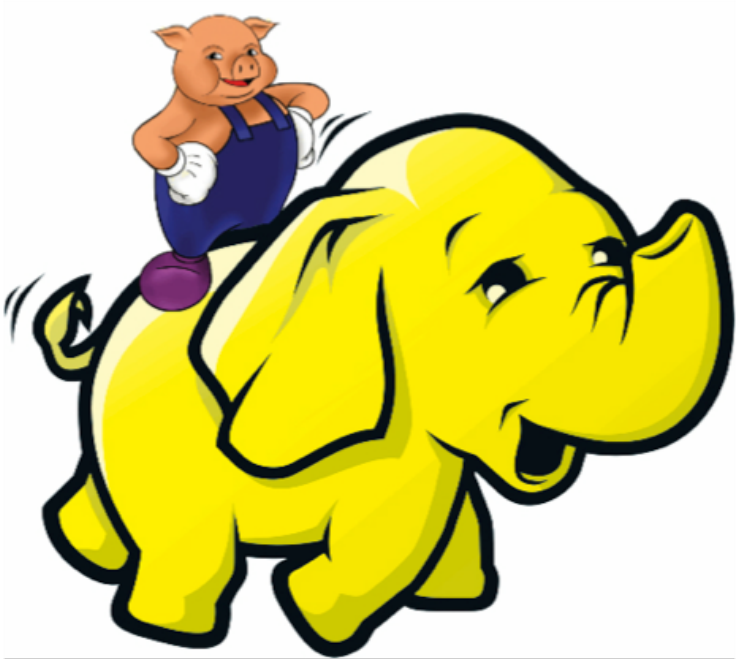
Lecture 23: Pig: Making Hadoop Easy (Slides provided by: Alan Gates, Yahoo!Research)

Friday, May 28, 2010

What is Pig?

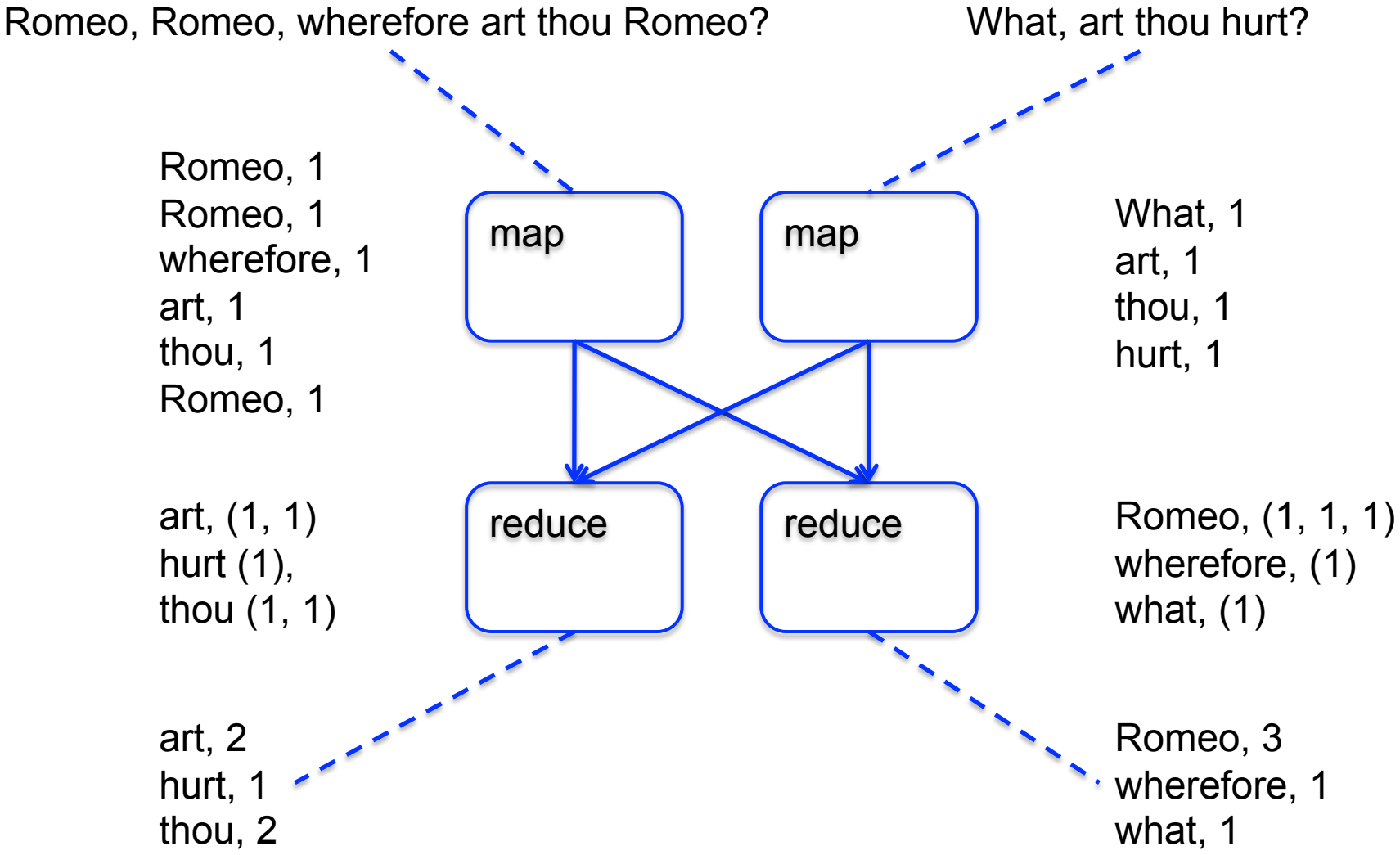
- An engine for executing programs on top of Hadoop
- It provides a language, Pig Latin, to specify these programs
- An Apache open source project
  http://hadoop.apache.org/pig/



Map-Reduce

- Computation is moved to the data
- A simple yet powerful programming model
  - Map: every record handled individually
  - Shuffle: records collected by key
  - Reduce: key and iterator of all associated values
- User provides:
  - input and output (usually files)
  - map Java function
  - key to aggregate on
  - reduce Java function
- Opportunities for more control: partitioning, sorting, partial aggregations, etc.

Map Reduce Illustrated

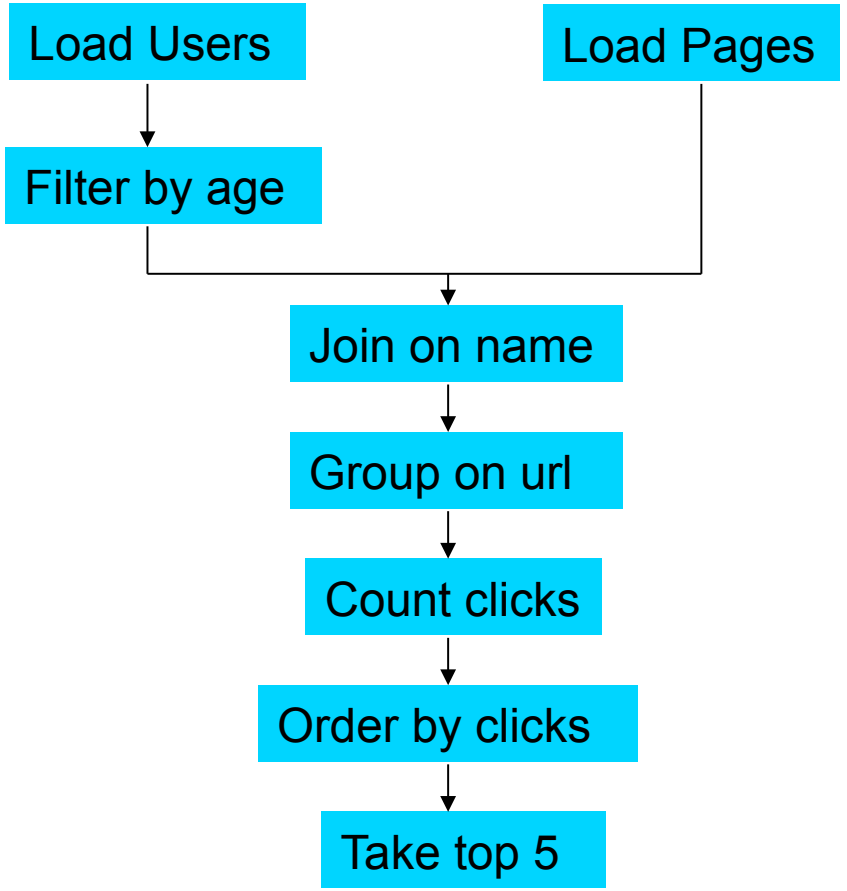


Making Parallelism Simple

- Sequential reads = good read speeds
- In large cluster failures are guaranteed; Map Reduce 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

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 Map-Reduce

```
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("1" + 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();
    }
}
```

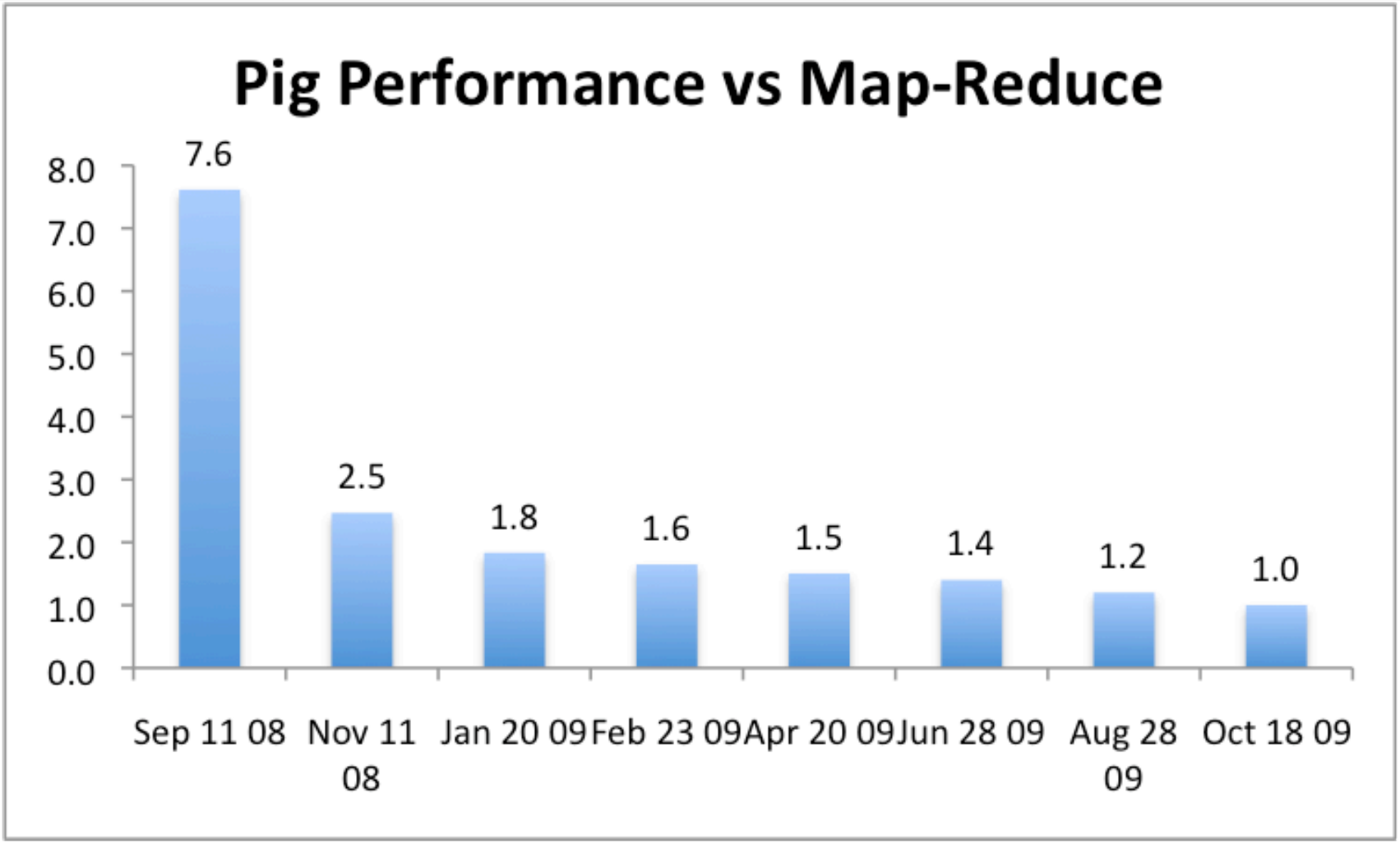
170 lines of code, 4 hours to write

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

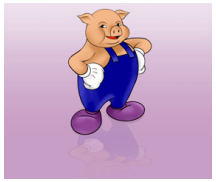
But can it fly?



Essence of Pig

- Map-Reduce is too low a level to program, SQL too high
- Pig Latin, a language intended to sit between the two:
  - Imperative
  - Provides standard relational transforms (join, sort, etc.)
  - Schemas are optional, used when available, can be defined at runtime
  - User Defined Functions are first class citizens
  - Opportunities for advanced optimizer but optimizations by programmer also possible

How It Works



Script

```
A = load
B = filter
C = group
D = foreach
```

Parser

Logical Plan ≈ relational algebra

Logical Plan

Semantic Checks

Logical Plan

Plan standard optimizations

Logical Optimizer

Logical Plan

Logical to Physical Translator

Physical Plan

Physical To MR Translator

Map-Reduce Plan

MapReduce Launcher

Jar to hadoop

Map-Reduce Plan = physical operators broken into Map, Combine, and Reduce stages

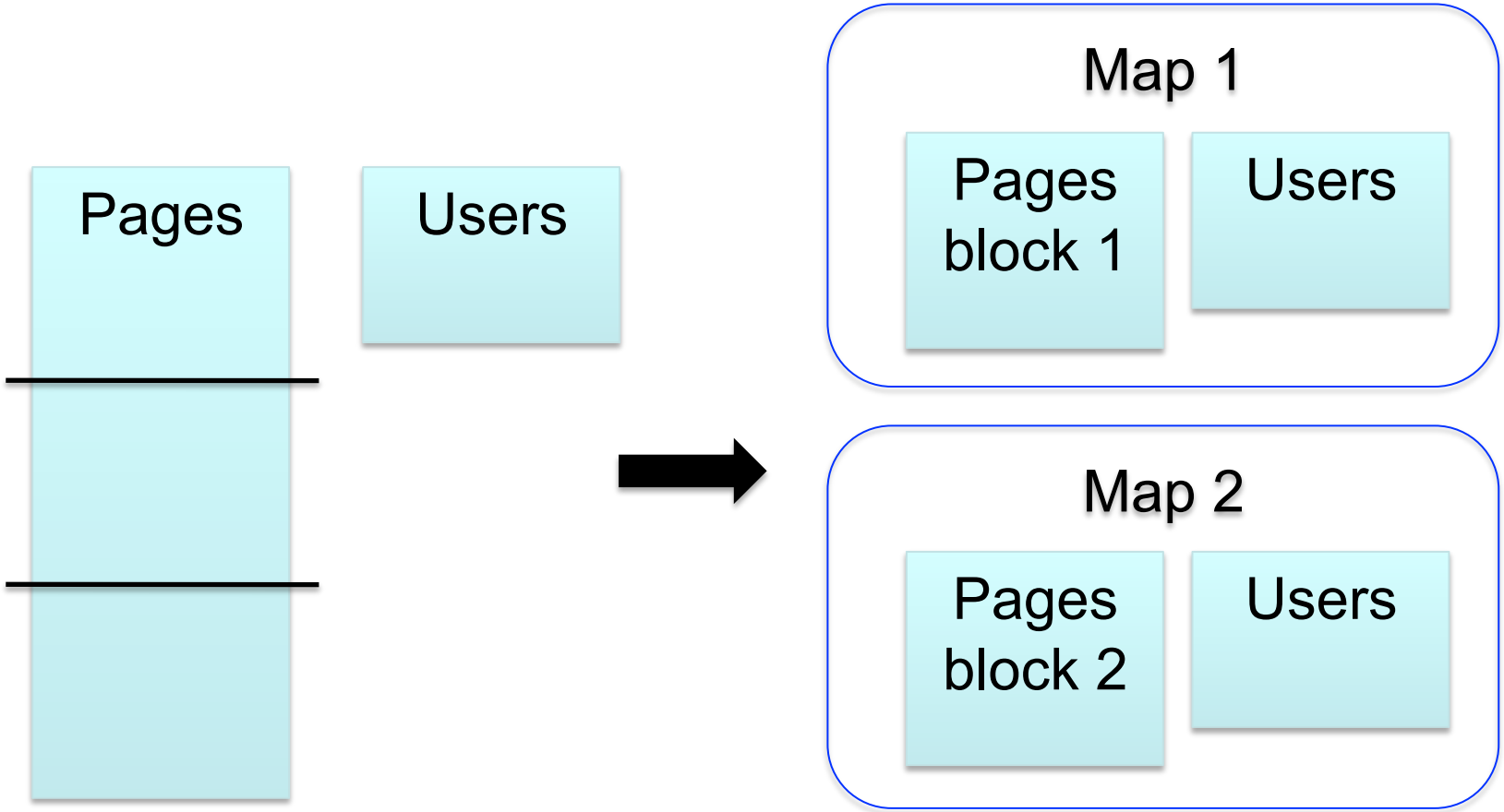
Physical Plan = physical operators to be executed

Cool Things We've Added In the Last Year

- Multiquery – Ability to combine multiple group bys into a single MR job (0.3)
- Merge join – If data is already sorted on join key, do join via merge in map phase (0.4)
- Skew join – Hash join for data with skew in join key. Allows splitting of key across multiple reducers to handle skew. (0.4)
- Zebra – Contrib project that provides columnar storage of data (0.4)
- Rework of Load and Store functions to make them much easier to write (0.7, branched but not released)
- Owl, a metadata service for the grid (committed, will be released in 0.8).

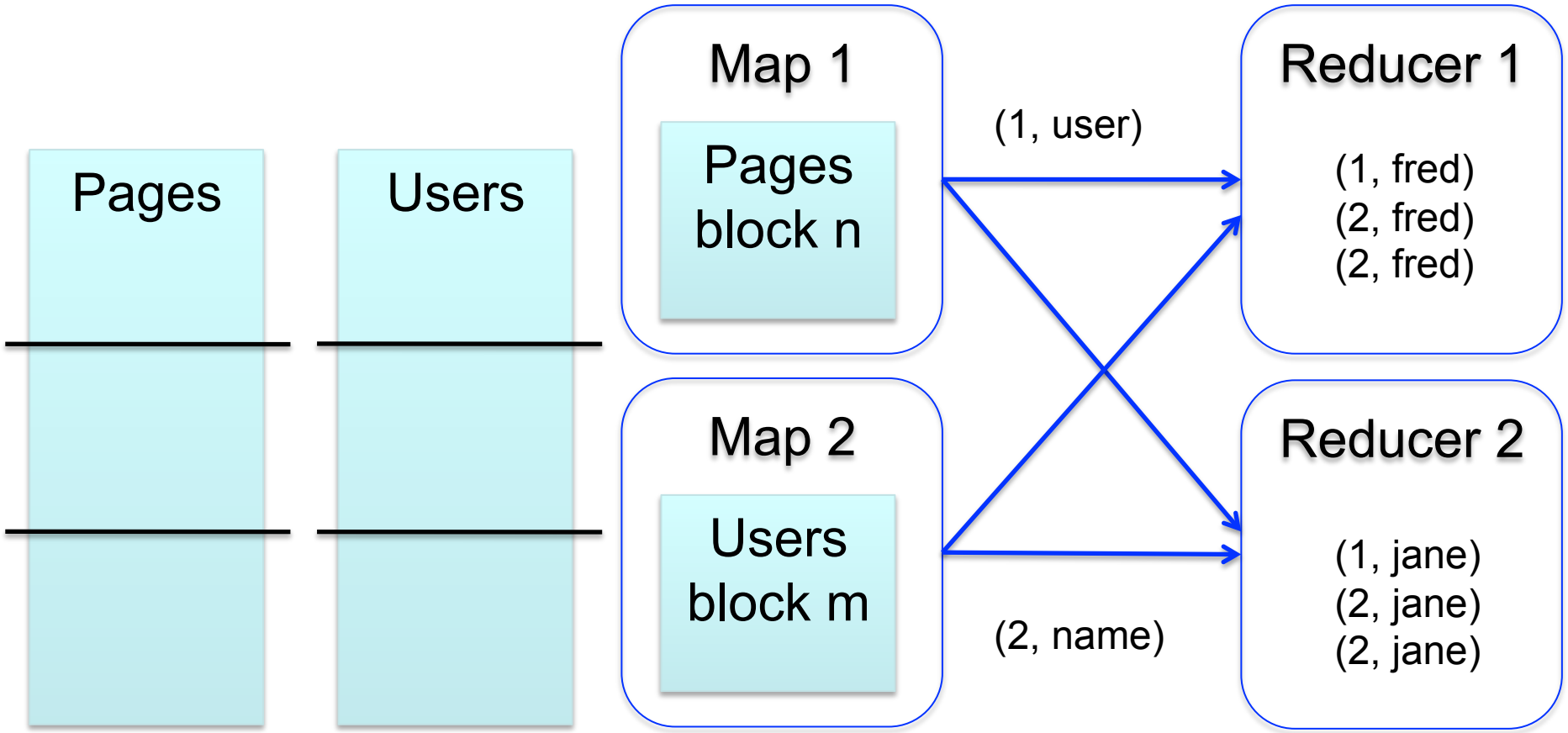
Fragment Replicate Join

```
Users = load 'users' as (name, age);
Pages = load 'pages' as (user, url);
Jnd = join Pages by user, Users by name using "replicated";
```



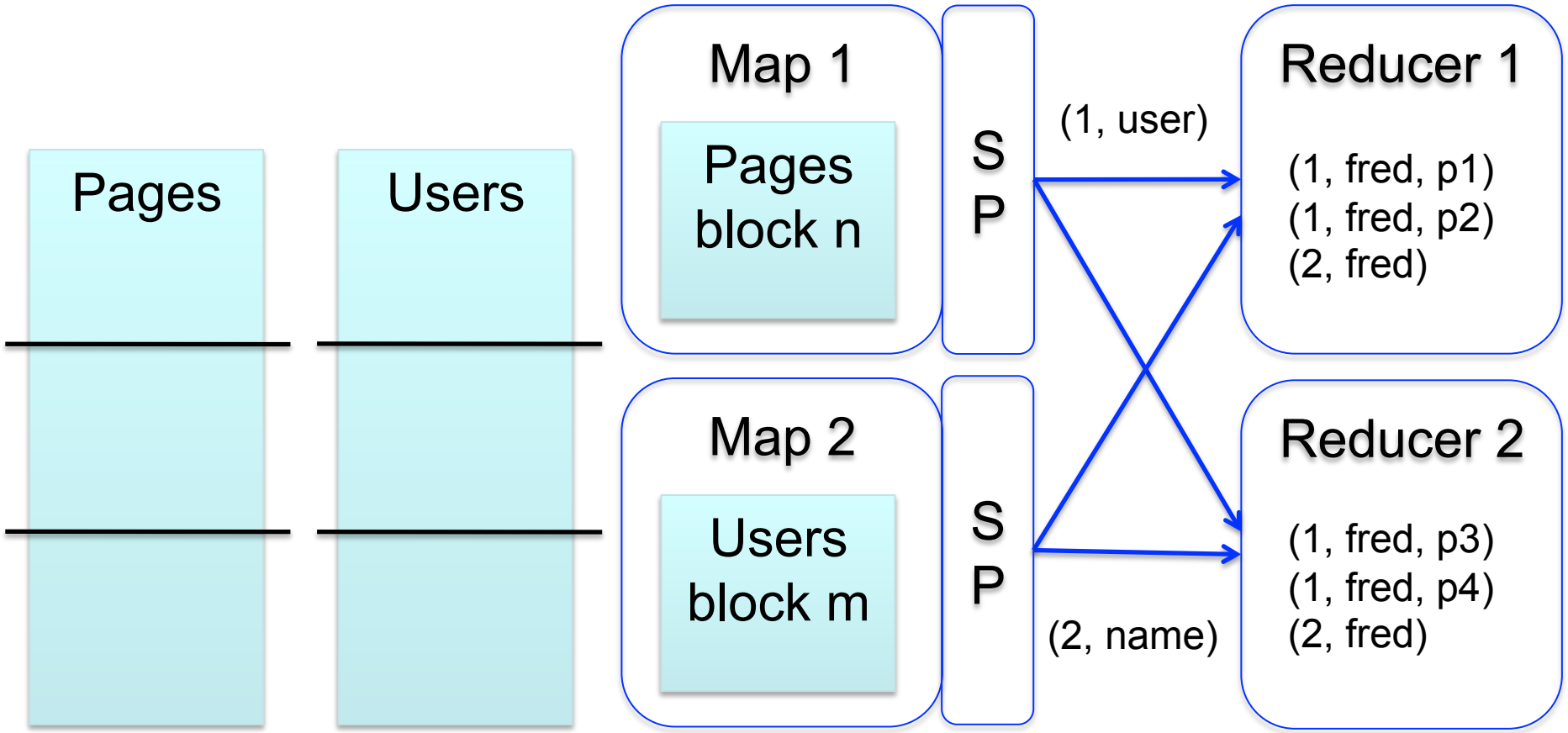
Hash Join

```
Users = load 'users' as (name, age);
Pages = load 'pages' as (user, url);
Jnd = join Users by name, Pages by user;
```



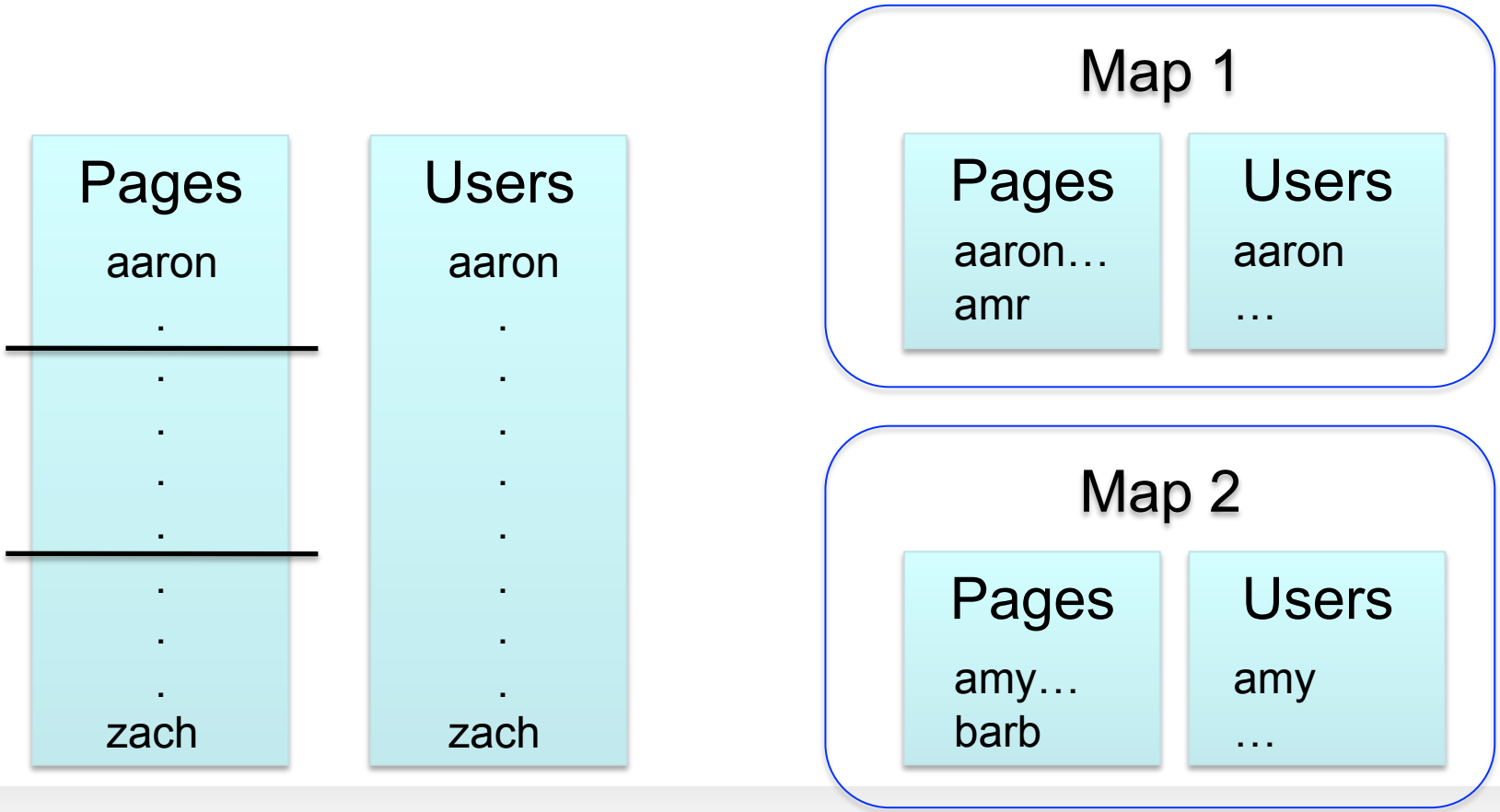
Skew Join

```
Users = load 'users' as (name, age);
Pages = load 'pages' as (user, url);
Jnd = join Pages by user, Users by name using "skewed";
```



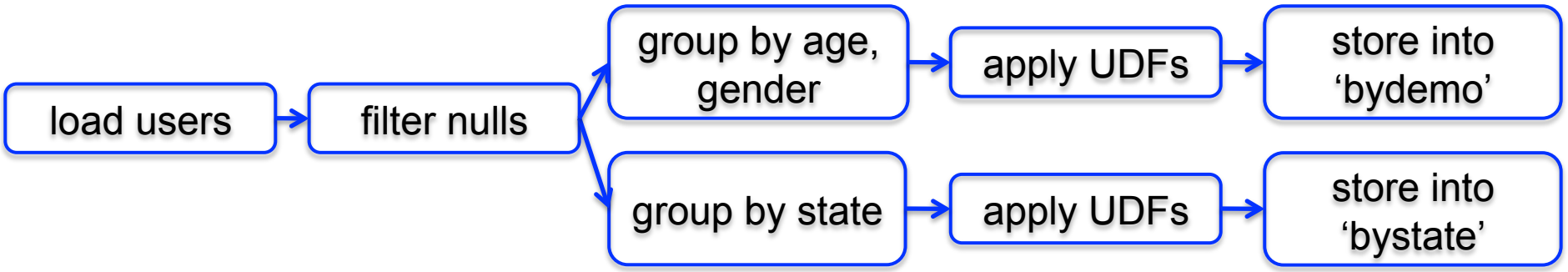
Merge Join

```
Users = load 'users' as (name, age);
Pages = load 'pages' as (user, url);
Jnd = join Pages by user, Users by name using "merge";
```

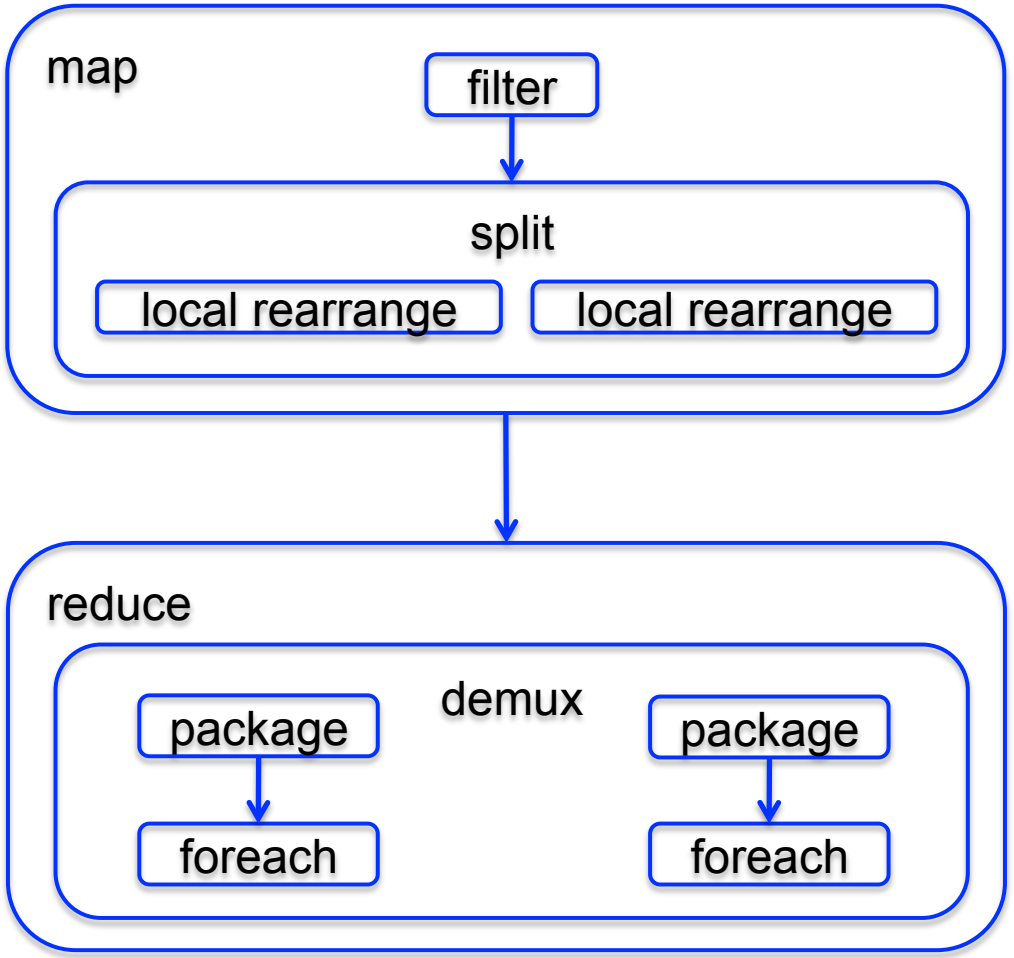


Multi-store script

```
A = load 'users' as (name, age, gender,
      city, state);
B = filter A by name is not null;
C1 = group B by age, gender;
D1 = foreach C1 generate group, COUNT(B);
store D into 'bydemo';
C2= group B by state;
D2 = foreach C2 generate group, COUNT(B);
store D2 into 'bystate';
```



Multi-Store Map-Reduce Plan



What are people doing with Pig

- At Yahoo ~70% of Hadoop jobs are Pig jobs
- Being used at Twitter, LinkedIn, and other companies
- Available as part of Amazon EMR web service and Cloudera Hadoop distribution
- What users use Pig for:
  - Search infrastructure
  - Ad relevance
  - Model training
  - User intent analysis
  - Web log processing
  - Image processing
  - Incremental processing of large data sets

What We're Working on this Year

- Optimizer rewrite
- Integrating Pig with metadata
- Usability – our current error messages might as well be written in actual Latin
- Automated usage info collection
- UDFs in python

Research Opportunities

- Cost based optimization – how does current RDBMS technology carry over to MR world?
- Memory Usage – given that data processing is very memory intensive and Java offers poor control of memory usage, how can Pig be written to use memory well?
- Automated Hadoop Tuning – Can Pig figure out how to configure Hadoop to best run a particular script?
- Indices, materialized views, etc. – How do these traditional RDBMS tools fit into the MR world?
- Human time queries – Analysts want access to the petabytes of data available via Hadoop, but they don't want to wait hours for their jobs to finish; can Pig find a way to answer analysts question in under 60 seconds?
- Map-Reduce-Reduce – Can MR be made more efficient for multiple MR jobs?
- How should Pig integrate with workflow systems?
- See more: http://wiki.apache.org/pig/PigJournal

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- On line tutorials
  - From Yahoo, http://developer.yahoo.com/hadoop/tutorial/
  - From Cloudera, http://www.cloudera.com/hadoop-training
- A couple of Hadoop books are available that include chapters on Pig, search at your favorite bookstore
- Join the mailing lists:
  - pig-user@hadoop.apache.org for user questions
  - pig-dev@hadoop.apache.com for developer issues
- Contribute your work, over 50 people have so far