

# MapReduce

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# MapReduce

- Goals: large data sets, distributed processing
  - Hide details of parallelization, data distribution, fault tolerance, load balancing
  - Inspired by functional PLs: Lisp, Scheme, Haskell, ...
  - Functional programming: no side effects → automatic parallelization
- MapReduce programming model:
  - sets of key/value pairs
  - Developer implements interface of two (side-effect free) functions:

`map (inKey, inValue) -> (outKey, intermediateValuelist )`

← aka „group by“ in SQL

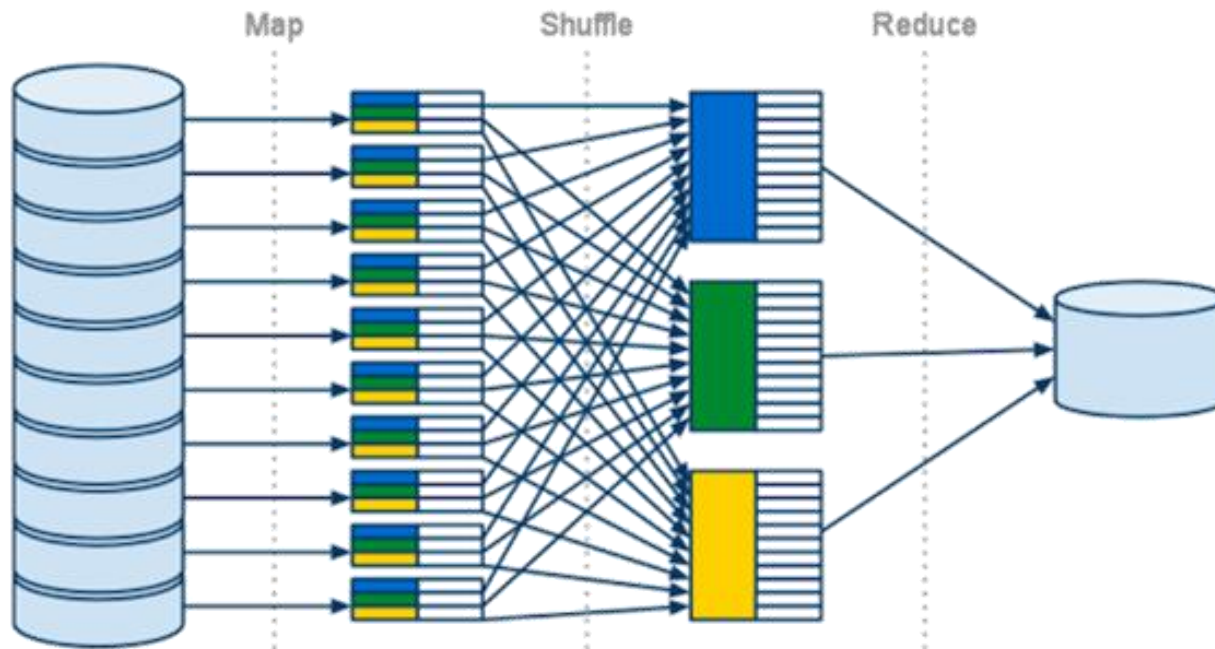
`reduce(outKey, intermediateValuelist) -> outValuelist`

← aka aggregation in SQL

# Ex 1: Count Word Occurrences

```
map(String inKey, String inValue):
    // inKey: document name
    // inValue: document contents
    for each word w in inValue:
        EmitIntermediate(w, "1");
```

```
reduce(String outputKey, Iterator auxValues):
    // outKey: a word
    // outValues: a list of counts
    int result = 0;
    for each v in auxValues:
        result += ParseInt(v);
    Emit( AsString(result) );
```



[image: Google]



# Hadoop: a MapReduce implementation

## Credits:

- David Maier, U Wash
- Costin Raiciu
- “The Google File System” by S. Ghemawat, H. Gobioff, and S.-T. Leung, 2003
- [https://hadoop.apache.org/docs/r1.0.4/hdfs\\_design.html](https://hadoop.apache.org/docs/r1.0.4/hdfs_design.html)

# Hadoop Key Components

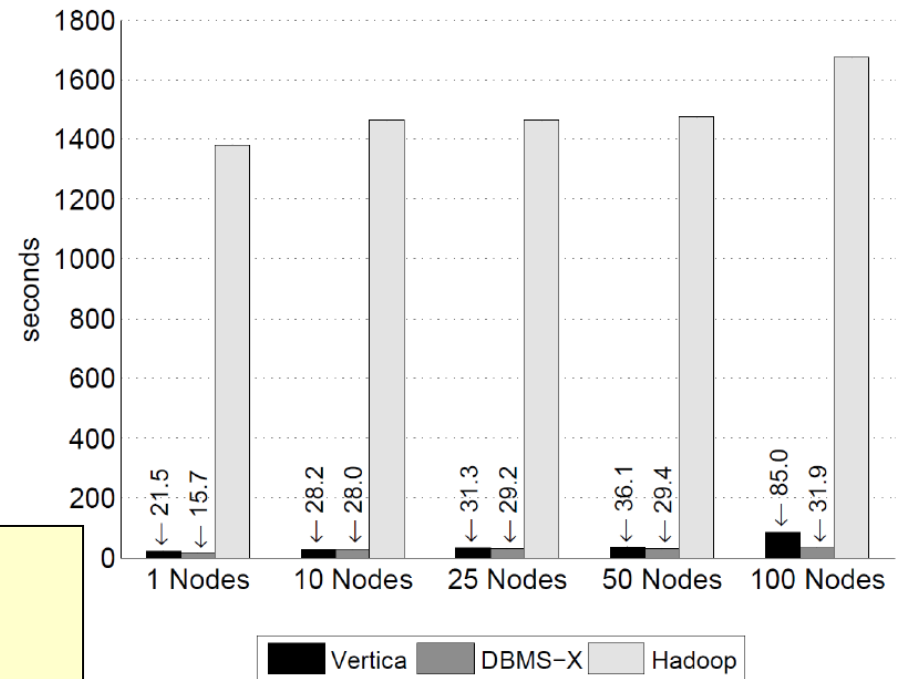
- Hadoop Job Management Framework
  - JobTracker = daemon service for submitting & tracking MapReduce jobs
  - TaskTracker = slave node daemon in the cluster accepting tasks (Map, Reduce, & Shuffle operations) from a JobTracker
- Hadoop File System (HDFS) = scalable, fault-tolerant file system
  - modeled after Google File System (GFS)
  - programs request data as 64 MB blocks („chunks“) from server, Hadoop ships
- *Data processing, not management*

# Query Languages for MapReduce

- MapReduce powerful, but slow and fairly low-level
  - algorithms need cumbersome rewriting = special-skill programming
  - common “job patterns”, like SQL?

```
SELECT INTO Temp
  UV.sourceIP,
  AVG(R.pageRank) AS avgPageRank,
  SUM(UV.adRevenue) AS totalRevenue
FROM Rankings AS R, UserVisits AS UV
WHERE R.pageURL = UV.destURL
  AND UV.visitDate BETWEEN
    DATE('2000-01-15') AND
    DATE('2000-01-22')
GROUP BY UV.sourceIP
```

```
SELECT sourceIP,
  avgPageRank,
  totalRevenue
FROM Temp
ORDER BY totalRevenue
DESC LIMIT 1
```



[A. Pavlo et al.: A Comparison of Approaches to Large-Scale Data Analysis]

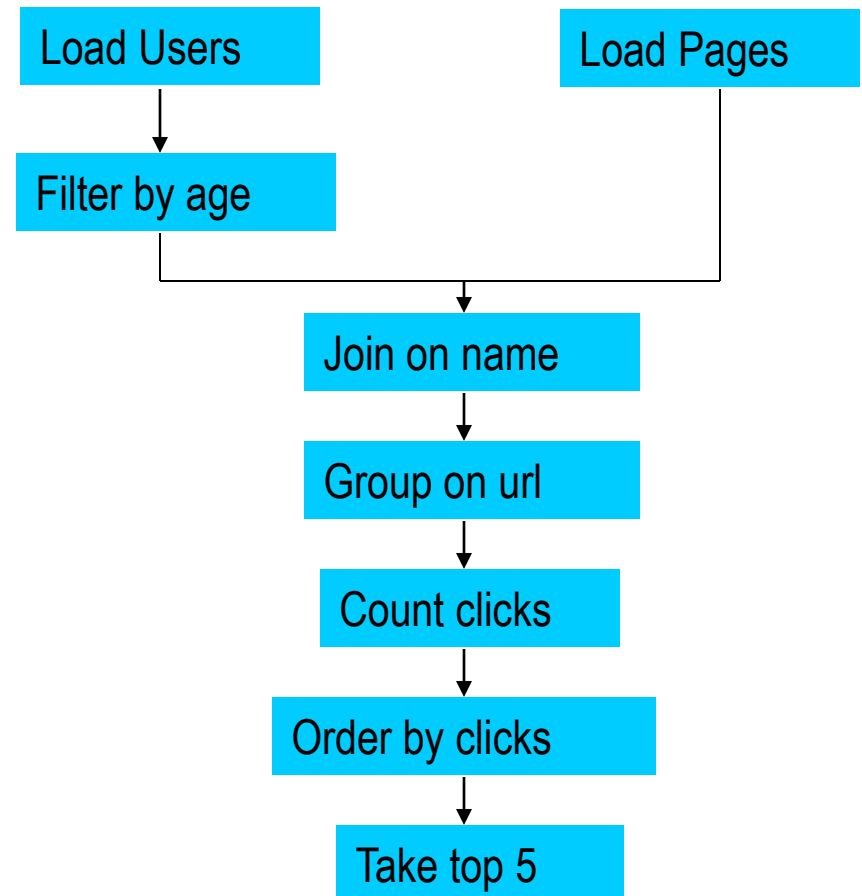
# Pig

- Pig = declarative query language
  - Yahoo! Research
- Features:
  - sequences of MapReduce jobs
  - relational (SQL) operators (JOIN, GROUP BY, etc)
  - Easy to plug in Java functions



# Example Problem

- user data in one file
- website data in another
- find top 5 most visited pages
- by users aged 18-25



[<http://wiki.apache.org/pig-data/attachments/PigTalksPapers/attachments/ApacheConEurope09.ppt>]



# MapReduce vs. Pig Latin

```
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;

    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> {

        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(LoadedFilterUsers.class);
```

Users = load 'users' as (name, age);  
 Filtered = filter Users by age >= 18 and age <= 25;  
 Pages = load 'pages' as (user, url);  
 Joined = join Filtered by name, Pages by user;  
 Grouped = group Joined by url;  
 Summed = foreach Grouped generate group, count(Joined) as clicks;  
 Sorted = order Summed by clicks desc;  
 Top5 = limit Sorted 5;  
 store Top5 into 'top5sites';

```
// 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 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);

        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();
    }
}

}
```

[<http://wiki.apache.org/pig-data/attachments/PigTalksPapers/attachments/ApacheConEurope09.ppt>]

# Hive

- **Relational** database built on Hadoop
  - Facebook, now Apache
- Common relational features:
  - table partitioning, complex data types, sampling
  - some query optimization

■ **Ex:**

```
SELECT word, count(1) AS count
FROM (SELECT explode(split(line, '\s')) AS word
      FROM docs) temp
GROUP BY word
ORDER BY word
```



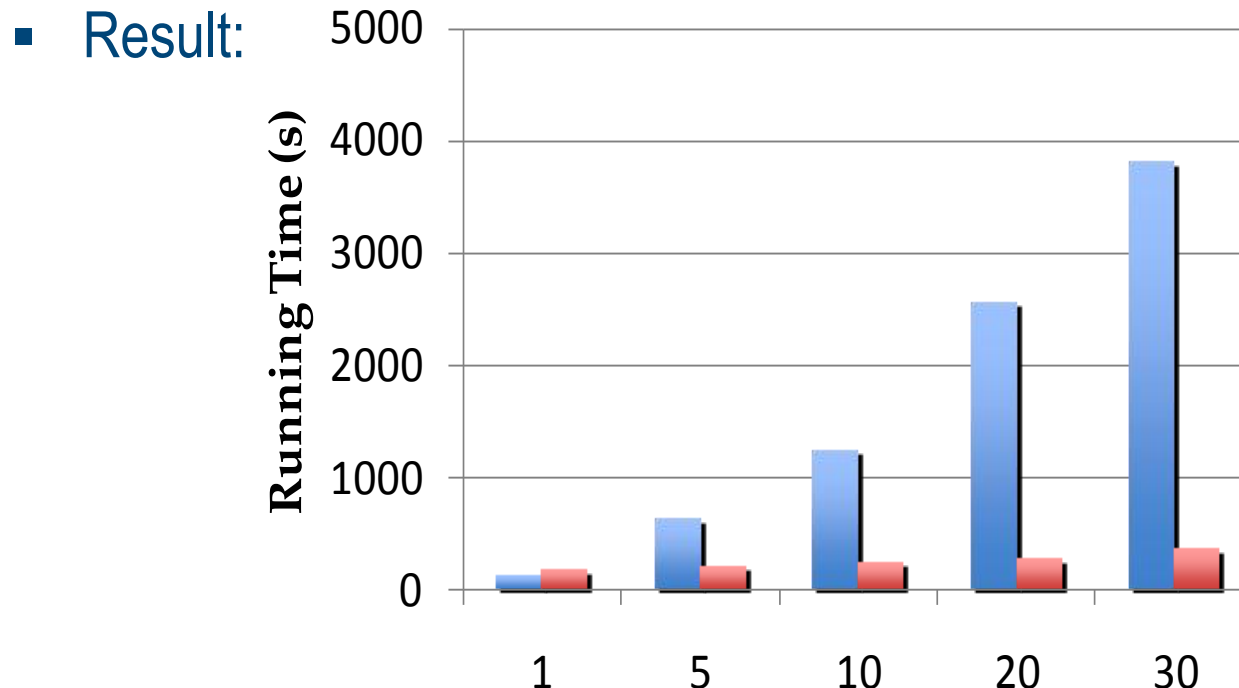
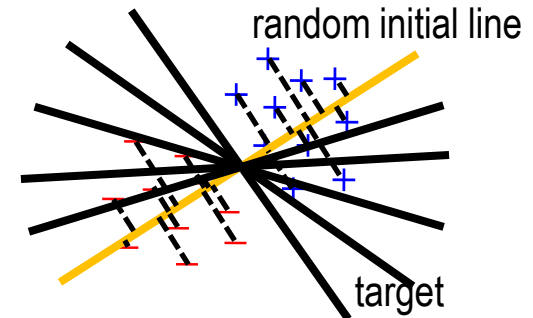
# Spark: improving Hadoop

- After initial Hadoop hype, shortcomings perceived
  - Difficulty of use, efficiency, tool integration, ...
- Spark = cluster-computing framework by Berkeley AMPLab
  - Now Apache
- MapReduce, but:
  - Disk-based comm → **in-memory** comm
  - Java → Scala
  - Resilient Distributed Datasets (RDDs)
    - Objects split **across cluster**
    - Remember sequence of transformations → can **recompute** on failure
- *Data processing, **not** management*



# Ex: Logistic Regression Performance

- Find best line separating two sets of points
- 29 GB dataset
- 20x EC2 m1.xlarge 4-core machines



127 s / iteration

127 s / iteration

first iteration 174 s  
further iterations 6 s

# Conclusion

- MapReduce = **specialized** (synchronous) distributed processing paradigm
  - Optimized for horizontal scaling in commodity clusters (!), fault tolerance
  - Efficiency? Hardware, energy, ... (see [\[0\]](#), [\[1\]](#), [\[2\]](#), [\[3\]](#) etc.)
    - “Adding more compute servers did not yield significant improvement” [\[src\]](#)
  - Well suited for sets, less so for highly connected data (graphs, arrays)
  - Need to **rewrite algorithms**
- Apache **Hadoop** = MapReduce implementation (HDFS, Java)
- Apache **Spark** = improved MapReduce implementation (HDFS, DSS, Scala)
- **Query languages** on top of MapReduce
  - HLQLs: Pig, Hive, JAQL, ASSET, ...