Introduction to Data Science with Hadoop

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May 2017

Short and Sweet
Hadoop
What About Spark?
Machine Learning
The Future

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Data Science is …

- gathering data,
  potentially of many types and from many sources,
- wrangling that data into useful forms,
  and
- applying statistical programming and machine learning,
  to gain new information from the data.

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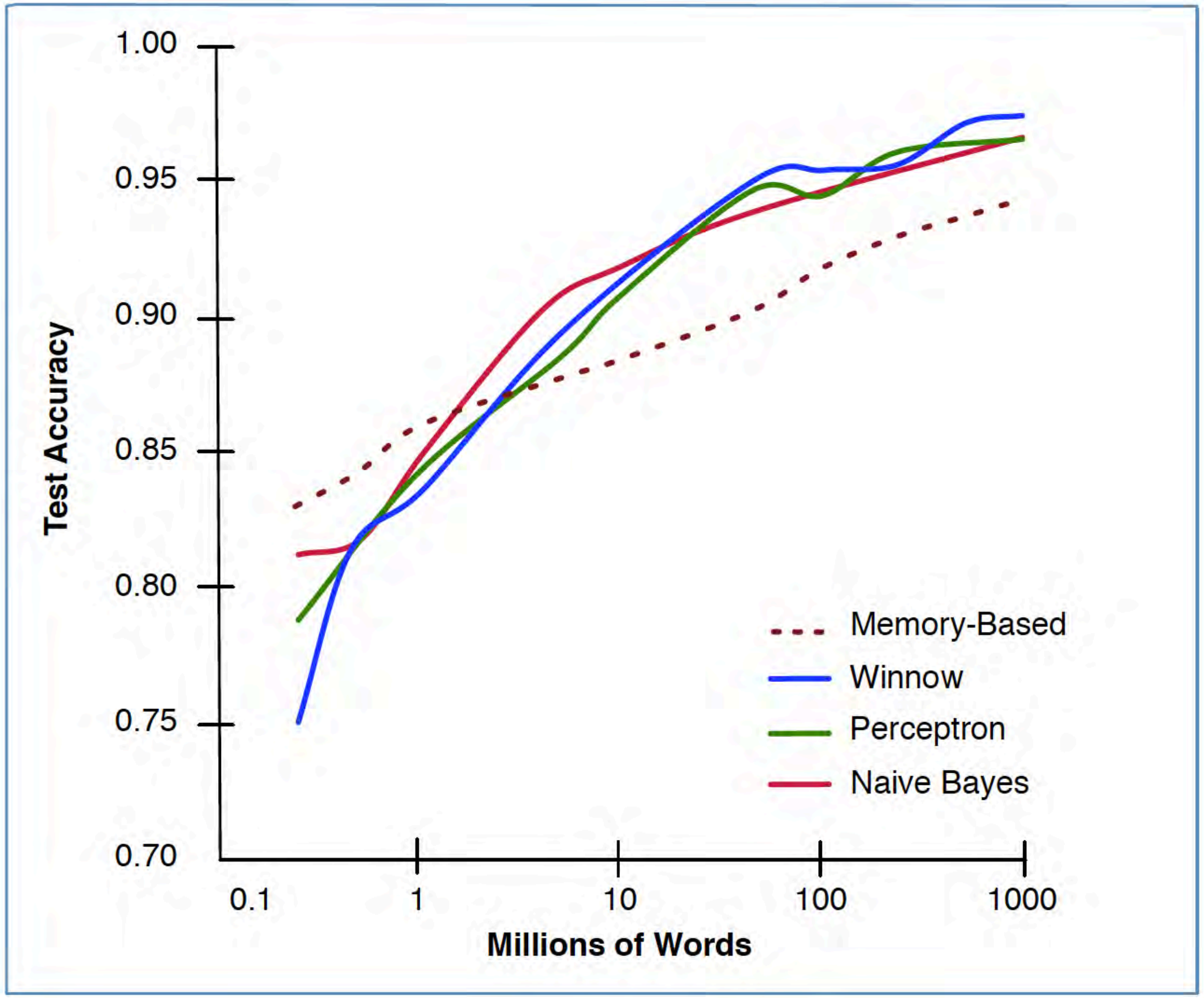
Machine Learning and Data Volume



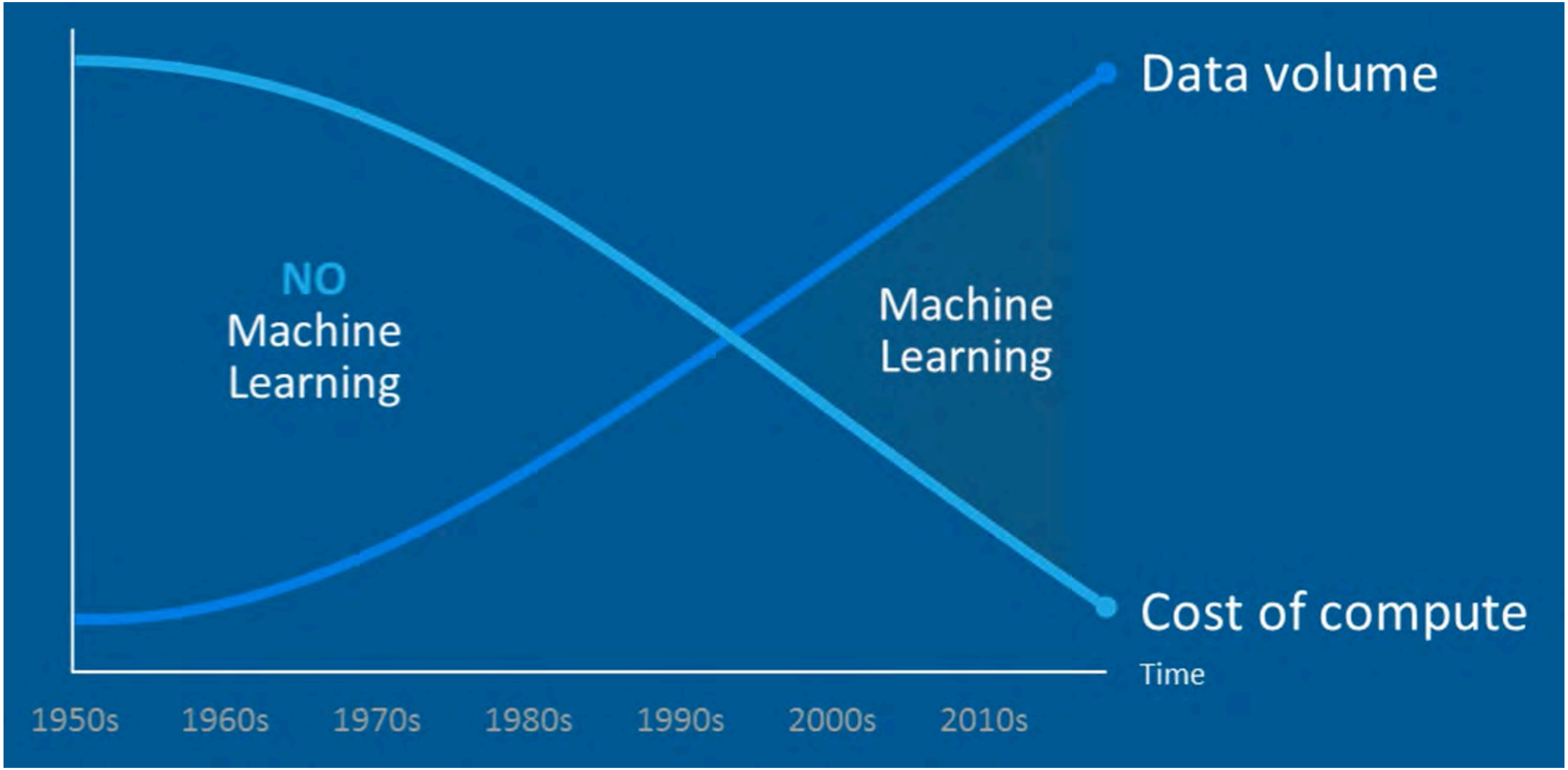
"It's not who has the best algorithms who wins. It's who has the most data."

[Banko and Brill, 2001]

Hadoop is …

- an open source software platform for
- acquiring, storing, and processing massive volumes of data,
- economically.

The Age of Machine Learning



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The word “Hadoop” means

- a child’s toy

  or
- Hadoop Core

  or
- the Hadoop Ecosystem.

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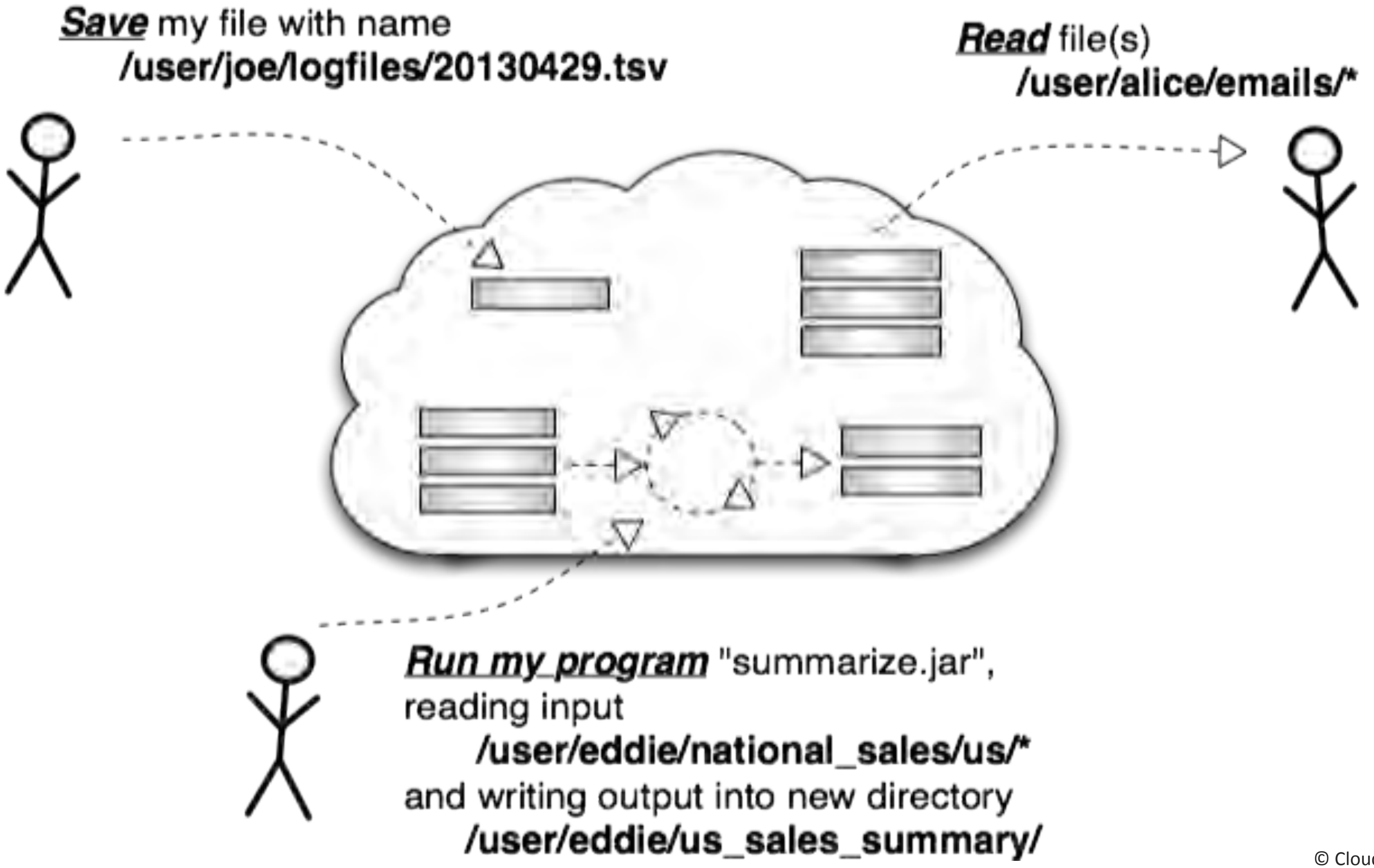
Hadoop Core

hadoop.apache.org

- A free open source software software project
- Managed transparently online, at the Apache Software Foundation (ASF), apache.org
- The project was started in 2006, based on papers from Google, in 2003 and 2004

- Consists of:
  - HDFS (Hadoop Distributed File System), for storage
  - Hadoop MapReduce, for processing
  - YARN (Yet Another Resource Negotiator)

Hadoop Core main features: File storage and batch programming



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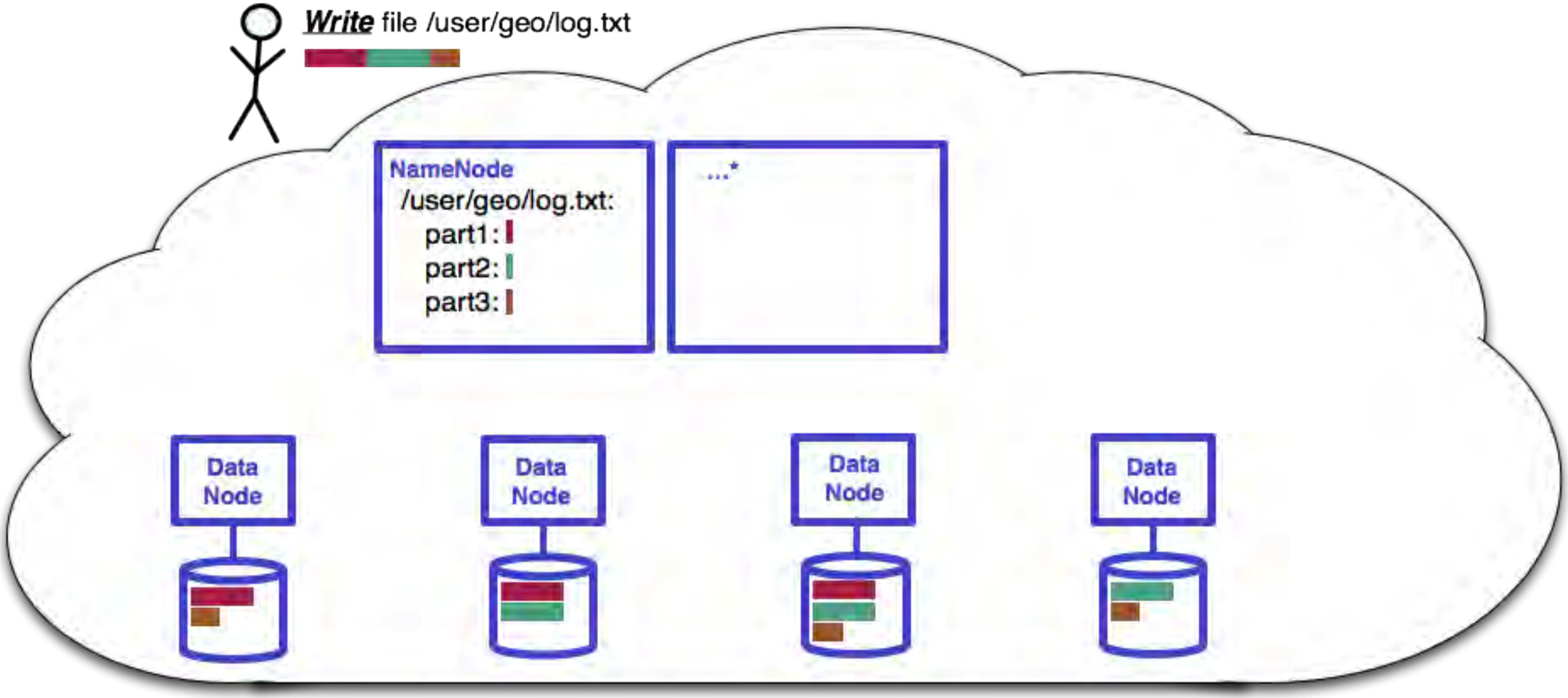
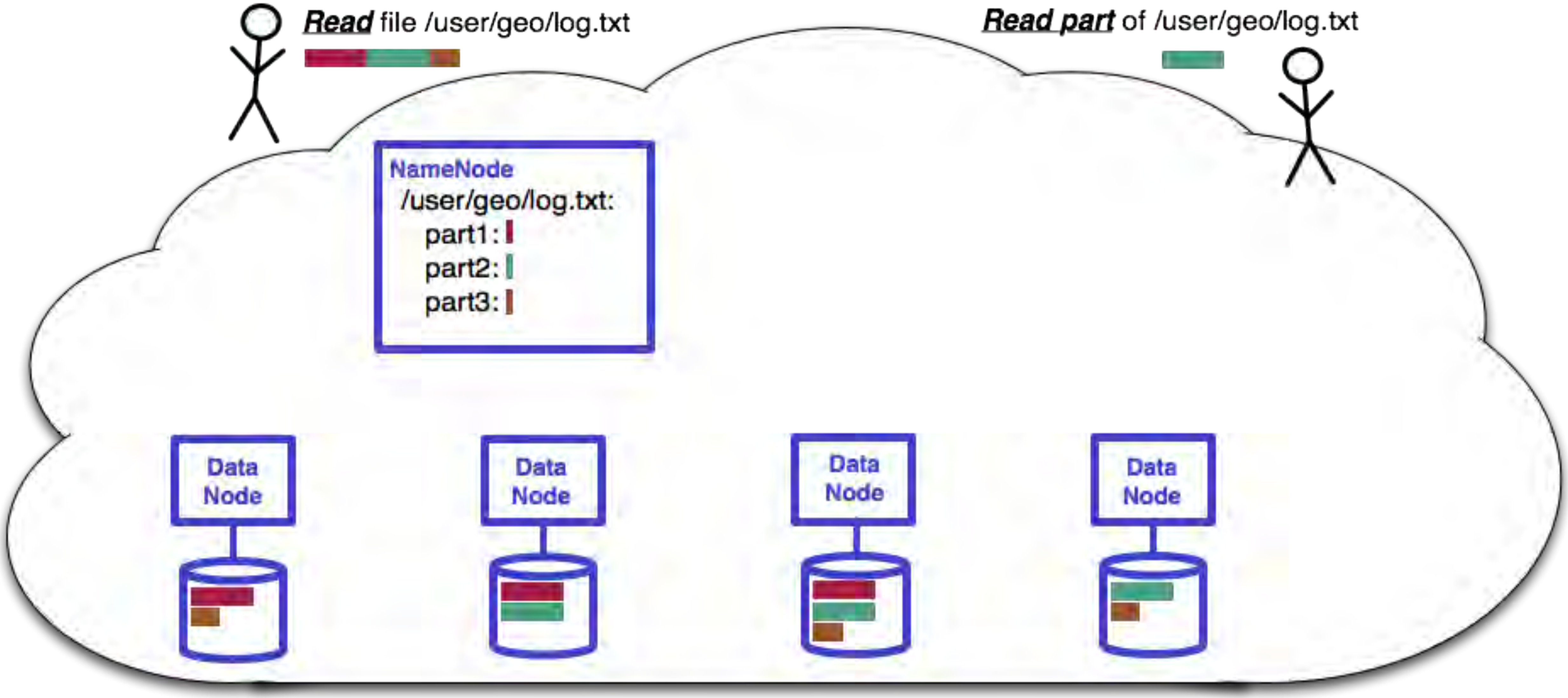
HDFS Writes



Write file /user/geo/log.txt
NameNode
/user/geo/log.txt:
part1 :
part2:
part3:
...*
Data Node
Data Node
Data Node
Data Node

HDFS Reads



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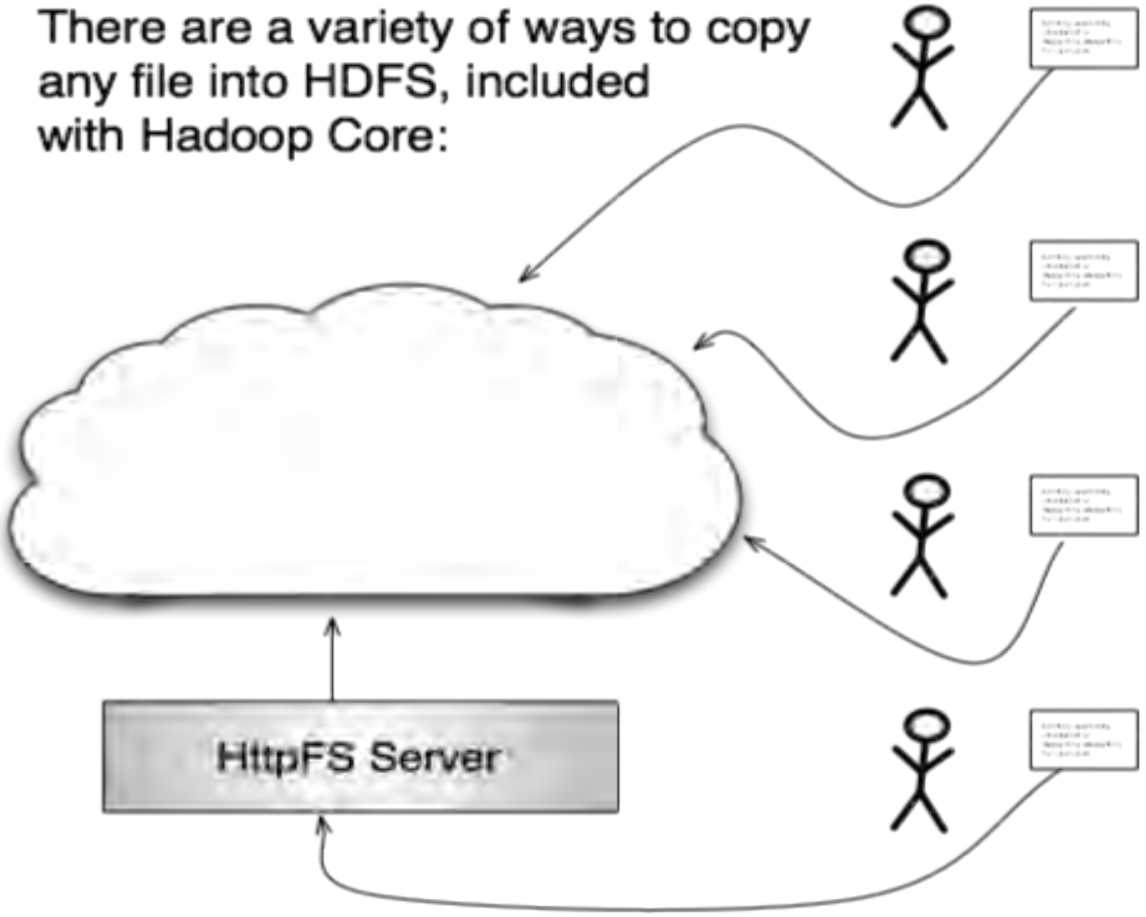
General File Input/Output

There are a variety of ways to copy any file into HDFS, included with Hadoop Core:



Single line command:

```
hadoop fs
  -put myfile hadfile
```

FUSE

```
cp myfile /hdfs/hadfile
```

Java program using HDFS API

HttpFS

```
curl "http://host:14...
```

Each of these has a complement for copying a file from HDFS

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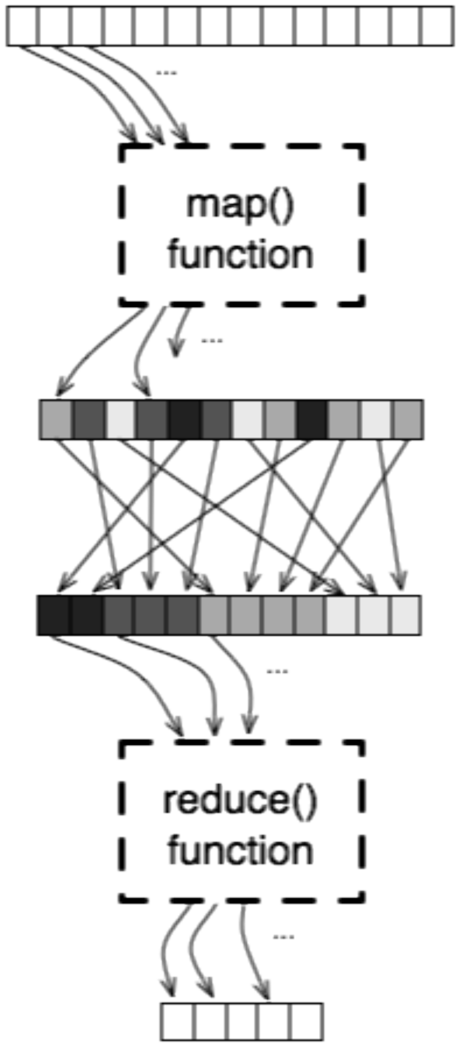
HDFS Strengths and Weaknesses

- HDFS is good at:
  - storing enormous files
  - storing lots of data reliably
  - throughput on sequential writes
  - throughput on sequential reads of a file or part of a file
- HDFS is not good at:
  - high speed (low latency) random reads of parts of a file
- HDFS cannot:
  - update any part of a file once written*

  * but you can always write a new file and/or delete, move, and rename files and directories

MapReduce: Programming with simple functions



Input records

Map function takes one input record, returns 0 or more intermediate records

Intermediate records must be of the form (key, value)

Shuffle sorts records by key

Reduce function takes records of one key, returns 0 or more output records

Output records

MapReduce Example: Word Count

Count the number of occurrences of each word over a large amount of input data

- This is the 'hello world' of MapReduce programming

```
map(String input_key, String input_value)
    foreach word w in input_value:
        emit(w, 1)
```

```
reduce(String output_key,
                    Iterator<int> intermediate_vals)
    set count = 0
    foreach v in intermediate_vals:
        count += v
    emit(output_key, count)
```

Word Count, continued

Input to the Mapper:

```
(3414, 'the cat sat on the mat')
(3437, 'the aardvark sat on the sofa')
```

Output from the Mapper:

```
('the', 1), ('cat', 1), ('sat', 1), ('on', 1),
('the', 1), ('mat', 1), ('the', 1), ('aardvark', 1),
('sat', 1), ('on', 1), ('the', 1), ('sofa', 1)
```

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Word Count, continued

Intermediate data sent to the Reducer:

```
('aardvark', [1])
('cat', [1])
('mat', [1])
('on', [1, 1])
('sat', [1, 1])
('sofa', [1])
('the', [1, 1, 1, 1])
```

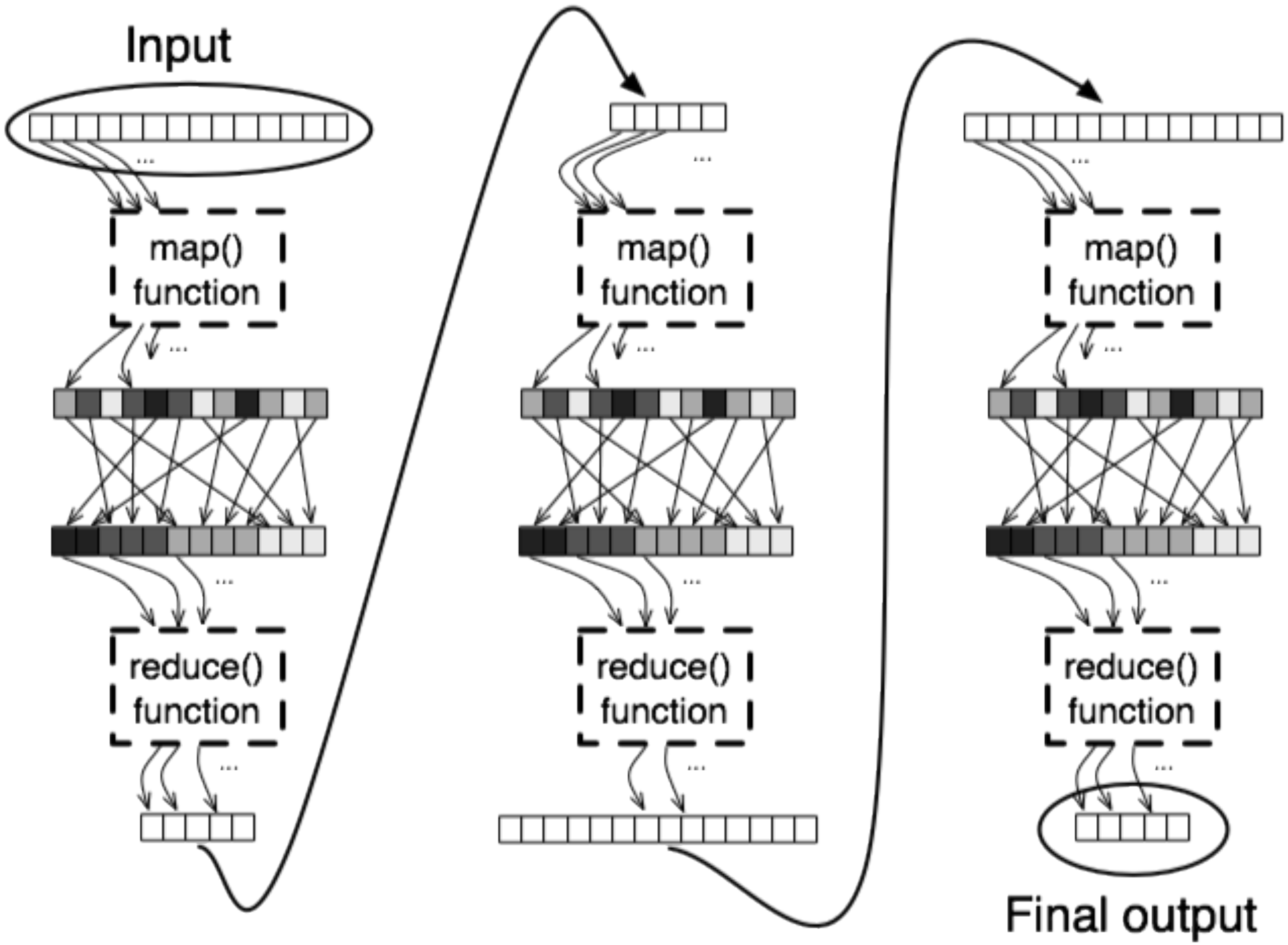
Final Reducer output:

```
('aardvark', 1)
('cat', 1)
('mat', 1)
('on', 2)
('sat', 2)
('sofa', 1)
('the', 4)
```

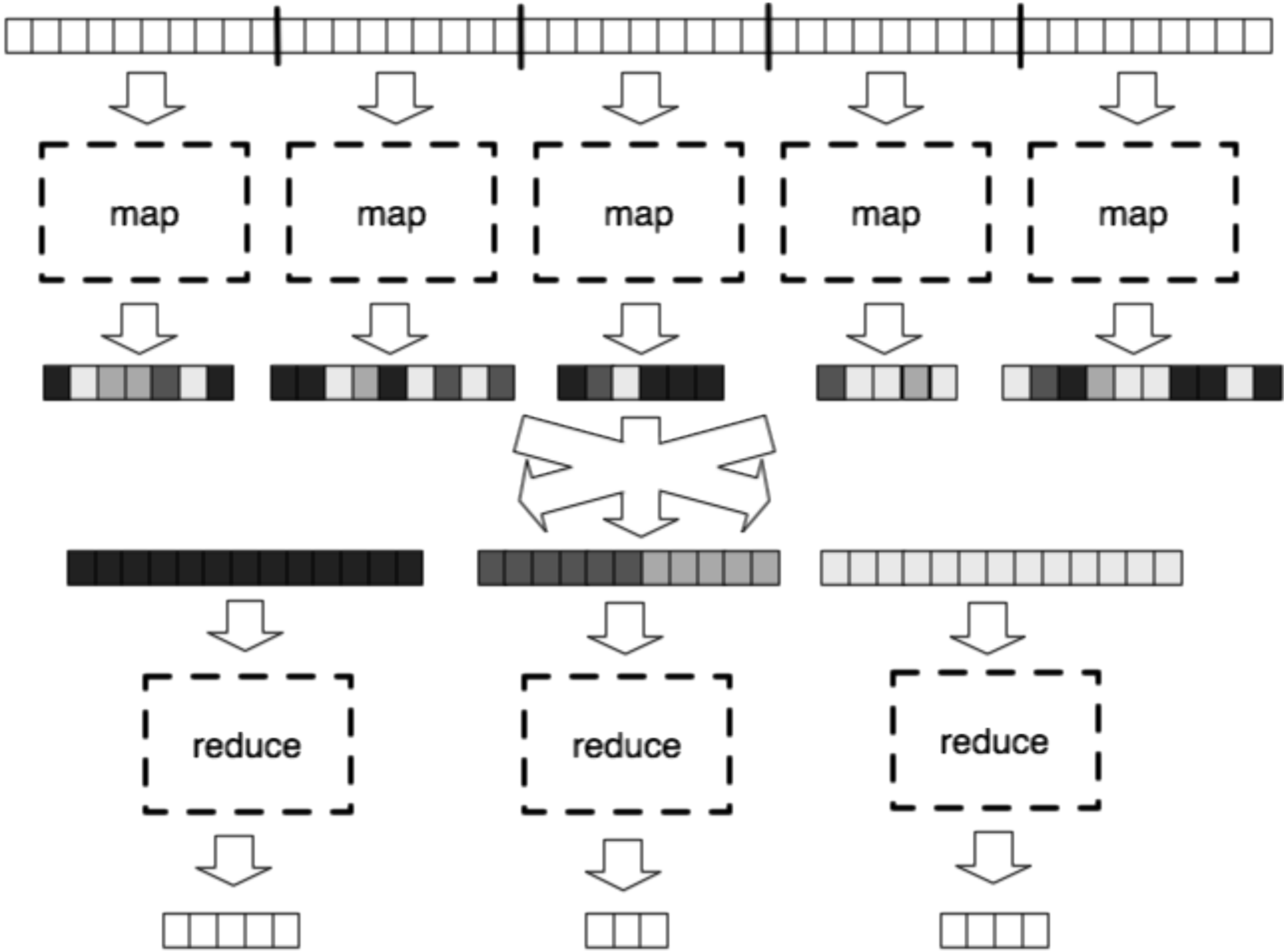
So we just counted words. So what?

- Many problems conform to this pattern:
  - Web log analysis: map() emits an IP address for each web log event; reduce() counts occurrences for each IP address
  - Indexing: For each document, map() emits each term of interest paired with the document ID; reduce() collects and emits all document IDs for each term
  - Page rank algorithm:
    - Every web page (URL) on the Web gets an initial score.
    - map() divides a page's score among all of its outlinks' URLs; reduce() sums the received scores for each URL.
    - Iterate on this procedure.

MapReduce Chains



MapReduce at Scale



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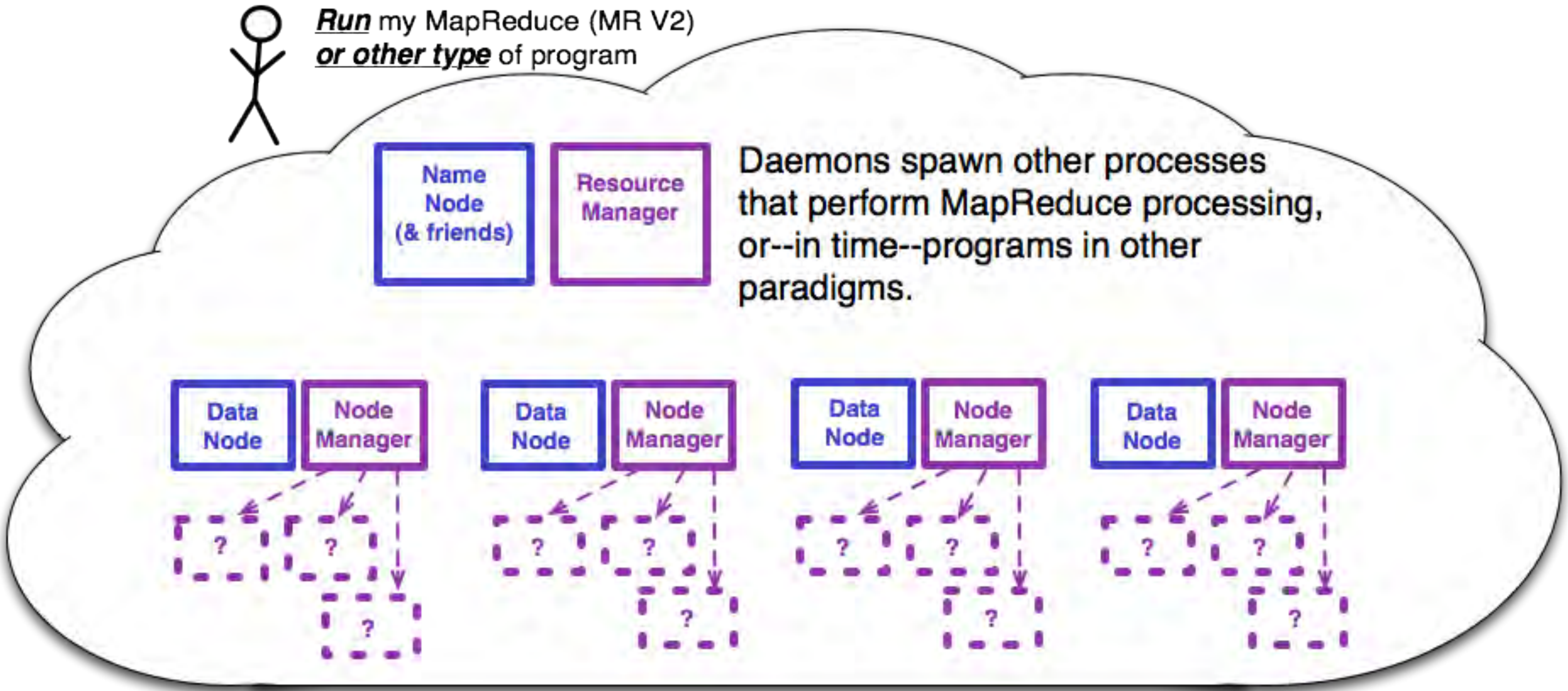
MapReduce Strengths and Weaknesses

- MapReduce is good at:
  - processing enormous volumes of data
  - scaling out as you add more machines
  - continuing to completion, even when some machines die
- MapReduce is not good at:
  - running any algorithm you can write in pseudocode
  - algorithms that require shared state overall*

    * but maybe you can get clever with your algorithm design
- MapReduce cannot:
  - run in real time: MapReduce jobs are batch jobs

YARN, Yet Another Resource Negotiator



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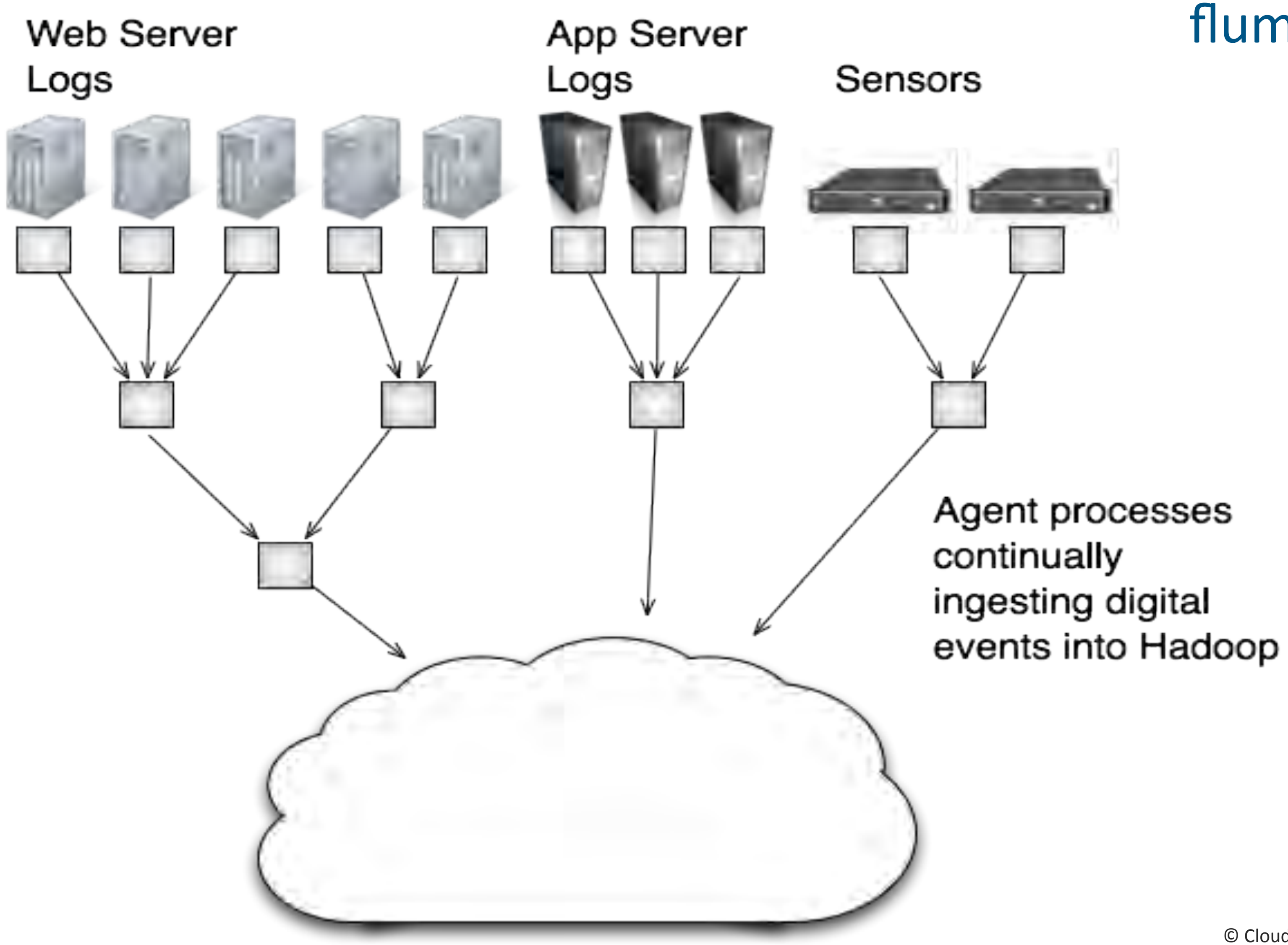
Sqoop: RDBMS to Hadoop and Back

sqoop.apache.org

- Uses MapReduce to run concurrent database queries that extract or insert data

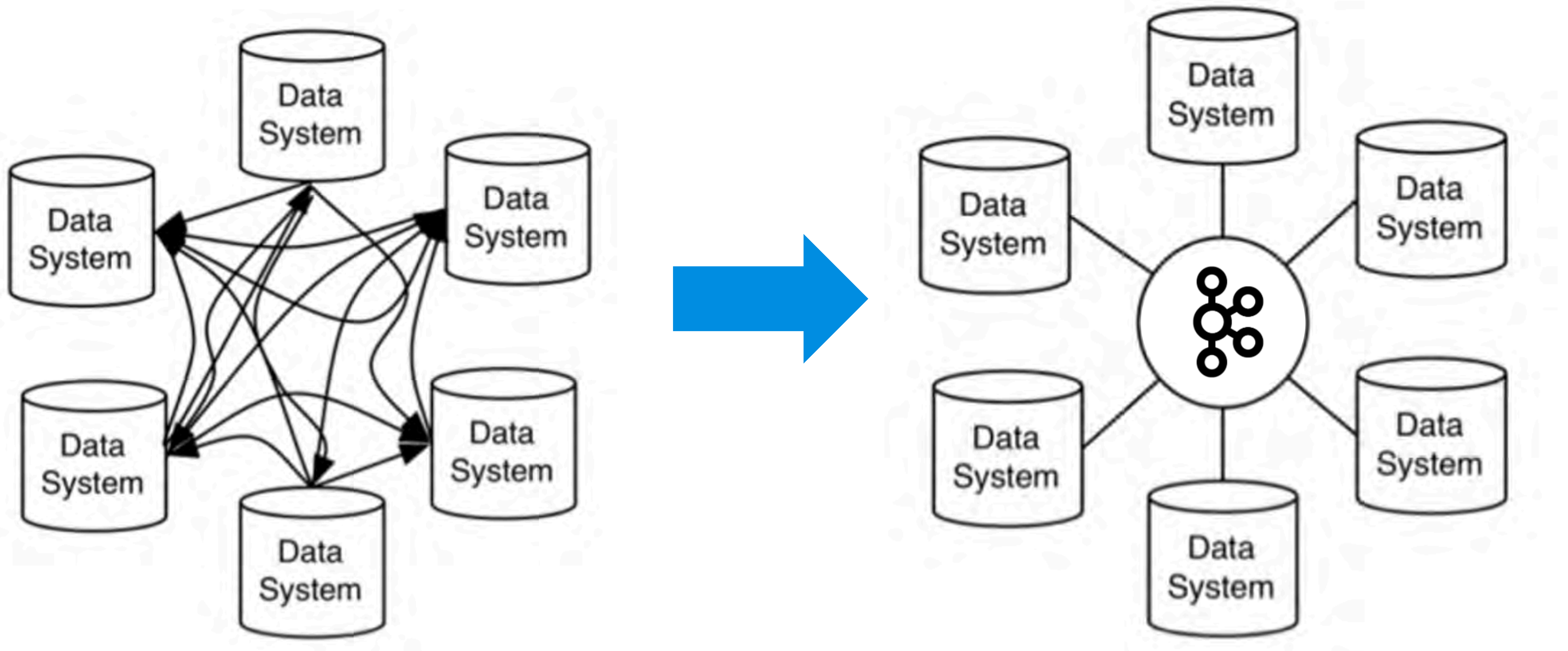
Flume: Ingesting Ongoing Event Data

flume.apache.org



Kafka: General Data Streaming

kafka.apache.org



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HBase: A NoSQL Database System

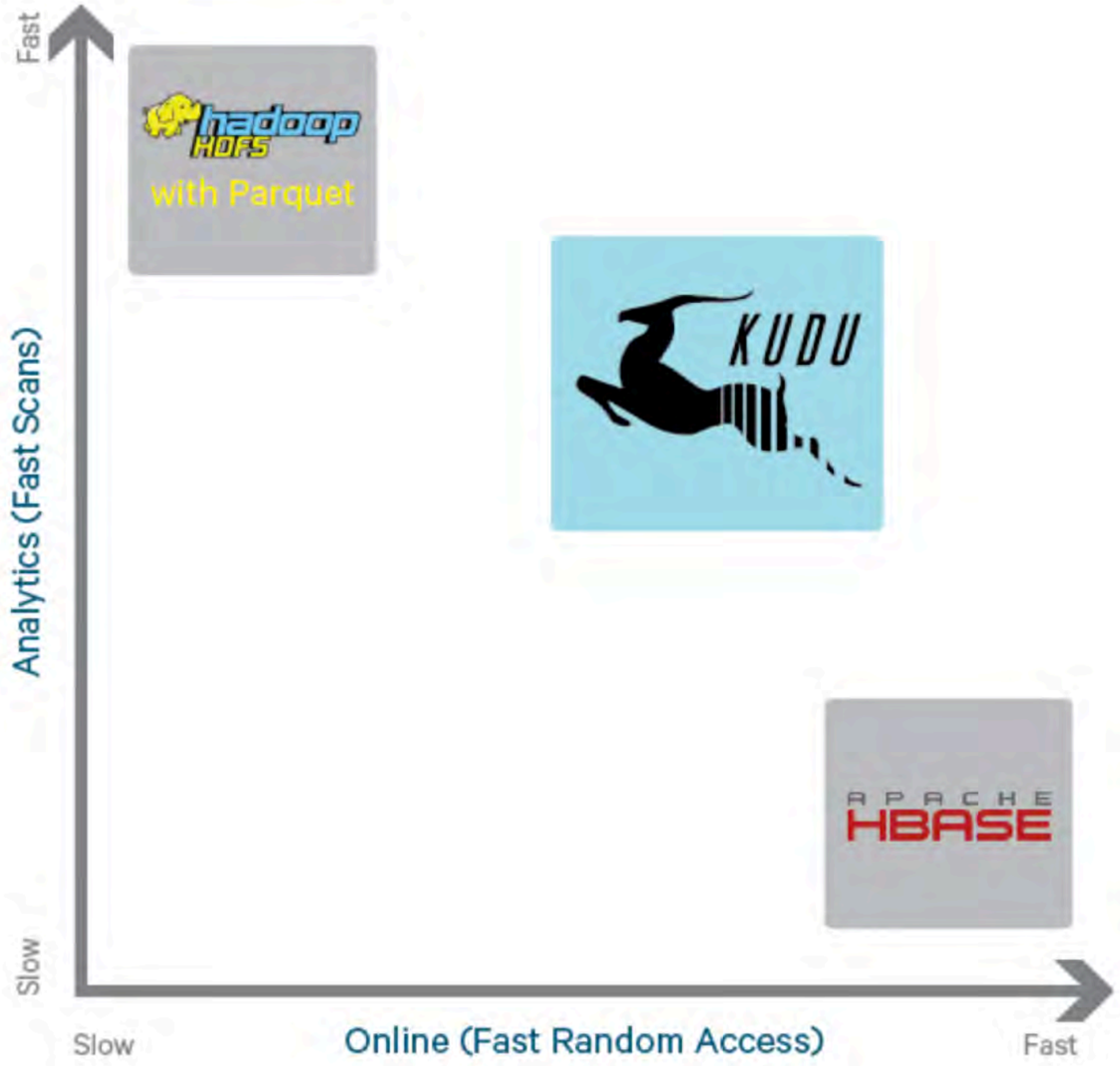
APACHE HBASE

hbase.apache.org

- A scalable key/value store
- Accommodates general binary data
- High volume, high performance access to individual items
- Random reads and writes
- Weaker query language than SQL (put, get, scan, delete)
- Lacks ACID-compliant transactions

Kudu: Scalable storage for structured data

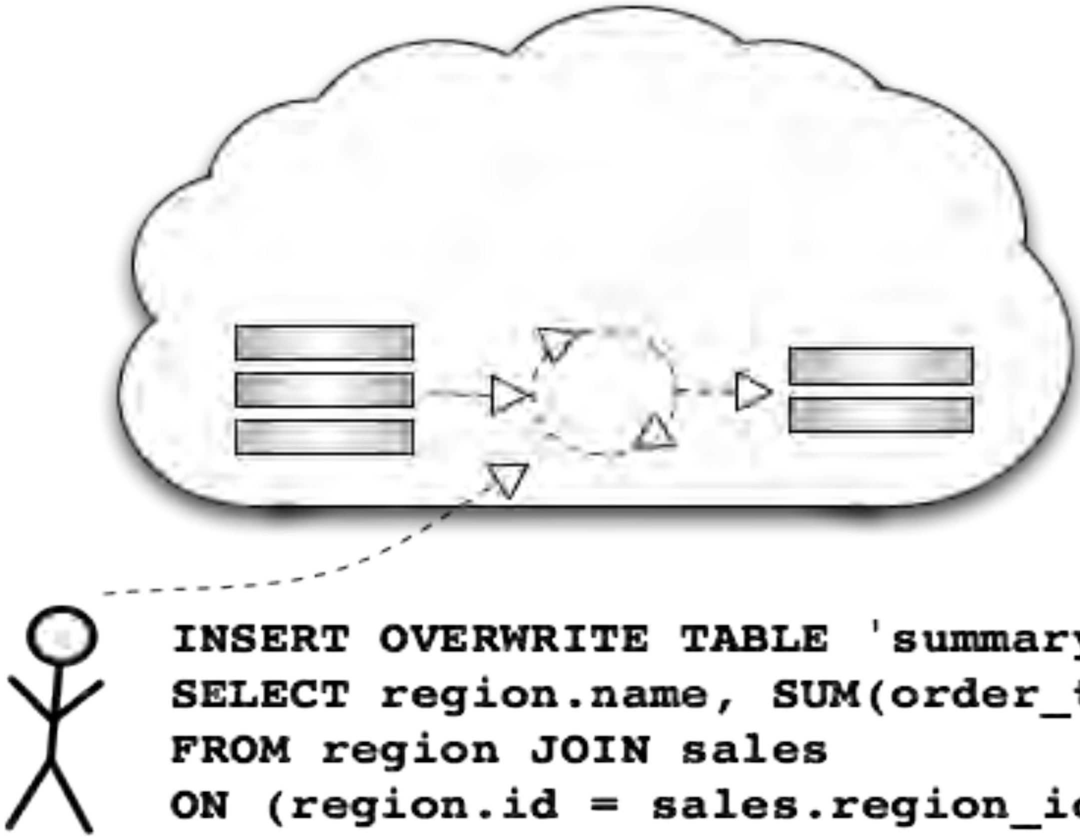
kudu.apache.org



Hive: MapReduce (or Spark) as “SQL”

hive.apache.org

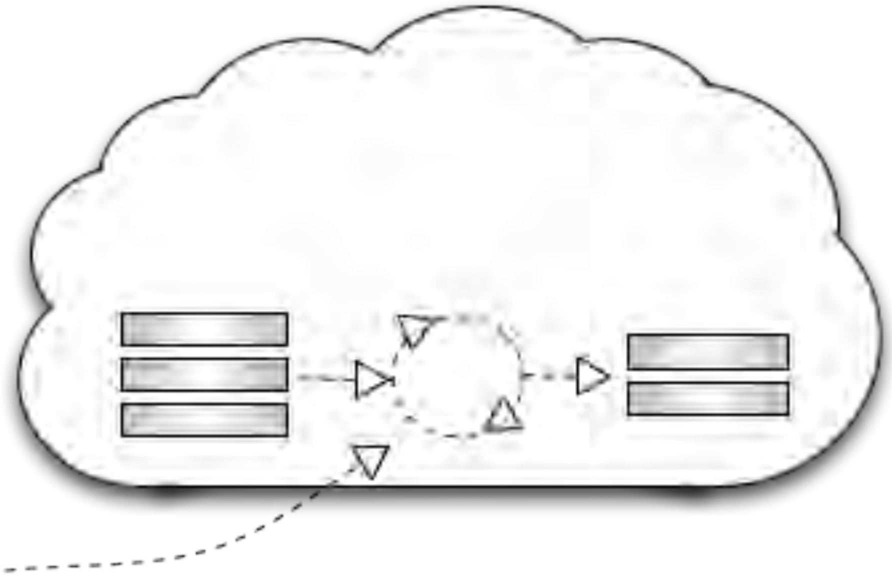
- Familiar language and programming paradigm
- Provides interface to many SQL-compliant tools



```
INSERT OVERWRITE TABLE 'summary'
SELECT region.name, SUM(order_total) region_sales
FROM region JOIN sales
ON (region.id = sales.region_id)
WHERE sales.sale_date > "20121231"
GROUP BY region.name
ORDER BY region_sales DESC;
```

Pig: Another Language for MapReduce (or Spark)

pig.apache.org



```
sales = LOAD 'sales' AS (orderId:INT, customerName:CHARARRAY,
  sale_date:INT, regionId:INT, orderTotal:FLOAT);
thisYearSales = FILTER sales BY sale_date > 20121231
region = LOAD 'region' AS (id:INT, name:CHARARRAY);
joined = JOIN region BY id, thisYearSales BY regionId;
grouped = GROUP joined BY region:id, region:name;
summary = FOREACH grouped GENERATE group.region:id,
  SUM(joined.orderTotal);
STORE summary INTO 'summary';
```

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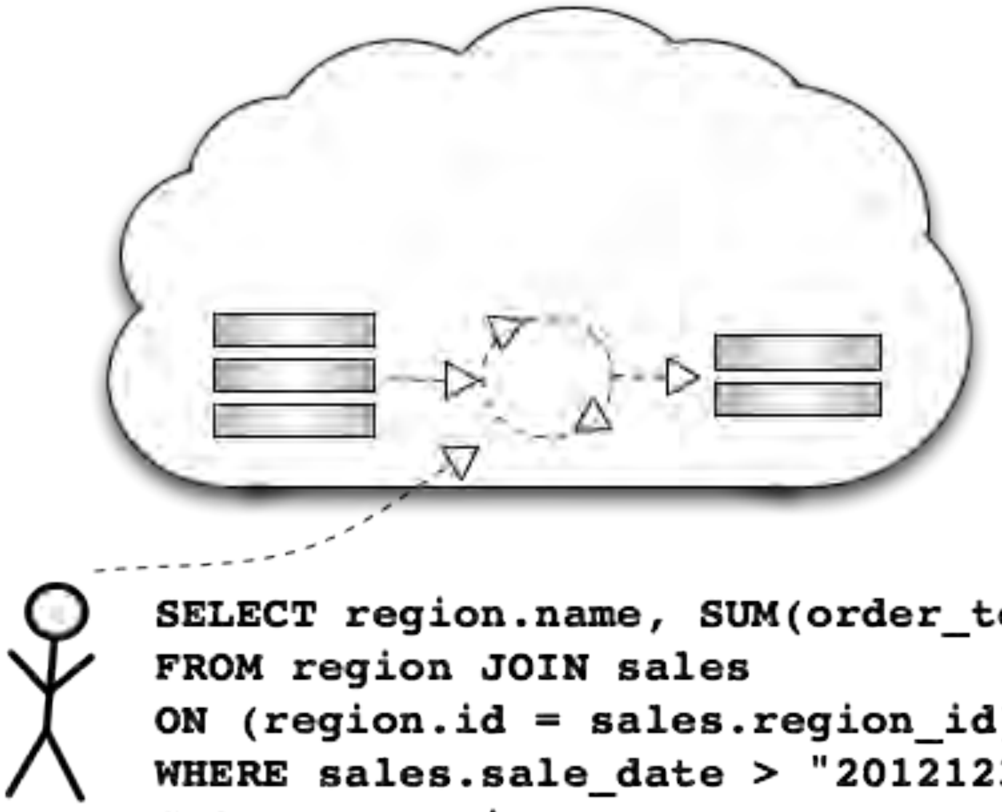
Impala: High Speed Analytics in Hadoop

incubator.apache.org/projects/impala.html

- Purpose-built for high speed analytic queries
- Does not use MapReduce or Spark
- Usually 5 to 30 times faster—sometimes 100 times faster!



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FROM region JOIN sales
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GROUP BY region.name
ORDER BY region_sales DESC;
```

And More

- Serialization and efficient file storage: Avro and Parquet

avro.apache.org

parquet.apache.org

- Workflow: Oozie

oozie.apache.org

And Even More…

- Security: Sentry and Record Service

sentry.apache.org

recordservice.io

- Machine Learning in MapReduce: Mahout

mahout.apache.org

- And …

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Spark: An Improvement on MapReduce

spark.apache.org

- Originally a research project at UC Berkeley RAD Lab—later the AMPLab, in 2009
- Addresses some fundamental pain points of MapReduce
- The Spark Streaming subproject of 2012 adds near real-time programming
    - using “micro-batches” as an adaptation of batch programming
    - a capability altogether lacking in Hadoop MapReduce

Similarities of MapReduce and Spark

- Processes massive volumes of data with a scale-out, distributed framework
- The framework provides reliability, even in the face of machine failure
- Programming with stateless functions
- Relies on expensive shuffle to reorganize data for aggregation, joins, sorting
- Still lacks a shared state among all processes
- Can run under YARN to share processing resources

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Improved API

- First-class APIs in Scala, Java, Python and R
- Data-flow programming paradigm (like Pig)
- Interactive shell—
  great for exploratory work
- Improved support for structured data and
  SQL-like processing

```
sc.textFile(file) \
 .flatMap(lambda s: s.split()) \
 .map(lambda w: (w,1)) \
 .reduceByKey(lambda v1,v2: v1+v2)
 .saveAsTextFile(output)
```

```
public class WordCount {
 public static void main(String[] args) throws
  Job job = new Job();
  job.setJarByClass(WordCount.class);
  job.setJobName("Word Count");
  FileInputFormat.setInputPaths(job, new Path(args[0]));
  FileOutputFormat.setOutputPath(job, new Path(args[1]));
  job.setMapperClass(WordMapper.class);
  job.setReducerClass(SumReducer.class);
  job.setMapOutputKeyClass(Text.class);
  job.setMapOutputValueClass(IntWritable.class);
  job.setOutputKeyClass(Text.class);
  job.setOutputValueClass(IntWritable.class);
  boolean success = job.waitForCompletion(true);
  System.exit(success ? 0 : 1);
 }
}

public class WordMapper extends Mapper<LongWritable, Text, Text,
IntWritable> {
public void map(LongWritable key, Text value,
Context context) throws IOException, InterruptedException {
  String line = value.toString();
  for (String word : line.split("\\W+")) {
   if (word.length() > 0)
    context.write(new Text(word), new IntWritable(1));
   }
  }
 }
}

public class SumReducer extends Reducer<Text, IntWritable, Text,
IntWritable> {
 public void reduce(Text key, Iterable<IntWritable>
 values, Context context) throws IOException, InterruptedException {
  int wordCount = 0;
  for (IntWritable value : values) {
   wordCount += value.get();
  }
  context.write(key, new IntWritable(wordCount));
 }
}
```

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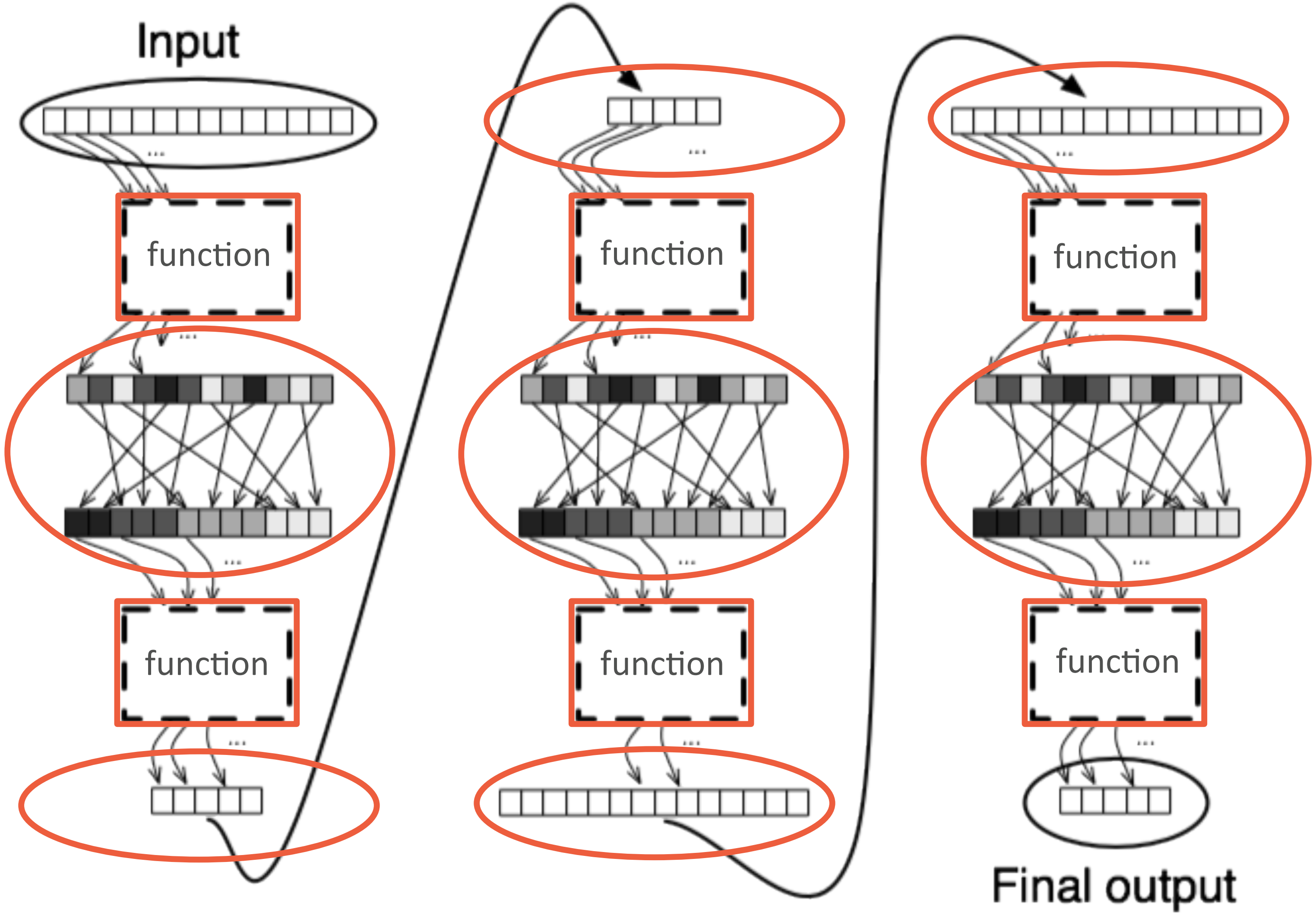
Processing Chains, Improved

Tasks, not new processes (JVMs)

Enhanced caching in memory



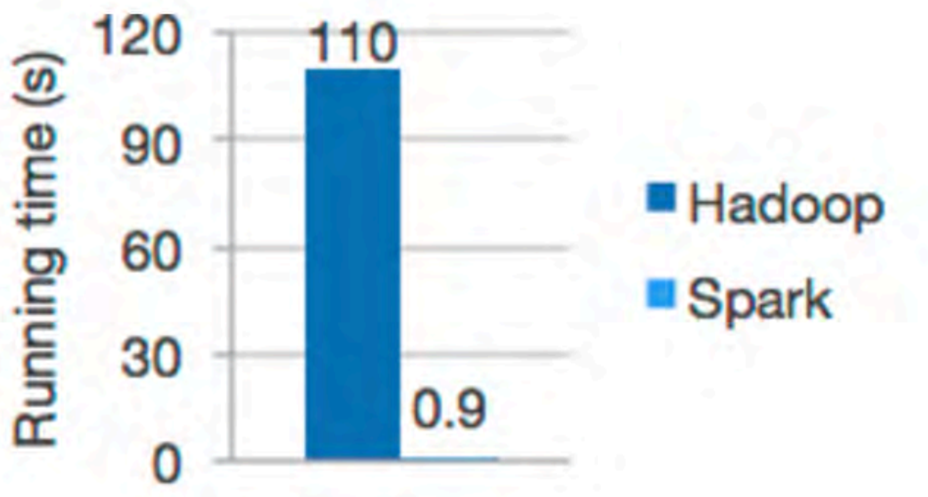
Eliminate I/O

Reduce I/O

Eliminate I/O

Spark MLlib: Machine Learning in Spark

- Subproject of Spark
- Effectively replaces Mahout for machine learning in Hadoop clusters
- From spark.apache.org, the front page:



Logistic regression in Hadoop and Spark

But just be clear what you mean by "Hadoop"!

Commercial Message # 1

Big Ecosystem

oozie.apache.org

Complete Big Data Platform

- Cloudera Manager can
  - install, monitor, manage, upgrade
    a coherent bundle of these projects and more
- Cloudera Director can
  - easily configure and deploy this platform on cloud services
    from Amazon, Google, or Microsoft
- !!!

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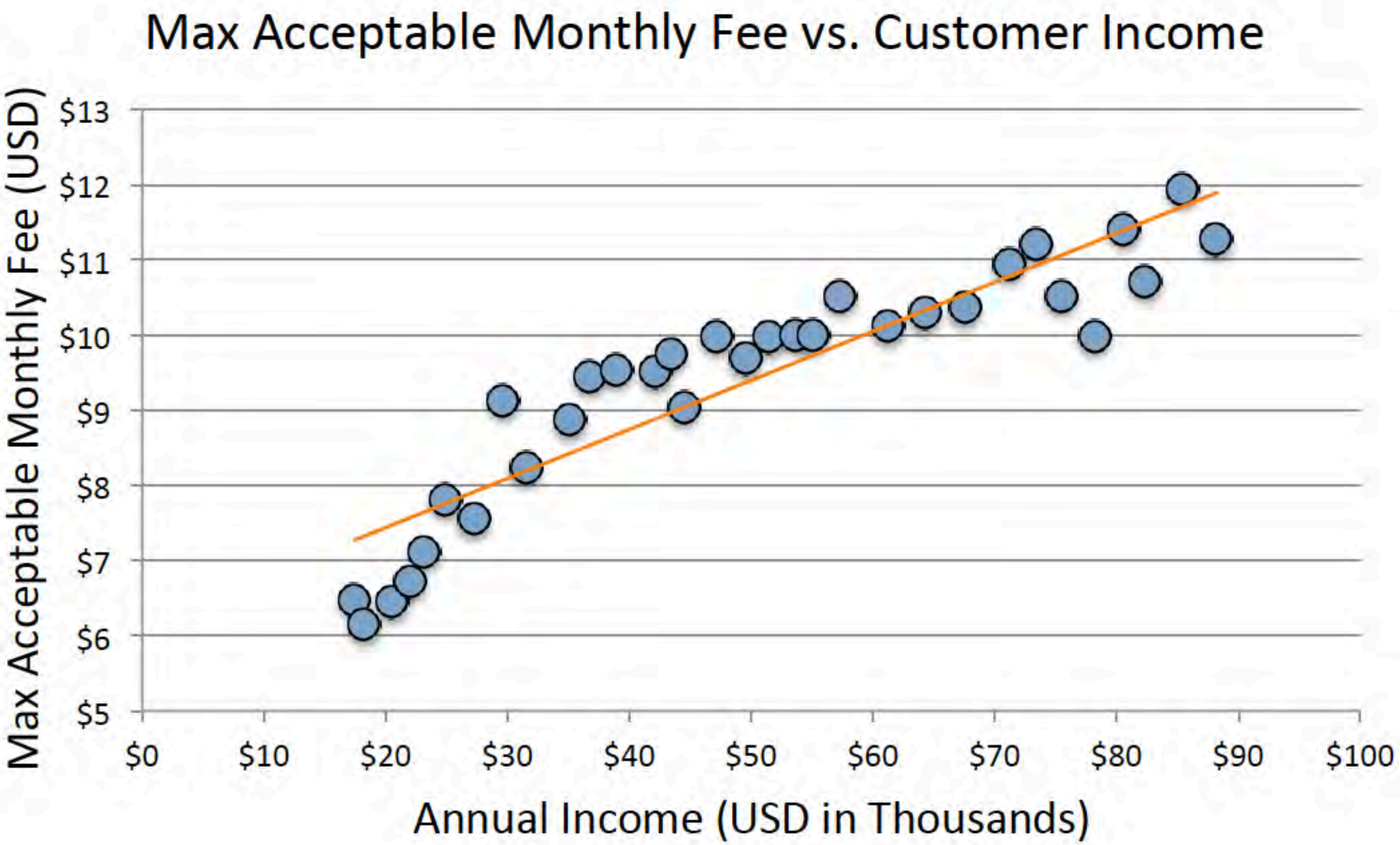
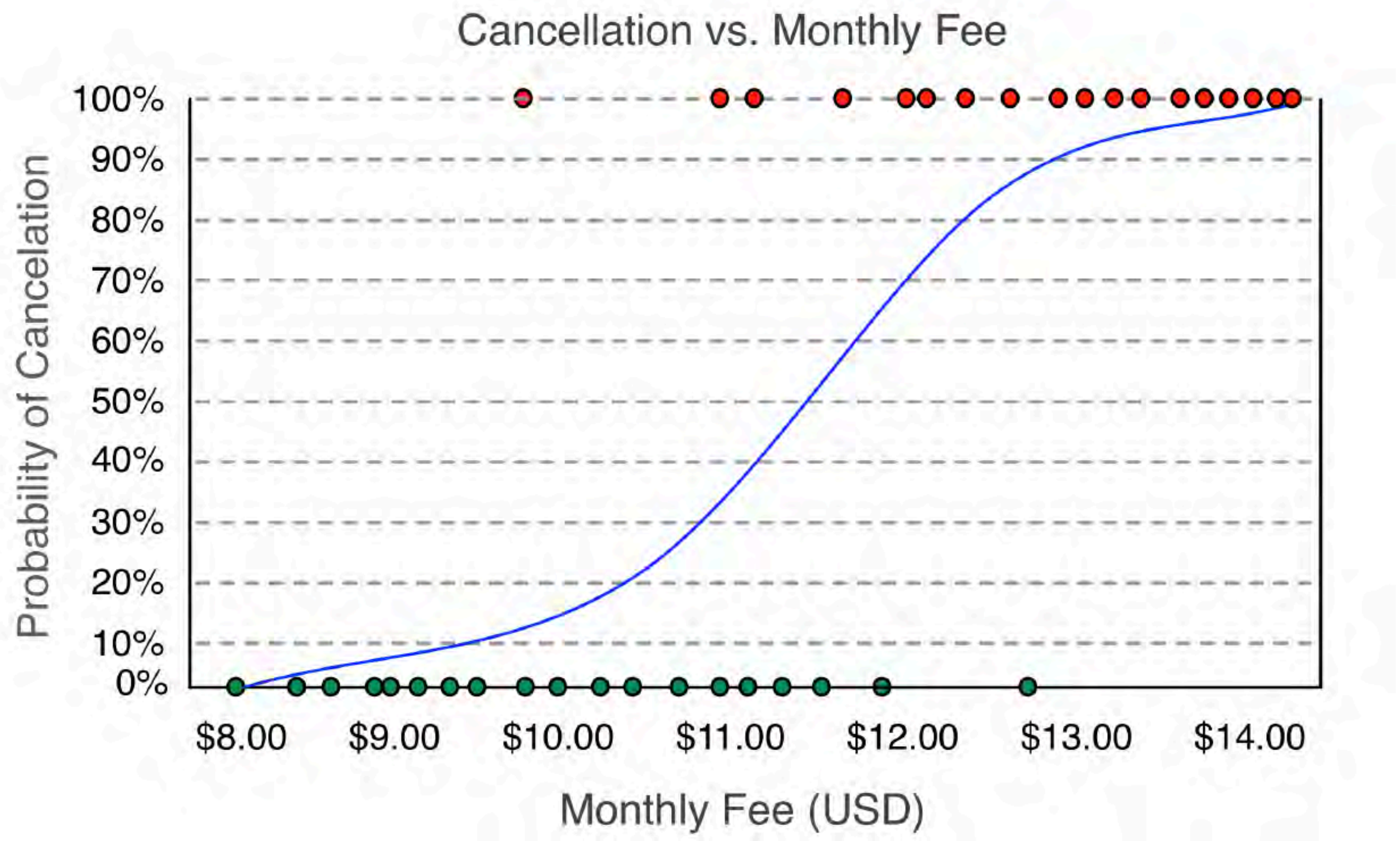
Machine Learning Algorithms

- Supervised Learning:
  - Start with correctly labeled records, and learn to estimate or predict labels for new records
  - Continuous labels: Regression
  - Discrete labels: Logistic Regression, Classifiers
- Unsupervised Learning:
  - Start with unlabeled records, try to tease patterns (labels) out of the data
  - There is not a single “correct” answer for labeling
  - Continuous labels: Collaborative Filters (Recommenders)
  - Discrete labels: Clustering

Linear Regression: Supervised Learning of a Continuous Label



Logistic Regression: Supervised Learning of a Binary Label



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Classifiers:
Supervised Learning of Discrete Labels

Training: Cat

Training: Table

Scoring: ???

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Collaborative Filters (Recommenders): Unsupervised Learning of Continuous Labels

	Alice	Bob	Chuck	Donna	Eddie	Frank	Gina
Airplane	1	4			5		
Bambi	4			5		2	
Caddyshack		4	3		4		5
Dracula			5			4	
Eat Pray Love		2		5	1		1
Friday		4					5
Gunsmoke						4	5
Hang 'Em High			5			4	5
Iron Man			3	1	4		5
Jane Eyre	5						
The Karate Kid	4		5	5	3		

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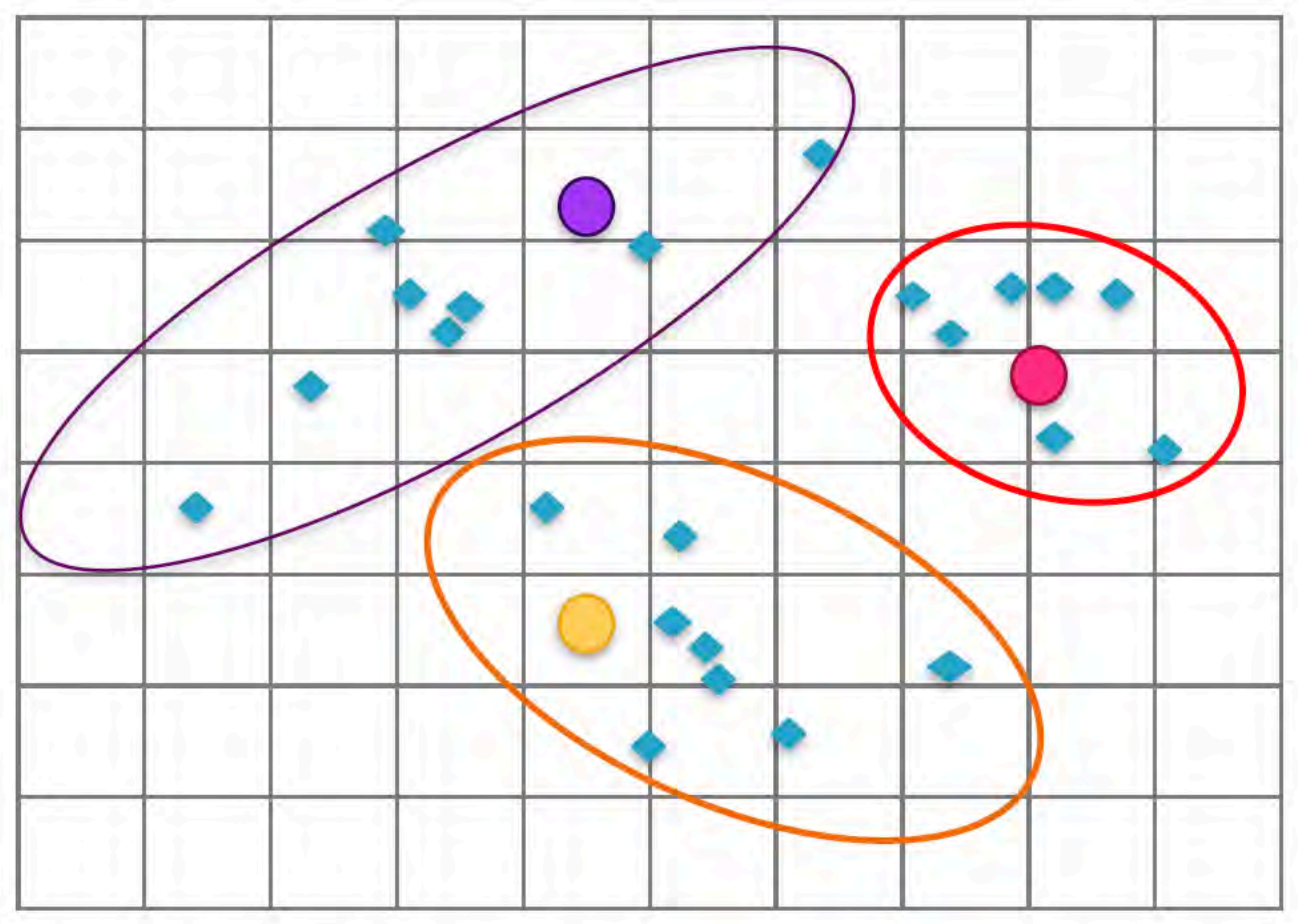
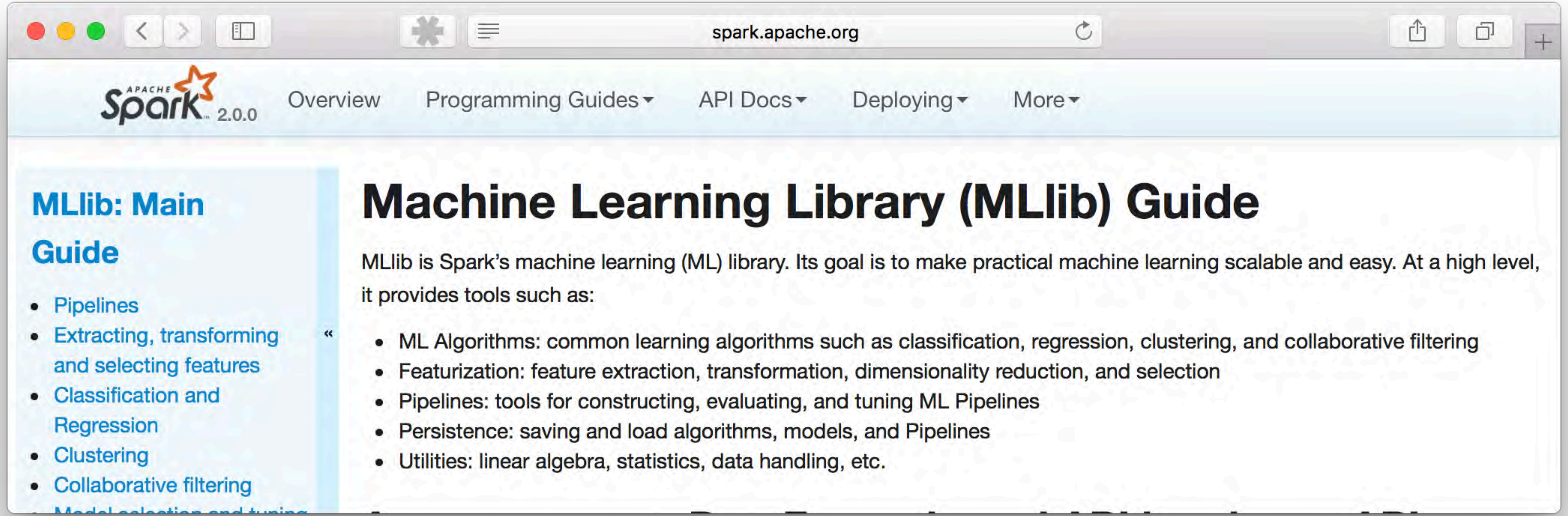
Clustering:
Unsupervised Learning of Discrete Labels



Spark MLlib: Machine Learning on Hadoop



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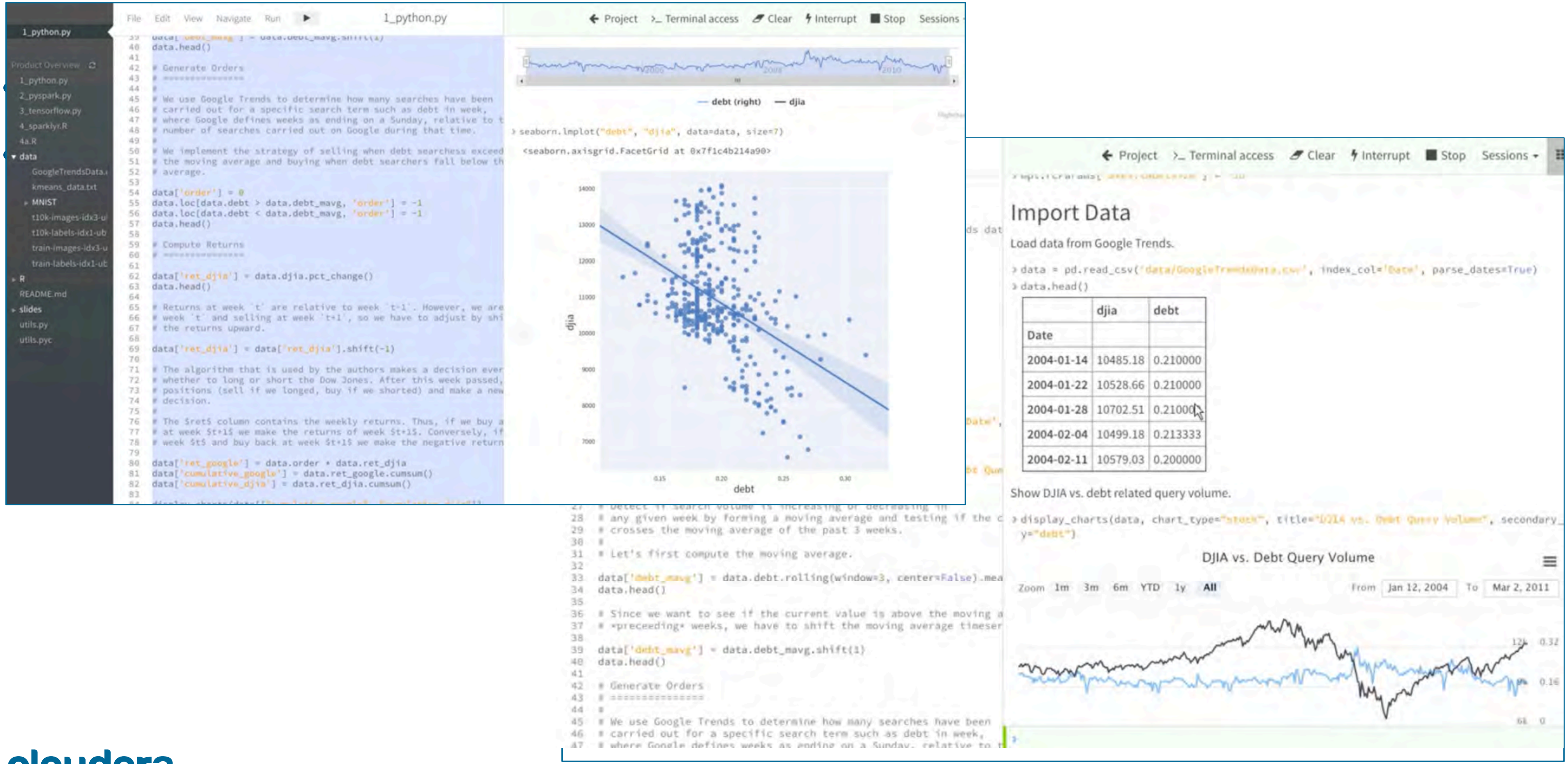
Commercial Message # 2

More DS Teams in the Organization

- Collaboration, repeatability within teams
- Differing security requirements
- Different preferred programing languages: Python, R, Scala
- Different software libraries: Pandas, H2O, etc.
- Even different versions of software

Cloudera Data Science Workbench



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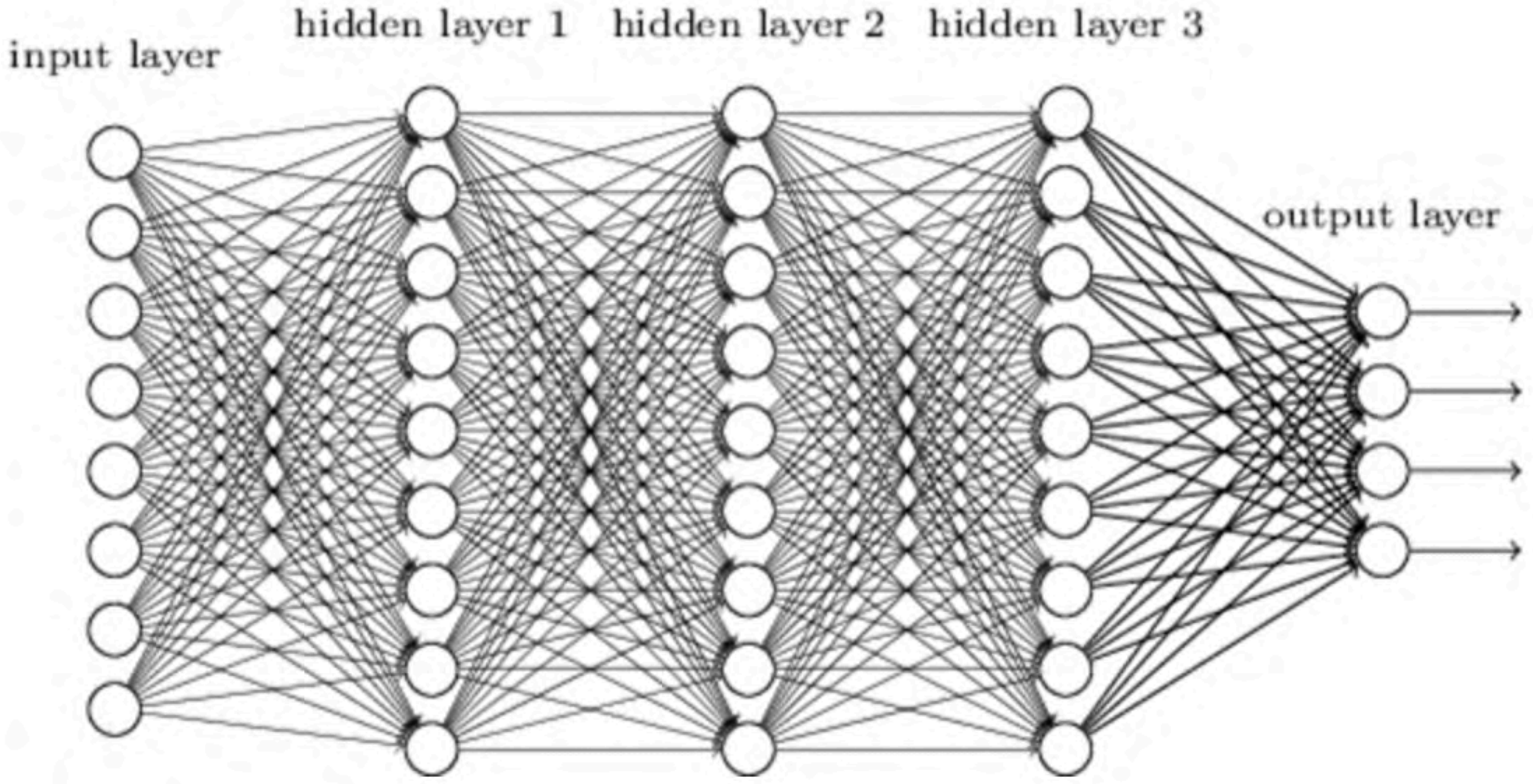
Deep Learning



Deep Learning on Hadoop

- Deep Learning refers to a category of classifier algorithms, mostly invented in 2006.
- Spark MLlib does not have any direct implementation of DL.
- There are several additional projects that can fit DL onto Spark/Hadoop:
  - BigDL
  - Caffe
  - TensorFlow
  - DL4J

The Road—or Runway(!)—Ahead

- It is a truism that organizations today have valuable insights hidden in their data that are waiting to be uncovered.
- 90% of all data that will exist in 2020 has yet to be created.
- Open source is here to stay.
- Hadoop as a data science platform is evolving, and its use is growing exponentially.

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Thank you

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