Data-Intensive Distributed Computing

CS 431/631 451/651 (Fall 2019)

Part 2: From MapReduce to Spark (1/2)

September 19, 2019

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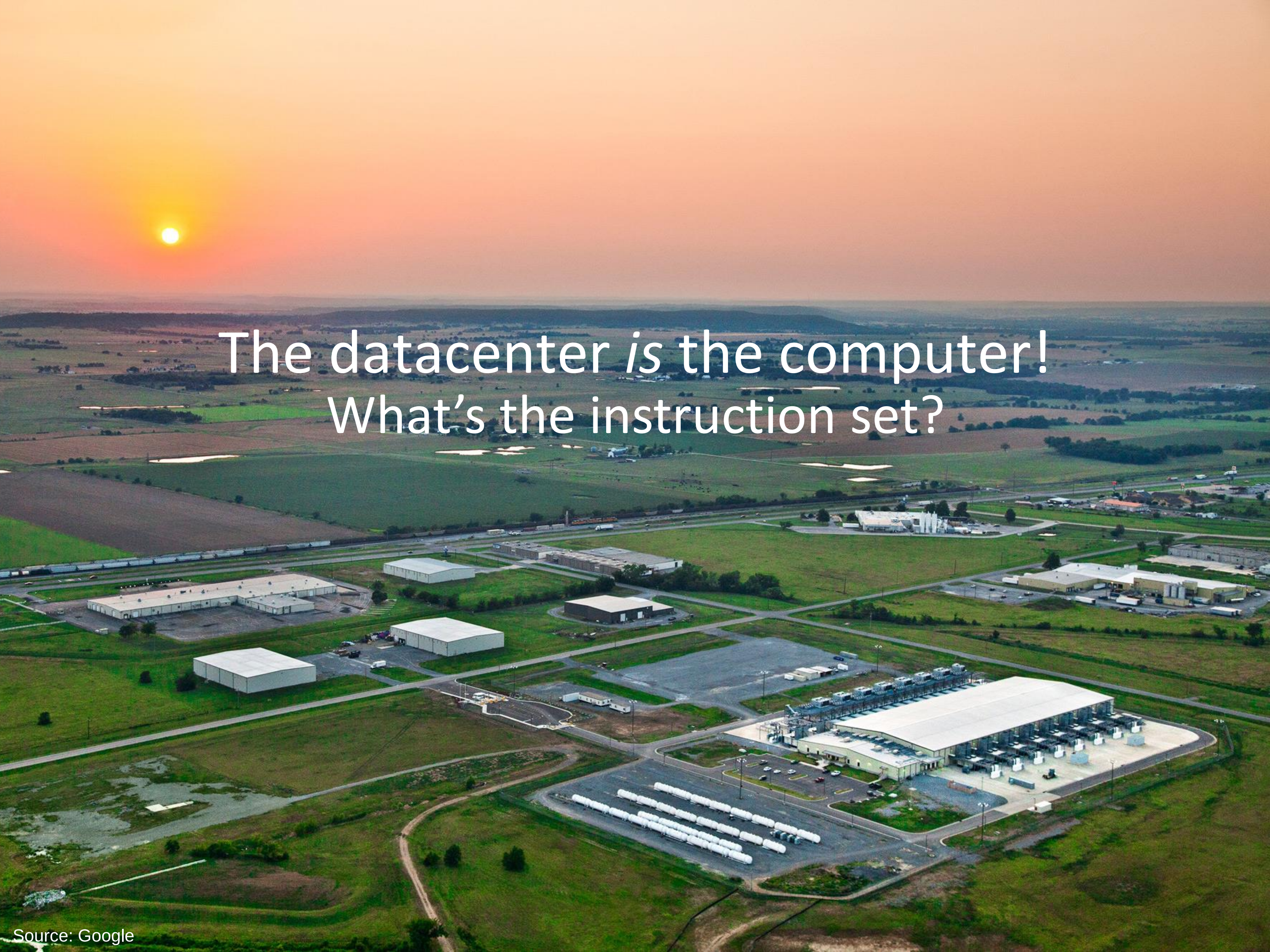
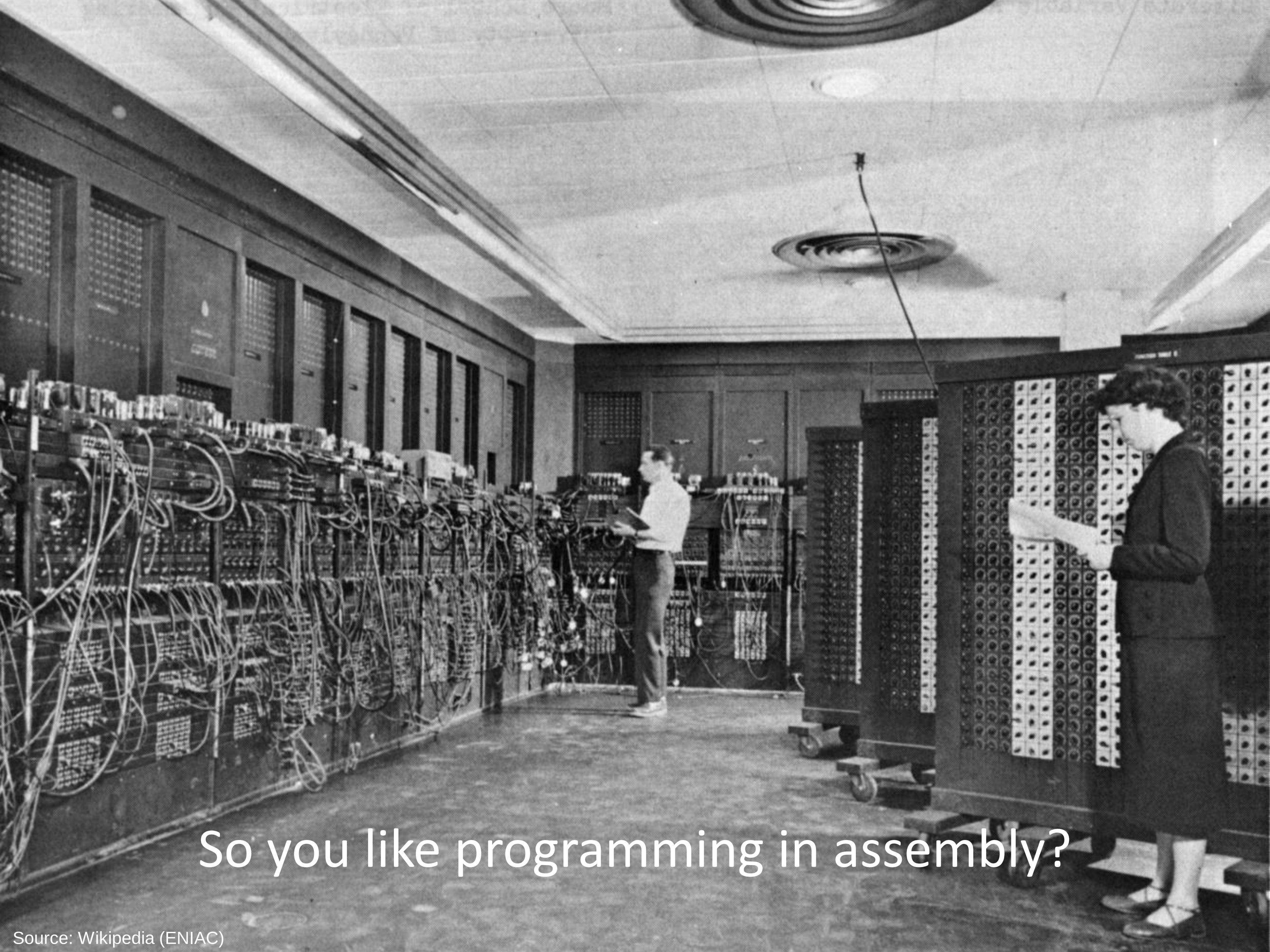
These slides are available at http://roegiest.com/bigdata-2019w/

The datacenter *is* the computer!
What’s the instruction set?



Source: Google



So you like programming in assembly?

Source: Wikipedia (ENIAC)

What’s the solution?

Design a higher-level language

Write a compiler

Hadoop is great, but it’s really waaaaay too low level!

facebook®

What we really need is SQL!

Answer:

YAHOO!®

What we really need is a scripting language!

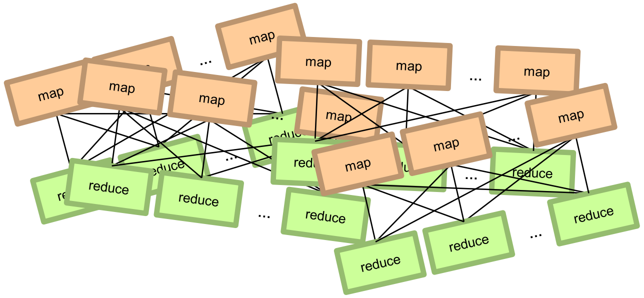
Answer:

facebook

HIVE

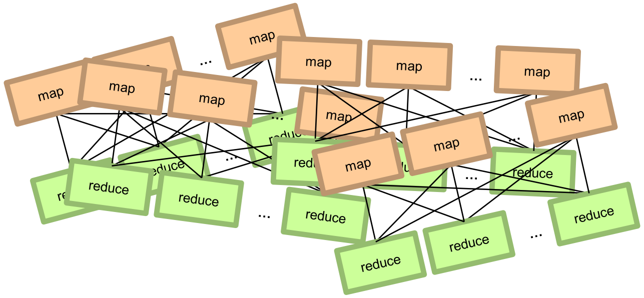
SQL

Aside: Why not just use a database?

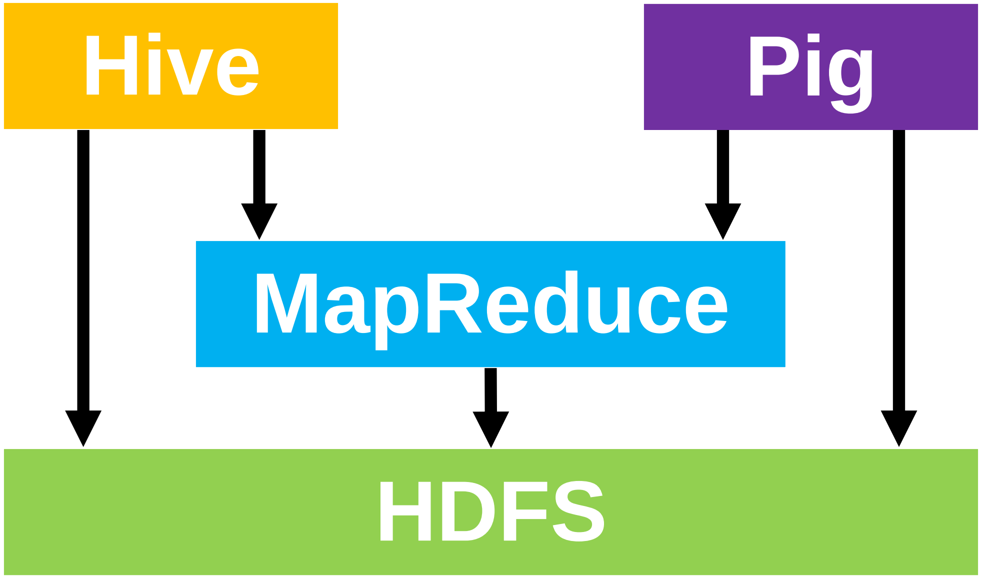


YAHOO!

Pig Scripts



Both open-source projects today!


Hive
Pig
MapReduce
HDFS

Pig!

Source: Wikipedia (Pig)

Pig: Example

Task: Find the top 10 most visited pages in each category

Visits

User	Url	Time
Amy	cnn.com	8:00
Amy	bbc.com	10:00
Amy	flickr.com	10:05
Fred	cnn.com	12:00

⋮

URL Info

Url	Category	PageRank
cnn.com	News	0.9
bbc.com	News	0.8
flickr.com	Photos	0.7
espn.com	Sports	0.9

⋮

Pig Slides adapted from Olston et al. (SIGMOD 2008)

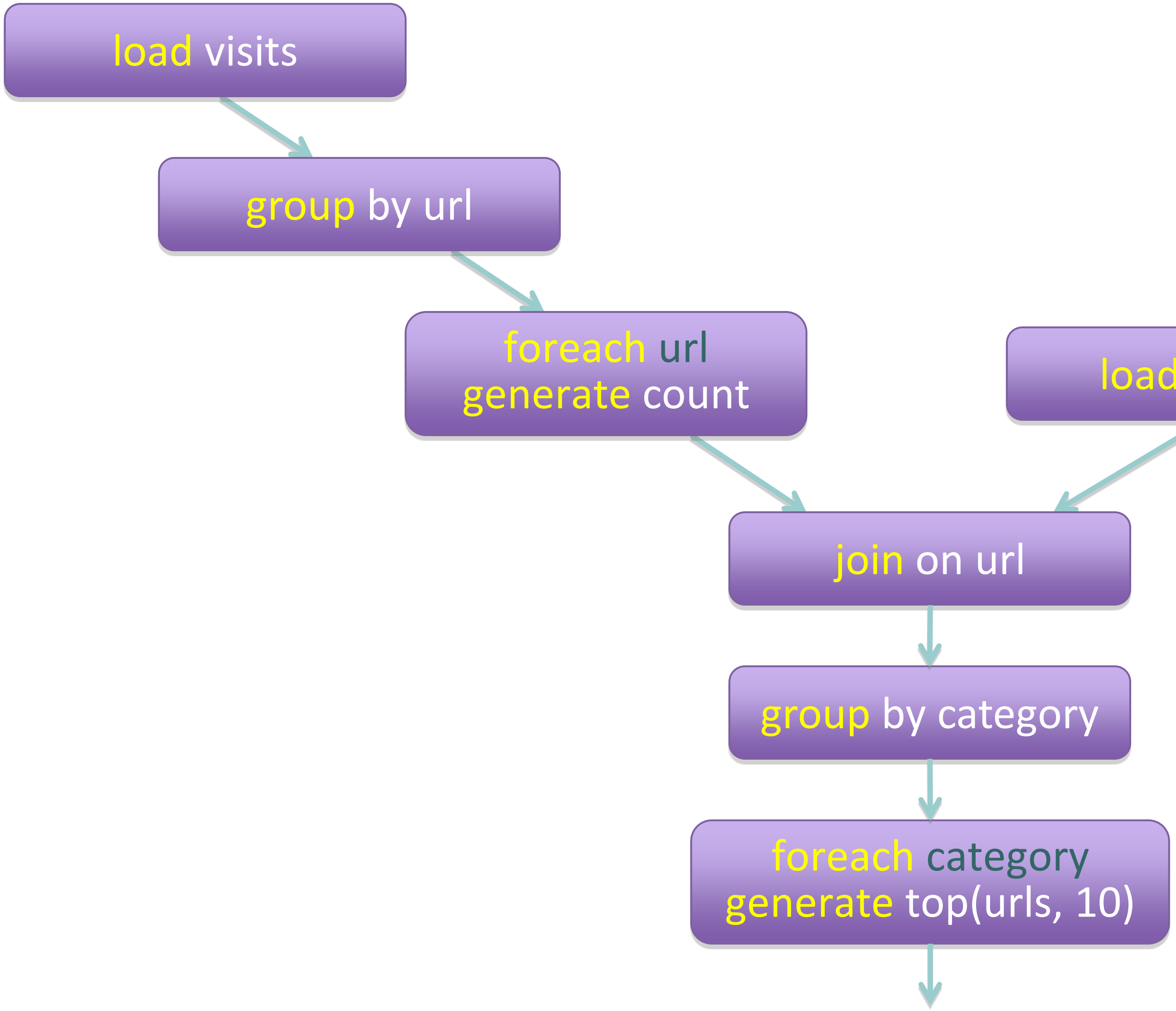
Pig: Example Script

```
visits = load ‘/data/visits’ as (user, url, time);
gVisits = group visits by url;
visitCounts = foreach gVisits generate url, count(visits);
urlInfo = load ‘/data/urlInfo’ as (url, category, pRank);
visitCounts = join visitCounts by url, urlInfo by url;
gCategories = group visitCounts by category;
topUrls = foreach gCategories generate top(visitCounts,10);

store topUrls into ‘/data/topUrls’;
```

Pig Slides adapted from Olston et al. (SIGMOD 2008)

Pig Query Plan



load visits

group by url

foreach url
generate count

load urlInfo

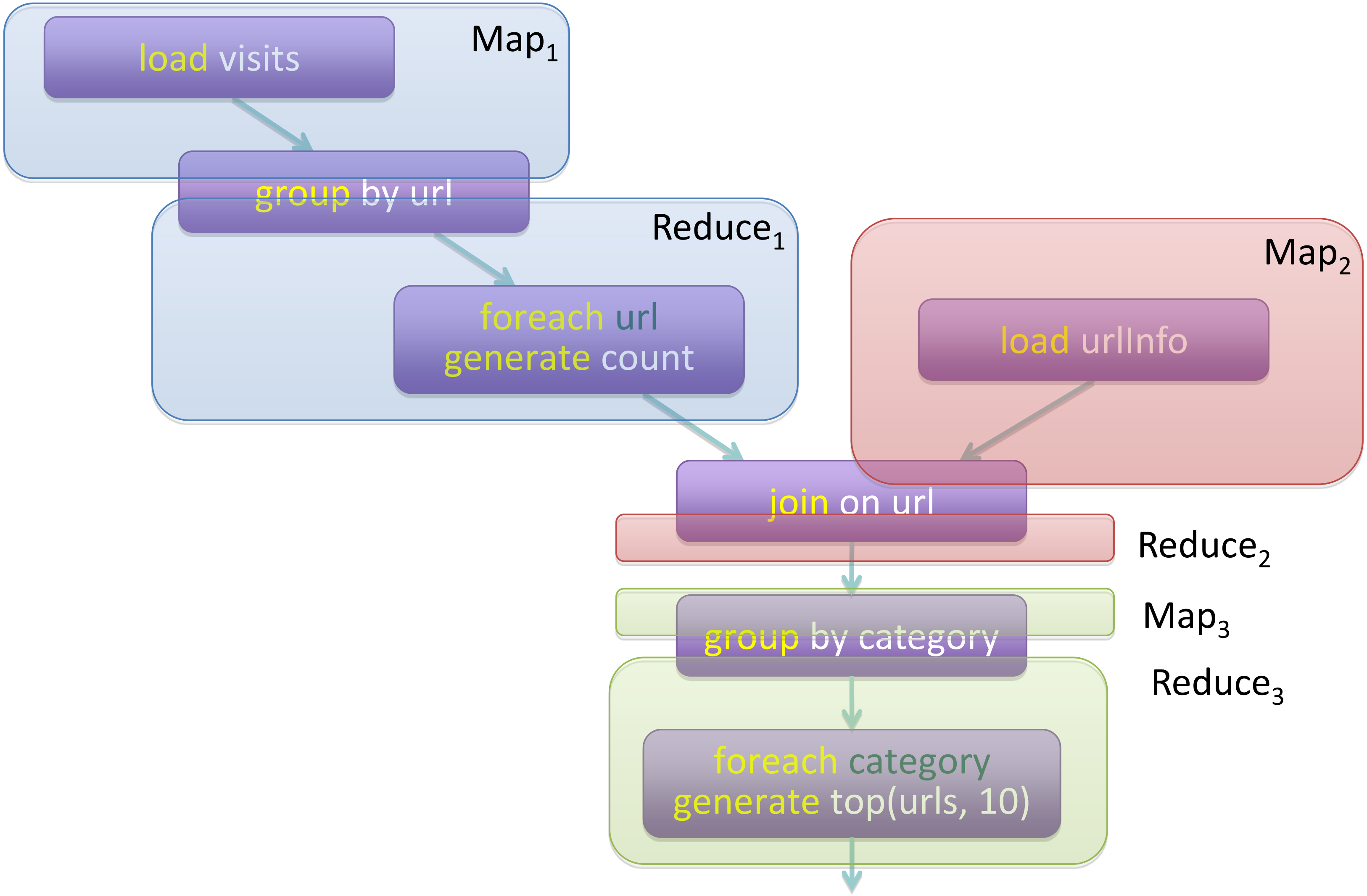
join on url

group by category

foreach category
generate top(urls, 10)

Pig Slides adapted from Olston et al. (SIGMOD 2008)

Pig: MapReduce Execution



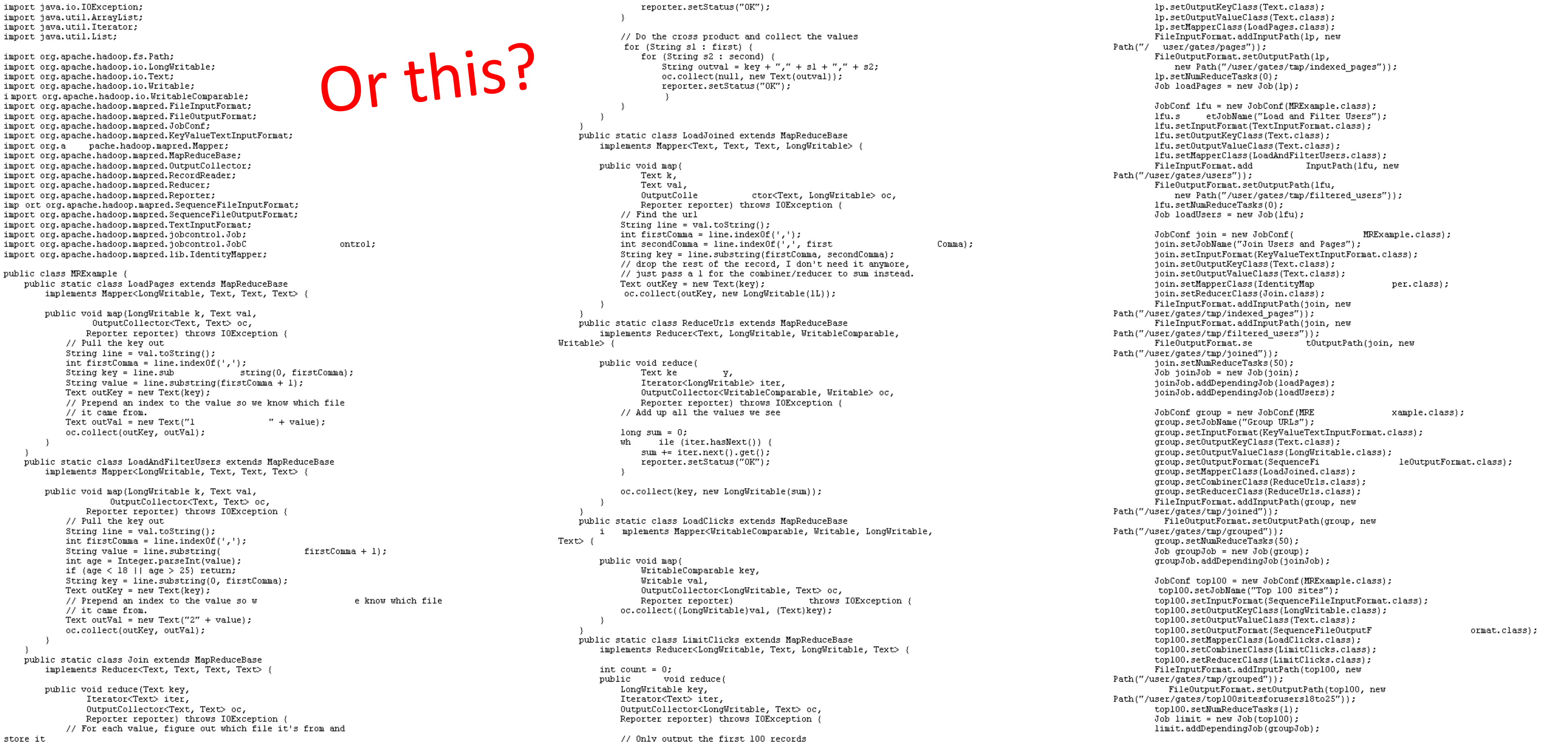
Pig Slides adapted from Olston et al. (SIGMOD 2008)

```
visits = load '/data/visits' as (user, url, time);
gVisits = group visits by url;
visitCounts = foreach gVisits generate url, count(visits);
urlInfo = load '/data/urlInfo' as (url, category, pRank);
visitCounts = join visitCounts by url, urlInfo by url;
gCategories = group visitCounts by category;
topUrls = foreach gCategories generate top(visitCounts,10);

store topUrls into '/data/topUrls';
```

This?

Or this?



```
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;
i mport 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.a     pache.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;
imp ort 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.JobC                   ontrol;
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.sub             string(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 w                   e 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
```

```
                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,
                OutputColle          ctor<Text, LongWritable> oc,
                Reporter reporter) throws IOException {
            // Find the url
            String line = val.toString();
            int firstComma = line.indexOf(',');
            int secondComma = line.indexOf(',', first                  Comma);
            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 ke        y,
                Iterator<LongWritable> iter,
                OutputCollector<WritableComparable, Writable> oc,
                Reporter reporter) throws IOException {
            // Add up all the values we see

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

            oc.collect(key, new LongWritable(sum));
        }
    }
    public static class LoadClicks extends MapReduceBase
        i   mplements 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
```

```
        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.s     etJobName("Load and Filter Users");
        lfu.setInputFormat(TextInputFormat.class);
        lfu.setOutputKeyClass(Text.class);
        lfu.setOutputValueClass(Text.class);
        lfu.setMapperClass(LoadAndFilterUsers.class);
        FileInputFormat.add          InputPath(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(IdentityMap               per.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.se          tOutputPath(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(MRE               xample.class);
        group.setJobName("Group URLs");
        group.setInputFormat(KeyValueTextInputFormat.class);
        group.setOutputKeyClass(Text.class);
        group.setOutputValueClass(LongWritable.class);
        group.setOutputFormat(SequenceFi                leOutputFormat.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(SequenceFileOutputF                    ormat.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);
```

But isn’t Pig slower?

Sure, but c can be slower than assembly too…

Pig: Basics

Sequence of statements manipulating relations

Data model

atoms
tuples
bags
maps

Pig: Common Operations

LOAD: load data (from HDFS)

FOREACH … GENERATE: per tuple processing

FILTER: discard unwanted tuples “map”

GROUP/COGROUP: group tuples

“reduce” JOIN: relational join

STORE: store data (to HDFS)

Pig: GROUPing

```
A = LOAD 'myfile.txt’ AS (f1: int, f2: int, f3: int);

    (1, 2, 3)
    (4, 2, 1)
    (8, 3, 4)
    (4, 3, 3)
    (7, 2, 5)
    (8, 4, 3)
```

```
X = GROUP A BY f1;

    (1, {(1, 2, 3)})
    (4, {(4, 2, 1), (4, 3, 3)})
    (7, {(7, 2, 5)})
    (8, {(8, 3, 4), (8, 4, 3)})
```

Pig: COGROUPing

A:
(1, 2, 3)
(4, 2, 1)
(8, 3, 4)
(4, 3, 3)
(7, 2, 5)
(8, 4, 3)

B:
(2, 4)
(8, 9)
(1, 3)
(2, 7)
(2, 9)
(4, 6)
(4, 9)

```
X = COGROUP A BY $0, B BY $0;
```

```
(1, {(1, 2, 3)}, {(1, 3)})
(2, {}, {(2, 4), (2, 7), (2, 9)})
(4, {(4, 2, 1), (4, 3, 3)}, {(4, 6),(4, 9)})
(7, {(7, 2, 5)}, {})
(8, {(8, 3, 4), (8, 4, 3)}, {(8, 9)})
```

Pig: JOINing

A:

```
(1, 2, 3)
(4, 2, 1)
(8, 3, 4)
(4, 3, 3)
(7, 2, 5)
(8, 4, 3)
```

B:

```
(2, 4)
(8, 9)
(1, 3)
(2, 7)
(2, 9)
(4, 6)
(4, 9)
```

```
X = JOIN A BY $0, B BY $0;
```

```
(1,2,3,1,3)
(4,2,1,4,6)
(4,3,3,4,6)
(4,2,1,4,9)
(4,3,3,4,9)
(8,3,4,8,9)
(8,4,3,8,9)
```

Pig UDFs

User-defined functions:

Java
Python
JavaScript
Ruby
…

UDFs make Pig arbitrarily extensible

Express “core” computations in UDFs
Take advantage of Pig as glue code for scale-out plumbing

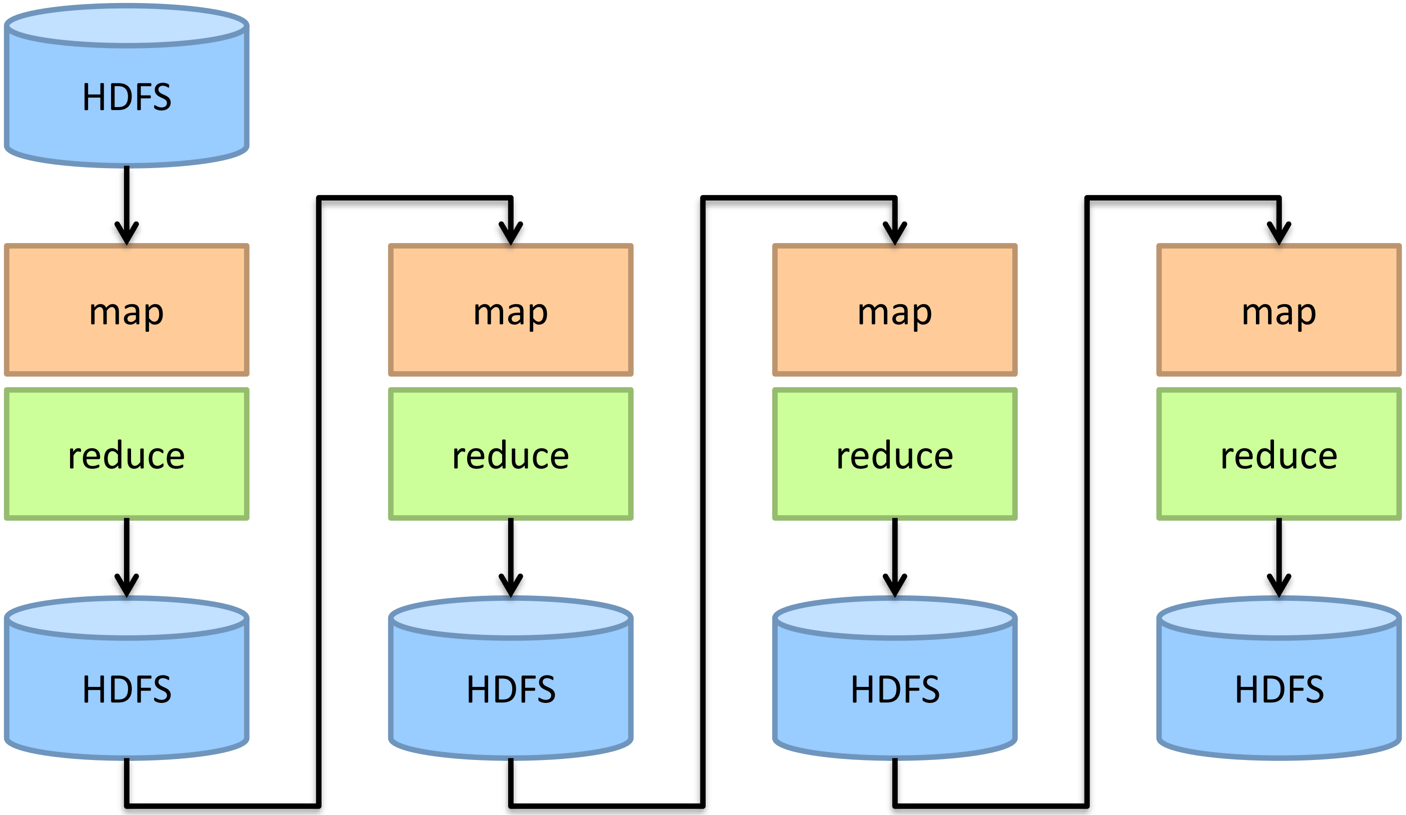
The datacenter *is* the computer!

What’s the instruction set?

Okay, let’s fix this!

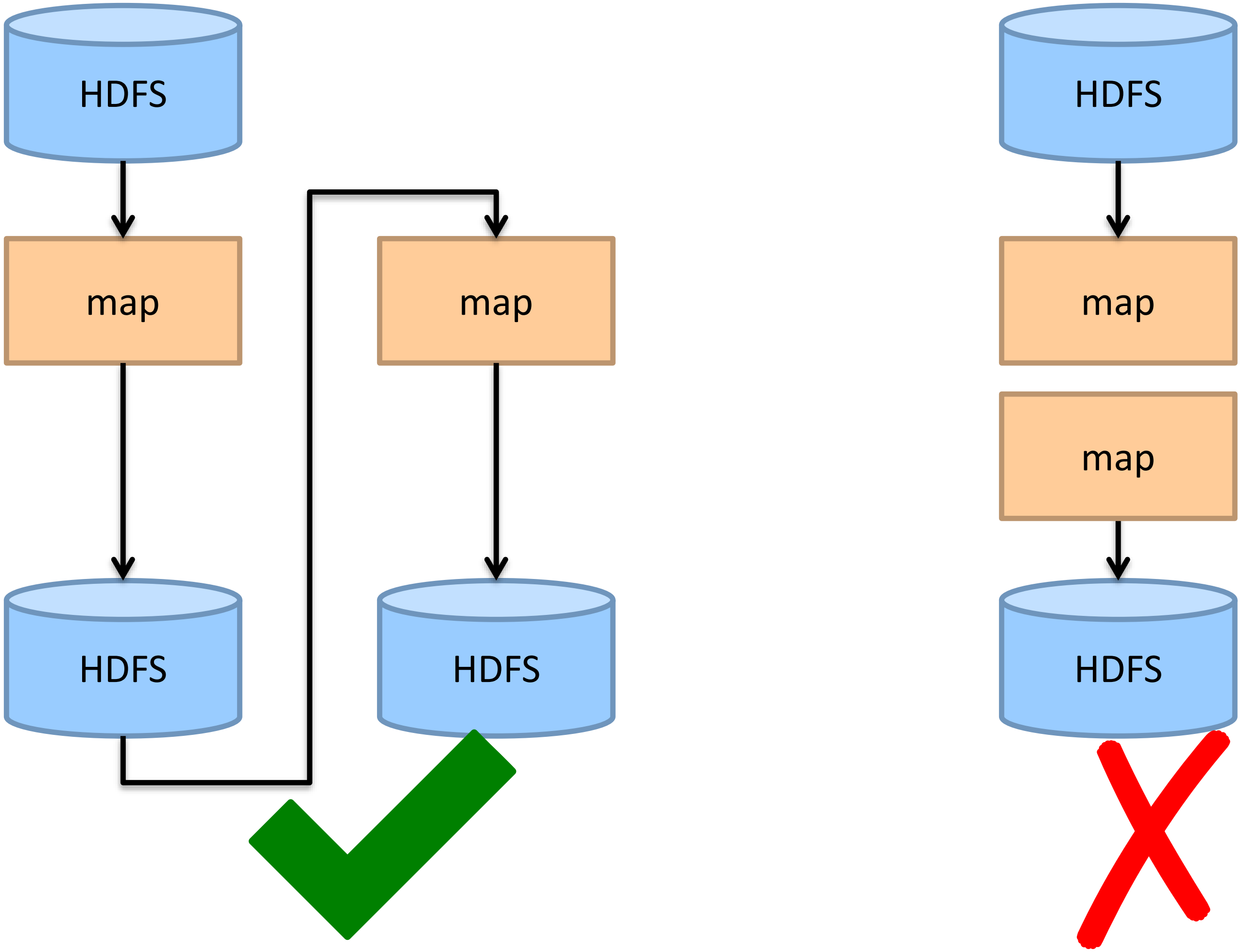
Source: Google

MapReduce Workflows

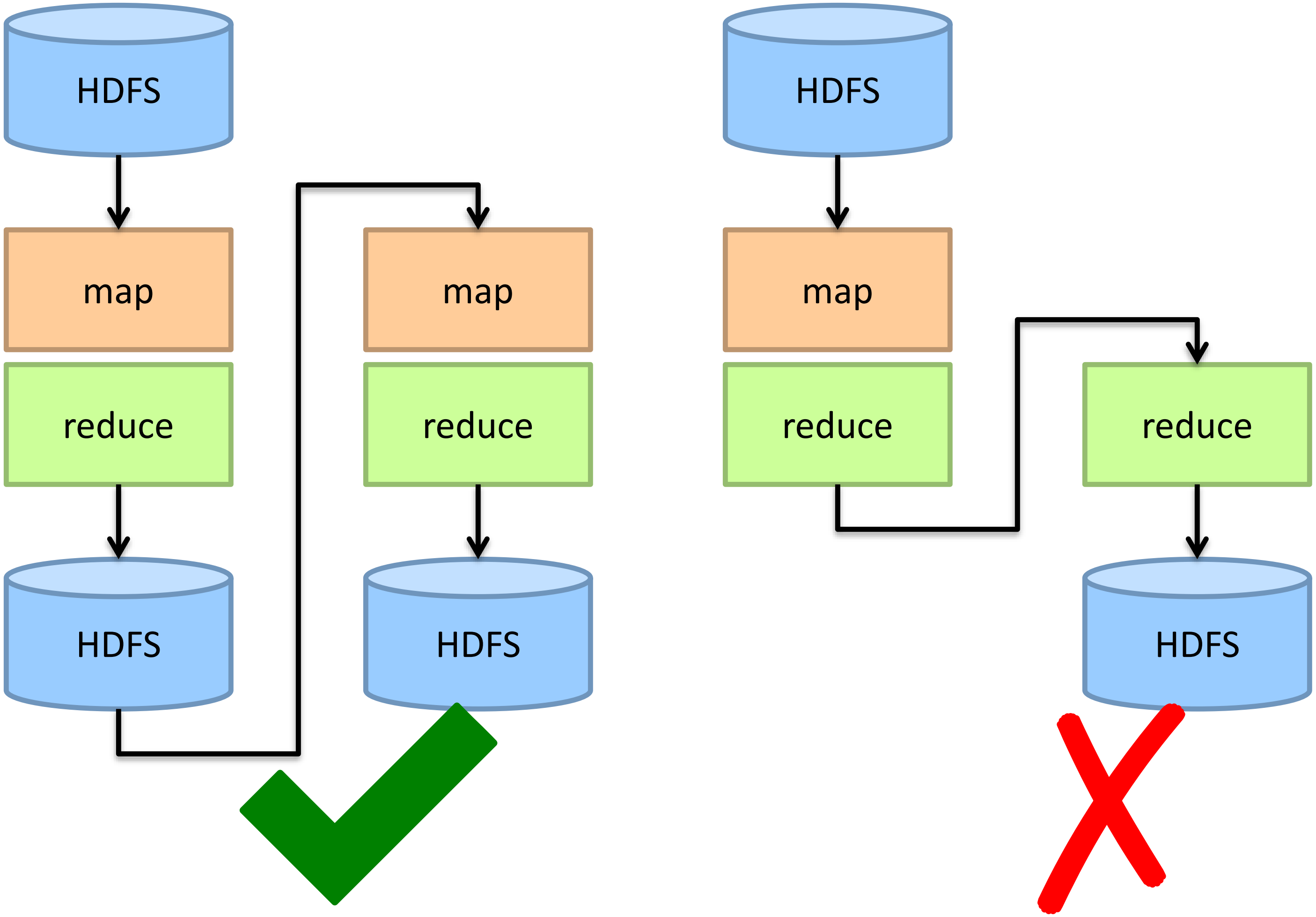


What’s wrong?

Want MM?



Want MRR?


HDFS
map
reduce
HDFS
map
reduce
HDFS
✓
HDFS
map
reduce
reduce
HDFS
✗

The datacenter *is* the computer!

Let’s enrich the instruction set!

Source: Google

Spark

Answer to “What’s beyond MapReduce?”

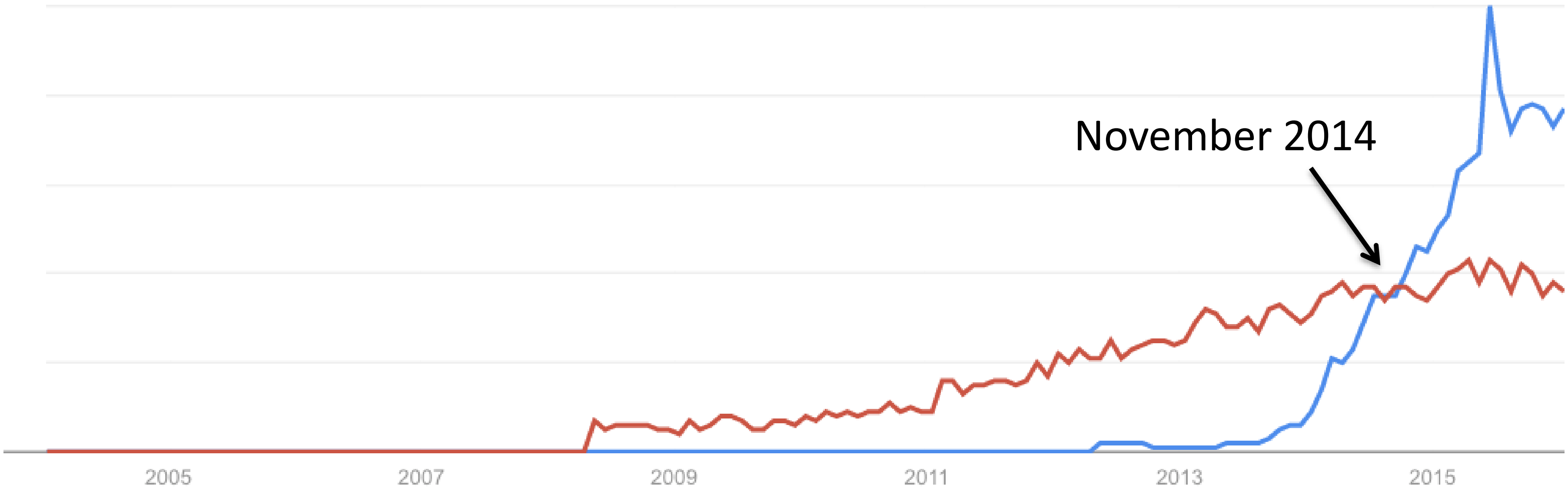
Brief history:

Developed at UC Berkeley AMPLab in 2009

Open-sourced in 2010

Became top-level Apache project in February 2014

Spark vs. Hadoop



November 2014

Google Trends

Source: Datanami (2014): http://www.datanami.com/2014/11/21/spark-just-passed-hadoop-popularity-web-heres/