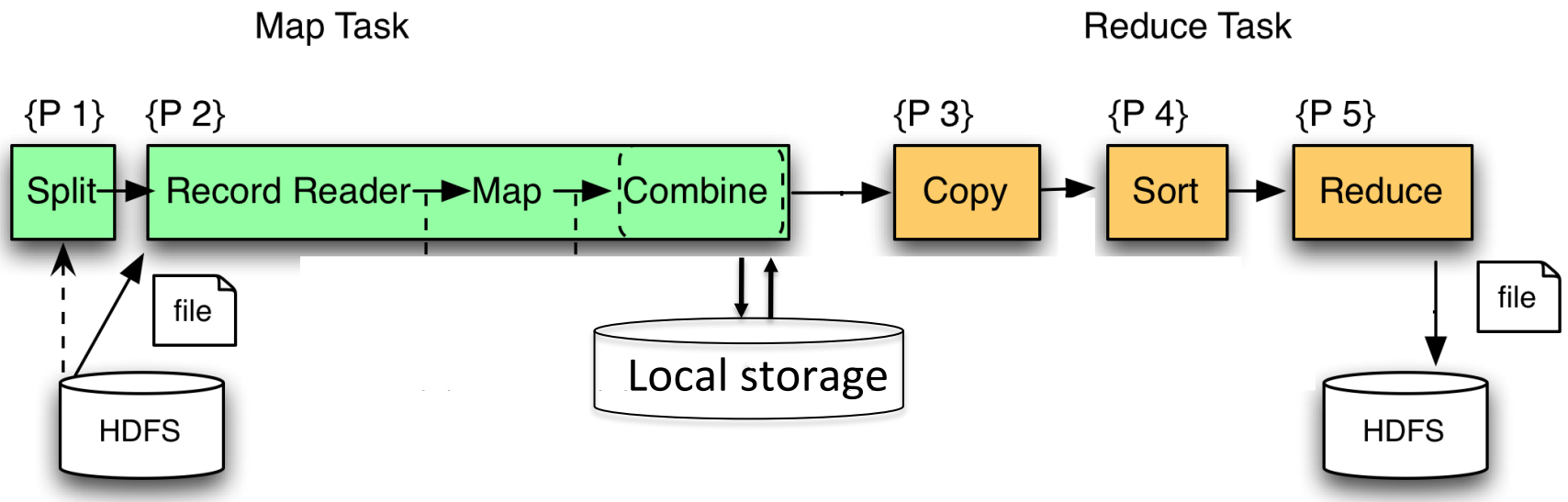
Implementation



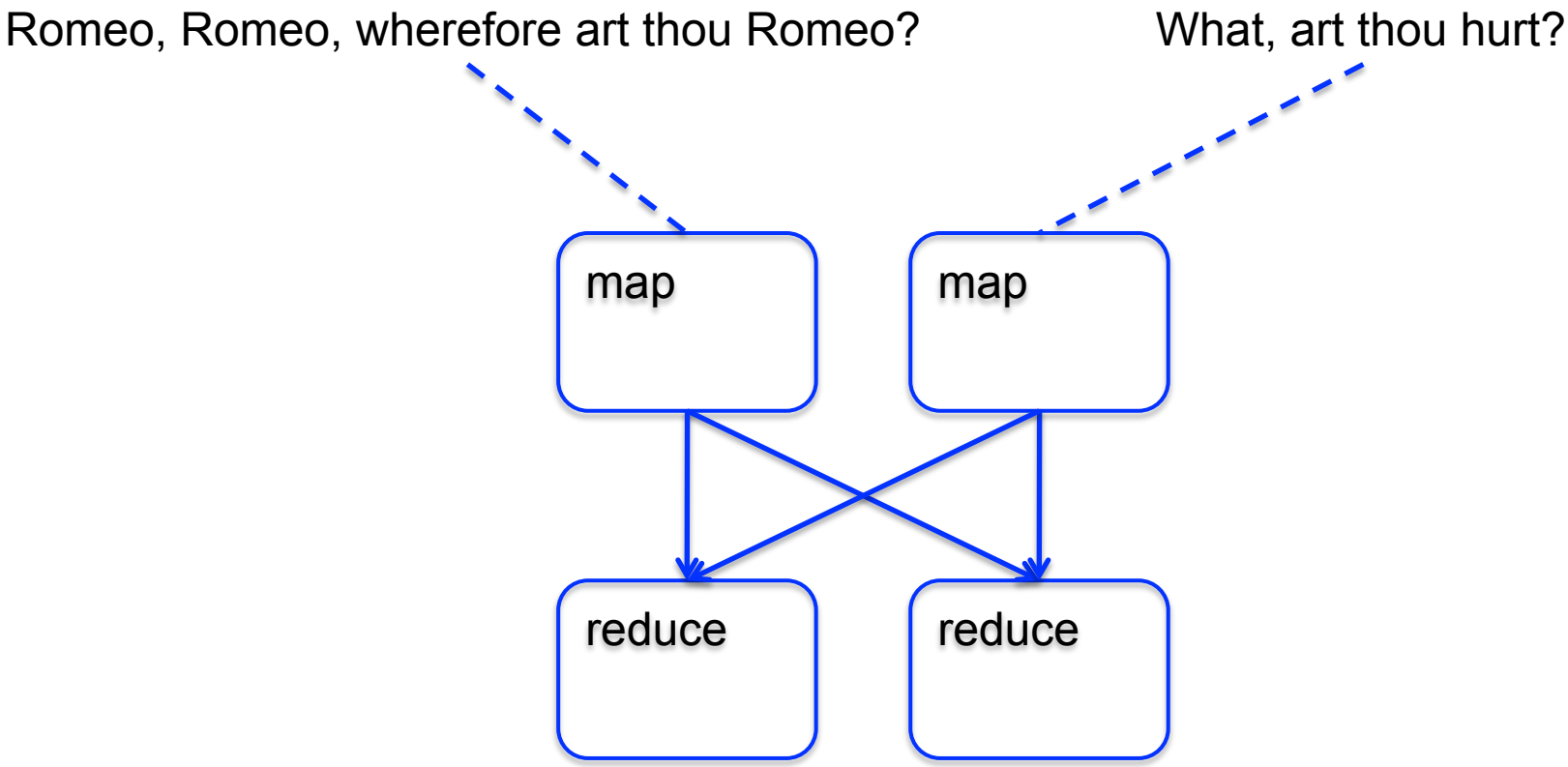
Review: MapReduce

- Data is typically a file in the Google File System
  - HDFS for Hadoop
  - File system partitions file into chunks
  - Each chunk is replicated on k (typically 3) machines
- Each machine can run a few map and reduce tasks simultaneously
- Each map task consumes one chunk
  - Can adjust how much data goes into each map task using “splits”
  - Scheduler tries to schedule map task where its input data is located
- Map output is partitioned across reducers
- Map output is also written locally to disk
- Number of reduce tasks is configurable
- System shuffles data between map and reduce tasks
- Reducers sort-merge data before consuming it

MapReduce Phases

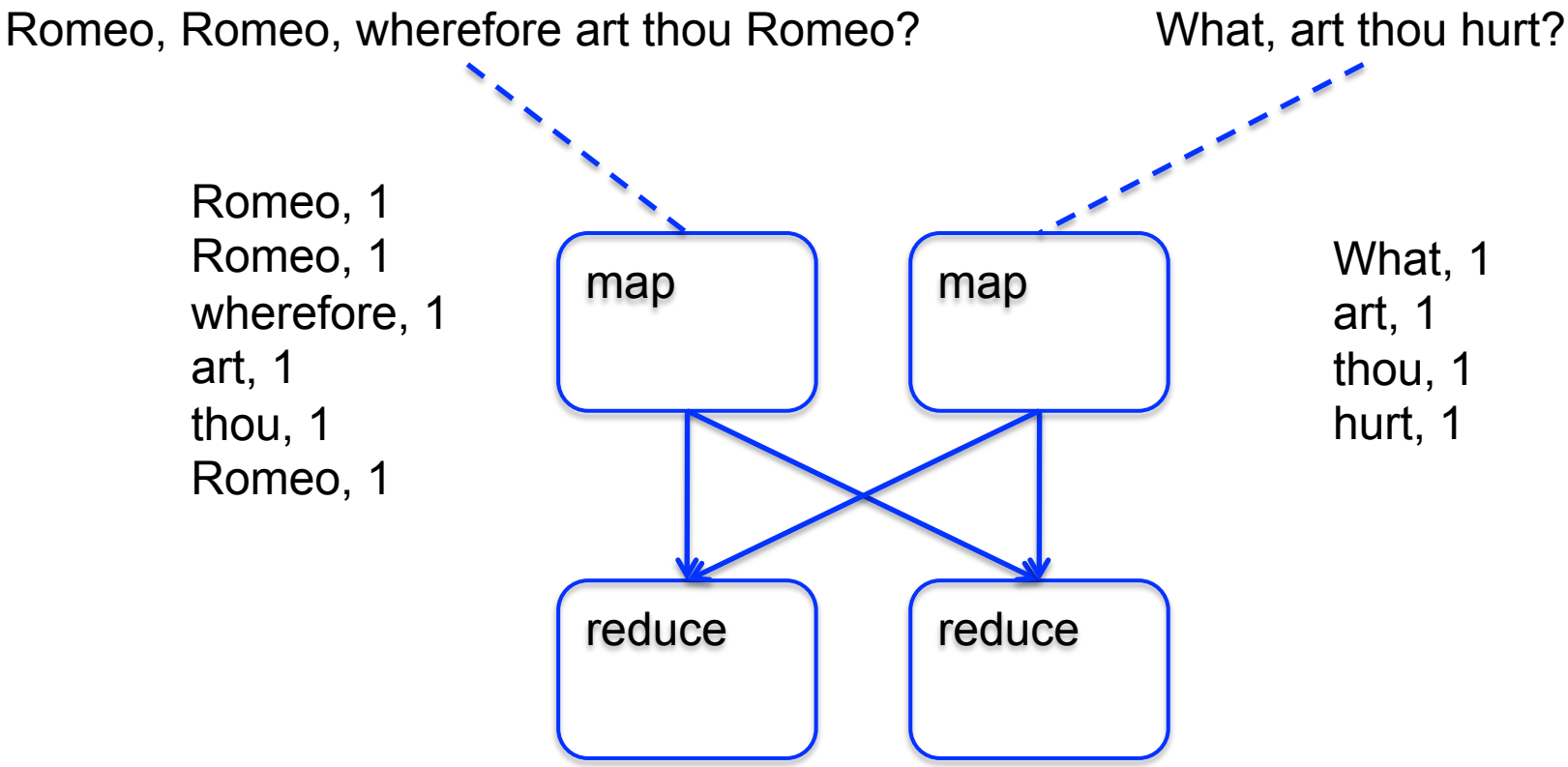


MapReduce Illustrated



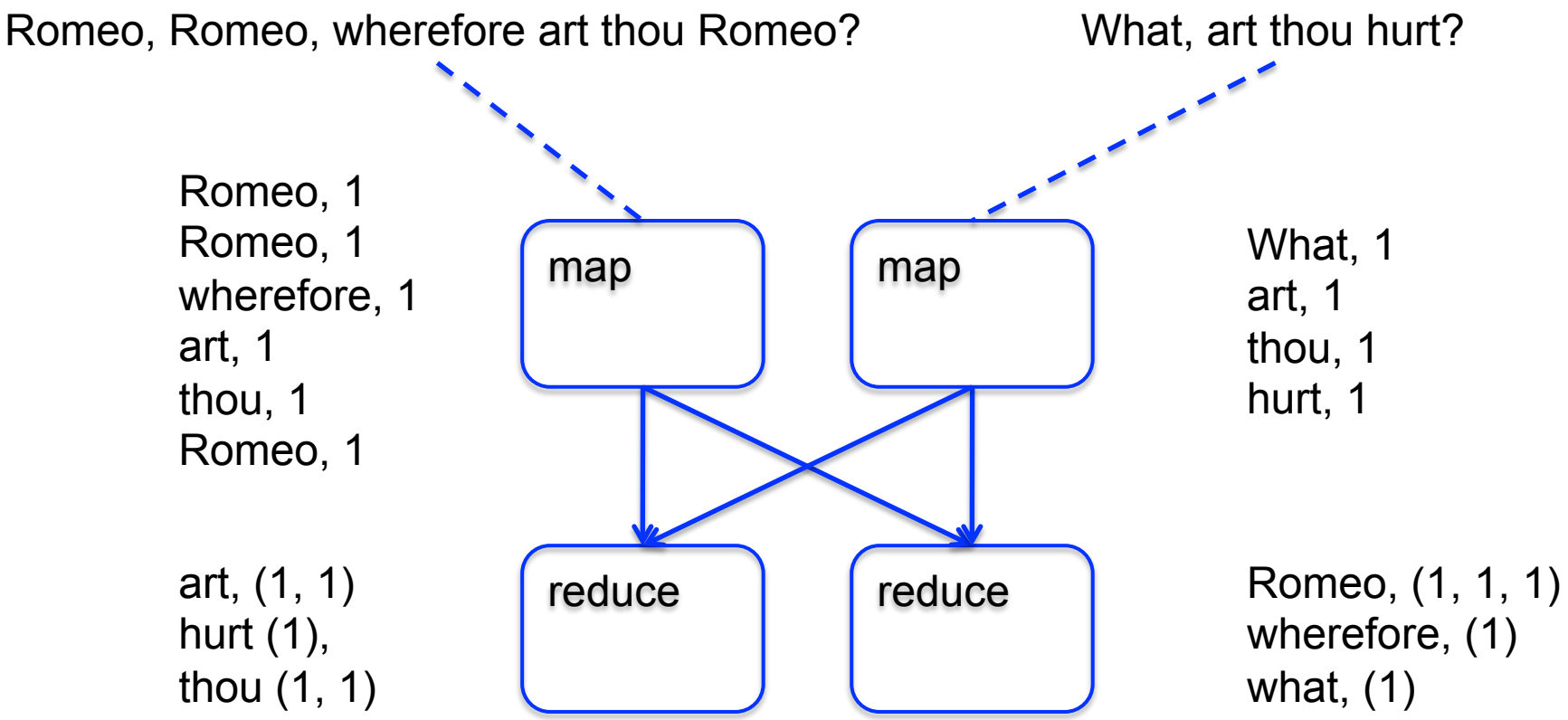
Ack: Alan Gates from Yahoo!

MapReduce Illustrated



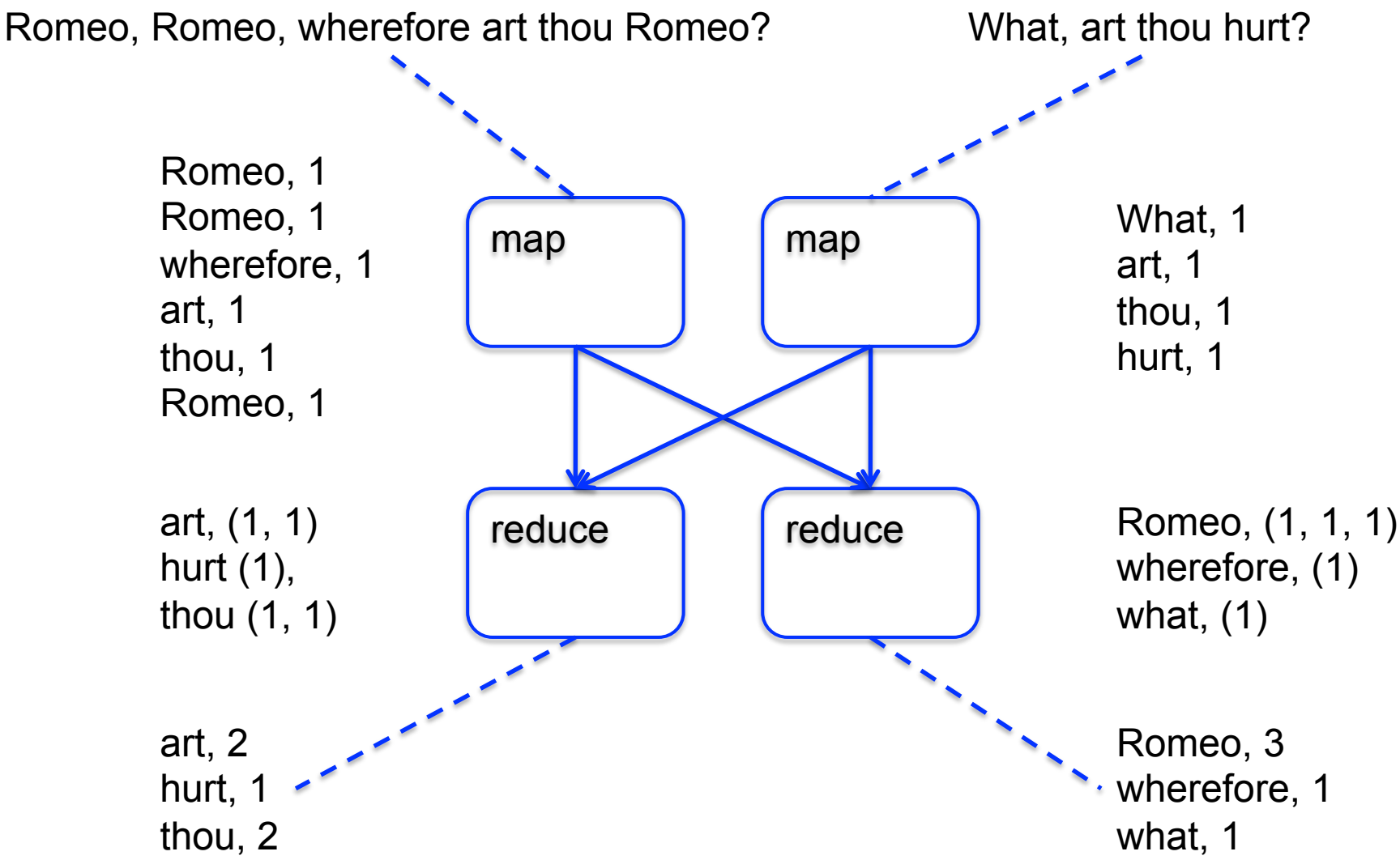
Ack: Alan Gates from Yahoo!

MapReduce Illustrated



Ack: Alan Gates from Yahoo!

MapReduce Illustrated



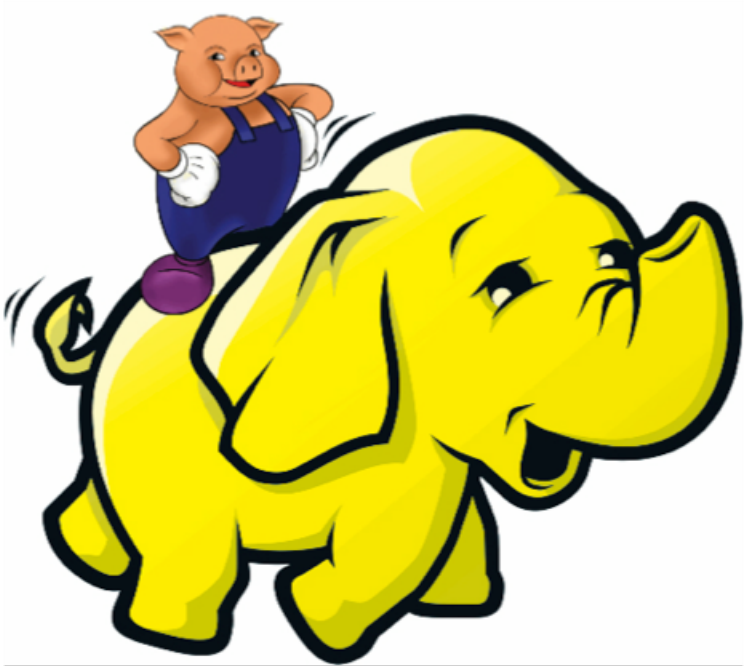
Ack: Alan Gates from Yahoo!

Making Parallelism Simple

- Sequential reads = good read speeds
- In large cluster failures are guaranteed; MapReduce handles retries
- Good fit for batch processing applications that need to touch all your data:
  - data mining
  - model tuning
- Bad fit for applications that need to find one particular record
- Bad fit for applications that need to communicate between processes; oriented around independent units of work

What is Pig?

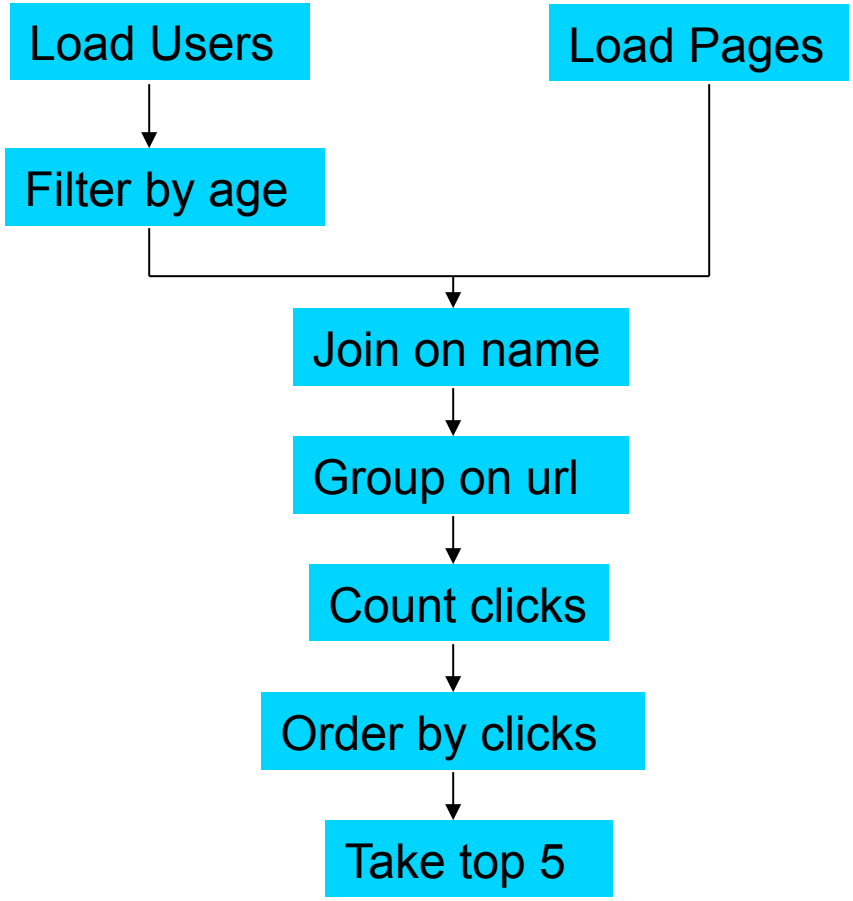
- An engine for executing programs on top of Hadoop
- It provides a language, Pig Latin, to specify these programs
- An Apache open source project
  http://hadoop.apache.org/pig/



Ack: Alan Gates from Yahoo!

Why use Pig?

Suppose you have user data in one file, website data in another, and you need to find the top 5 most visited sites by users aged 18 - 25.



In MapReduce

```
import java.io.IOException;
import java.util.ArrayList;
import java.util.Iterator;
import java.util.List;

import org.apache.hadoop.fs.Path;
import org.apache.hadoop.io.LongWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.io.Writable;
import org.apache.hadoop.io.WritableComparable;
import org.apache.hadoop.mapred.FileInputFormat;
import org.apache.hadoop.mapred.FileOutputFormat;
import org.apache.hadoop.mapred.JobConf;
import org.apache.hadoop.mapred.KeyValueTextInputFormat;
import org.apache.hadoop.mapred.Mapper;
import org.apache.hadoop.mapred.MapReduceBase;
import org.apache.hadoop.mapred.OutputCollector;
import org.apache.hadoop.mapred.RecordReader;
import org.apache.hadoop.mapred.Reducer;
import org.apache.hadoop.mapred.Reporter;
import org.apache.hadoop.mapred.SequenceFileInputFormat;
import org.apache.hadoop.mapred.SequenceFileOutputFormat;
import org.apache.hadoop.mapred.TextInputFormat;
import org.apache.hadoop.mapred.jobcontrol.Job;
import org.apache.hadoop.mapred.jobcontrol.JobControl;
import org.apache.hadoop.mapred.lib.IdentityMapper;

public class MRExample {
    public static class LoadPages extends MapReduceBase
        implements Mapper<LongWritable, Text, Text, Text> {

        public void map(LongWritable k, Text val,
                OutputCollector<Text, Text> oc,
                Reporter reporter) throws IOException {
            // Pull the key out
            String line = val.toString();
            int firstComma = line.indexOf(',');
            String key = line.substring(0, firstComma);
            String value = line.substring(firstComma + 1);
            Text outKey = new Text(key);
            // Prepend an index to the value so we know which file
            // it came from.
            Text outVal = new Text("l" + value);
            oc.collect(outKey, outVal);
        }
    }
    public static class LoadAndFilterUsers extends MapReduceBase
        implements Mapper<LongWritable, Text, Text, Text> {

        public void map(LongWritable k, Text val,
                OutputCollector<Text, Text> oc,
                Reporter reporter) throws IOException {
            // Pull the key out
            String line = val.toString();
            int firstComma = line.indexOf(',');
            String value = line.substring(firstComma + 1);
            int age = Integer.parseInt(value);
            if (age < 18 || age > 25) return;
            String key = line.substring(0, firstComma);
            Text outKey = new Text(key);
            // Prepend an index to the value so we know which file
            // it came from.
            Text outVal = new Text("2" + value);
            oc.collect(outKey, outVal);
        }
    }
    public static class Join extends MapReduceBase
        implements Reducer<Text, Text, Text, Text> {

        public void reduce(Text key,
                Iterator<Text> iter,
                OutputCollector<Text, Text> oc,
                Reporter reporter) throws IOException {
            // For each value, figure out which file it's from and
store it
            // accordingly.
            List<String> first = new ArrayList<String>();
            List<String> second = new ArrayList<String>();

            while (iter.hasNext()) {
                Text t = iter.next();
                String value = t.toString();
                if (value.charAt(0) == '1')
first.add(value.substring(1));
                else second.add(value.substring(1));
                reporter.setStatus("OK");
            }

            // Do the cross product and collect the values
            for (String s1 : first) {
                for (String s2 : second) {
                    String outval = key + "," + s1 + "," + s2;
                    oc.collect(null, new Text(outval));
                    reporter.setStatus("OK");
                }
            }
        }
    }
    public static class LoadJoined extends MapReduceBase
        implements Mapper<Text, Text, Text, LongWritable> {

        public void map(
                Text k,
                Text val,
                OutputCollector<Text, LongWritable> oc,
                Reporter reporter) throws IOException {
            // Find the url
            String line = val.toString();
            int firstComma = line.indexOf(',');
            int secondComma = line.indexOf(',', firstComma);
            String key = line.substring(firstComma, secondComma);
            // drop the rest of the record, I don't need it anymore,
            // just pass a 1 for the combiner/reducer to sum instead.
            Text outKey = new Text(key);
            oc.collect(outKey, new LongWritable(1L));
        }
    }
    public static class ReduceUrls extends MapReduceBase
        implements Reducer<Text, LongWritable, WritableComparable,
Writable> {

        public void reduce(
                Text key,
                Iterator<LongWritable> iter,
                OutputCollector<WritableComparable, Writable> oc,
                Reporter reporter) throws IOException {
            // Add up all the values we see

            long sum = 0;
            while (iter.hasNext()) {
                sum += iter.next().get();
                reporter.setStatus("OK");
            }

            oc.collect(key, new LongWritable(sum));
        }
    }
    public static class LoadClicks extends MapReduceBase
        implements Mapper<WritableComparable, Writable, LongWritable,
Text> {

        public void map(
                WritableComparable key,
                Writable val,
                OutputCollector<LongWritable, Text> oc,
                Reporter reporter) throws IOException {
            oc.collect((LongWritable)val, (Text)key);
        }
    }
    public static class LimitClicks extends MapReduceBase
        implements Reducer<LongWritable, Text, LongWritable, Text> {

        int count = 0;
        public void reduce(
                LongWritable key,
                Iterator<Text> iter,
                OutputCollector<LongWritable, Text> oc,
                Reporter reporter) throws IOException {

            // Only output the first 100 records
            while (count < 100 && iter.hasNext()) {
                oc.collect(key, iter.next());
                count++;
            }
        }
    }
    public static void main(String[] args) throws IOException {
        JobConf lp = new JobConf(MRExample.class);
        lp.setJobName("Load Pages");
        lp.setInputFormat(TextInputFormat.class);
        lp.setOutputKeyClass(Text.class);
        lp.setOutputValueClass(Text.class);
        lp.setMapperClass(LoadPages.class);
        FileInputFormat.addInputPath(lp, new
Path("/user/gates/pages"));
        FileOutputFormat.setOutputPath(lp,
                new Path("/user/gates/tmp/indexed_pages"));
        lp.setNumReduceTasks(0);
        Job loadPages = new Job(lp);

        JobConf lfu = new JobConf(MRExample.class);
        lfu.setJobName("Load and Filter Users");
        lfu.setInputFormat(TextInputFormat.class);
        lfu.setOutputKeyClass(Text.class);
        lfu.setOutputValueClass(Text.class);
        lfu.setMapperClass(LoadAndFilterUsers.class);
        FileInputFormat.addInputPath(lfu, new
Path("/user/gates/users"));
        FileOutputFormat.setOutputPath(lfu,
                new Path("/user/gates/tmp/filtered_users"));
        lfu.setNumReduceTasks(0);
        Job loadUsers = new Job(lfu);

        JobConf join = new JobConf(MRExample.class);
        join.setJobName("Join Users and Pages");
        join.setInputFormat(KeyValueTextInputFormat.class);
        join.setOutputKeyClass(Text.class);
        join.setOutputValueClass(Text.class);
        join.setMapperClass(IdentityMapper.class);
        join.setReducerClass(Join.class);
        FileInputFormat.addInputPath(join, new
Path("/user/gates/tmp/indexed_pages"));
        FileInputFormat.addInputPath(join, new
Path("/user/gates/tmp/filtered_users"));
        FileOutputFormat.setOutputPath(join, new
Path("/user/gates/tmp/joined"));
        join.setNumReduceTasks(50);
        Job joinJob = new Job(join);
        joinJob.addDependingJob(loadPages);
        joinJob.addDependingJob(loadUsers);

        JobConf group = new JobConf(MRExample.class);
        group.setJobName("Group URLs");
        group.setInputFormat(KeyValueTextInputFormat.class);
        group.setOutputKeyClass(Text.class);
        group.setOutputValueClass(LongWritable.class);
        group.setOutputFormat(SequenceFileOutputFormat.class);
        group.setMapperClass(LoadJoined.class);
        group.setCombinerClass(ReduceUrls.class);
        group.setReducerClass(ReduceUrls.class);
        FileInputFormat.addInputPath(group, new
Path("/user/gates/tmp/joined"));
        FileOutputFormat.setOutputPath(group, new
Path("/user/gates/tmp/grouped"));
        group.setNumReduceTasks(50);
        Job groupJob = new Job(group);
        groupJob.addDependingJob(joinJob);

        JobConf top100 = new JobConf(MRExample.class);
        top100.setJobName("Top 100 sites");
        top100.setInputFormat(SequenceFileInputFormat.class);
        top100.setOutputKeyClass(LongWritable.class);
        top100.setOutputValueClass(Text.class);
        top100.setOutputFormat(SequenceFileOutputFormat.class);
        top100.setMapperClass(LoadClicks.class);
        top100.setCombinerClass(LimitClicks.class);
        top100.setReducerClass(LimitClicks.class);
        FileInputFormat.addInputPath(top100, new
Path("/user/gates/tmp/grouped"));
        FileOutputFormat.setOutputPath(top100, new
Path("/user/gates/top100sitesforusers18to25"));
        top100.setNumReduceTasks(1);
        Job limit = new Job(top100);
        limit.addDependingJob(groupJob);

        JobControl jc = new JobControl("Find top 100 sites for users
18 to 25");
        jc.addJob(loadPages);
        jc.addJob(loadUsers);
        jc.addJob(joinJob);
        jc.addJob(groupJob);
        jc.addJob(limit);
        jc.run();
    }
}
```

170 lines of code, 4 hours to write

Ack: Alan Gates from Yahoo!

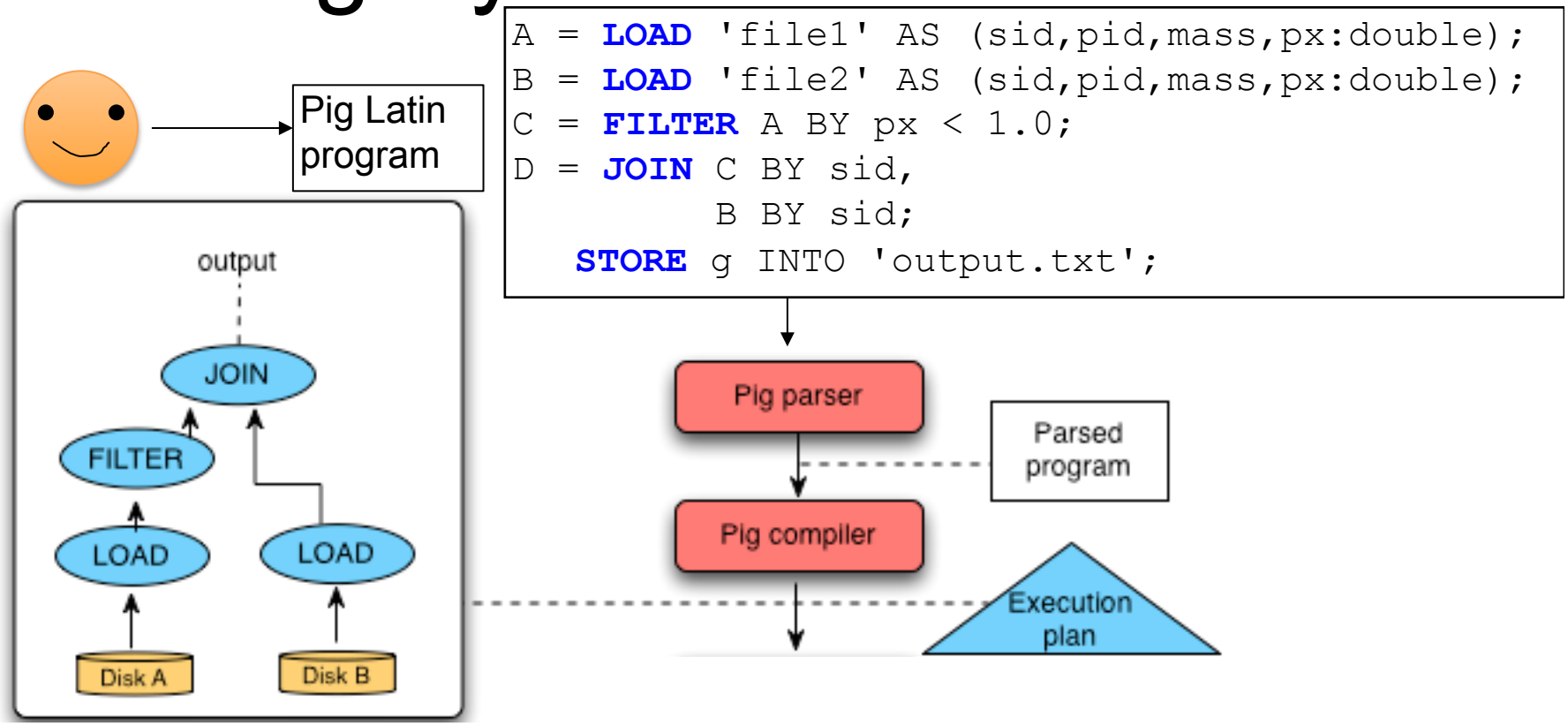
In Pig Latin

```
Users = load 'users' as (name, age);
Fltrd = filter Users by
        age >= 18 and age <= 25;
Pages = load 'pages' as (user, url);
Jnd = join Fltrd by name, Pages by user;
Grpd = group Jnd by url;
Smmd = foreach Grpd generate group,
       COUNT(Jnd) as clicks;
Srtd = order Smmd by clicks desc;
Top5 = limit Srtd 5;
store Top5 into 'top5sites';
```

9 lines of code, 15 minutes to write

Ack: Alan Gates from Yahoo!

Pig System Overview



But can it fly?