Distributed Computing with Spark and MapReduce

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Spark

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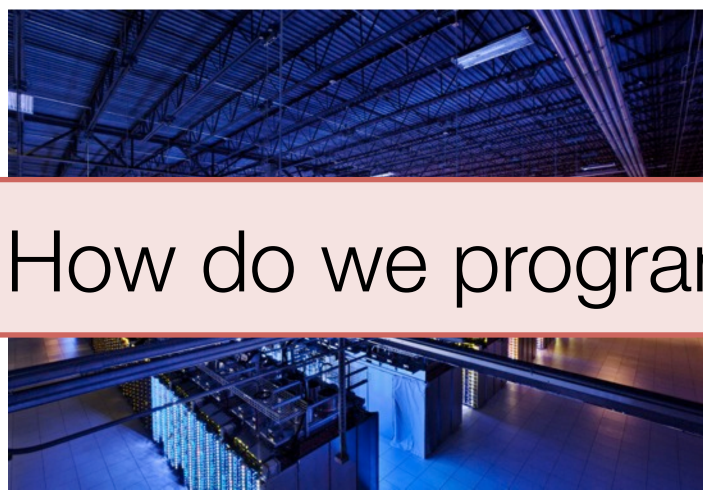
Problem

Data growing faster than processing speeds

Only solution is to parallelize on large clusters

» Wide use in both enterprises and web industry



How do we program these things?

Outline

Data flow vs. traditional network programming

Limitations of MapReduce

Spark computing engine

Current State of Spark Ecosystem

Built-in Libraries

Data flow vs. traditional network programming

Traditional Network Programming

Message-passing between nodes (e.g. MPI)

Very difficult to do at scale:

- » How to split problem across nodes?
  - Must consider network & data locality
- » How to deal with failures? (inevitable at scale)
- » Even worse: stragglers (node not failed, but slow)
- » Ethernet networking not fast
- » Have to write programs for each machine

Rarely used in commodity datacenters

Disk vs Memory

L1 cache reference:	0.5 ns
L2 cache reference:	7 ns
Mutex lock/unlock:	100 ns
Main memory reference:	100 ns
Disk seek:	10,000,000 ns

Network vs Local

Send 2K bytes over 1 Gbps network:	20,000 ns
Read 1 MB sequentially from memory:	250,000 ns
Round trip within same datacenter:	500,000 ns
Read 1 MB sequentially from network:	10,000,000 ns
Read 1 MB sequentially from disk:	30,000,000 ns
Send packet CA->Netherlands->CA:	150,000,000 ns

Data Flow Models

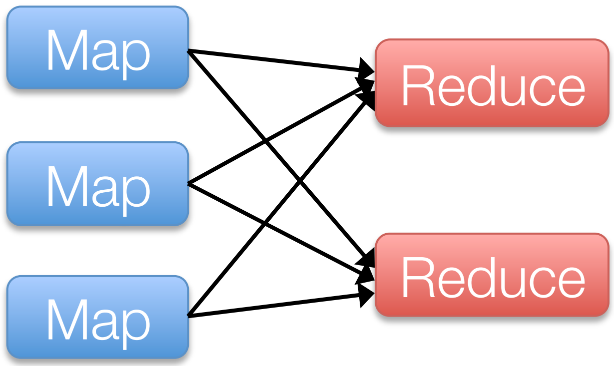
Restrict the programming interface so that the system can do more automatically

Express jobs as graphs of high-level operators

» System picks how to split each operator into tasks and where to run each task

» Run parts twice fault recovery

Biggest example: MapReduce



MapReduce + GFS

Most of early Google infrastructure, tremendously successful

Replicate disk content 3 times, sometimes 8

Rewrite algorithms for MapReduce

Diagram of typical cluster

http://insightdataengineering.com/blog/pipeline_map.html

Example MapReduce Algorithms

Matrix-vector multiplication

Power iteration (e.g. PageRank)

Gradient descent methods

Stochastic SVD

Tall skinny QR

Many others!

Why Use a Data Flow Engine?

Ease of programming

- » High-level functions instead of message passing

Wide deployment

- » More common than MPI, especially “near” data

Scalability to very largest clusters

- » Even HPC world is now concerned about resilience

Examples: Pig, Hive, Scalding, Storm

Limitations of MapReduce

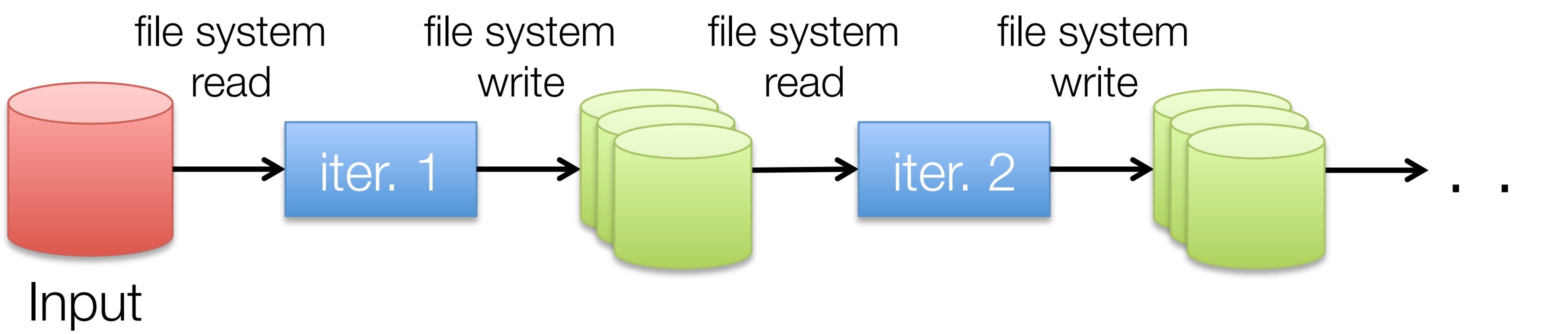
Limitations of MapReduce

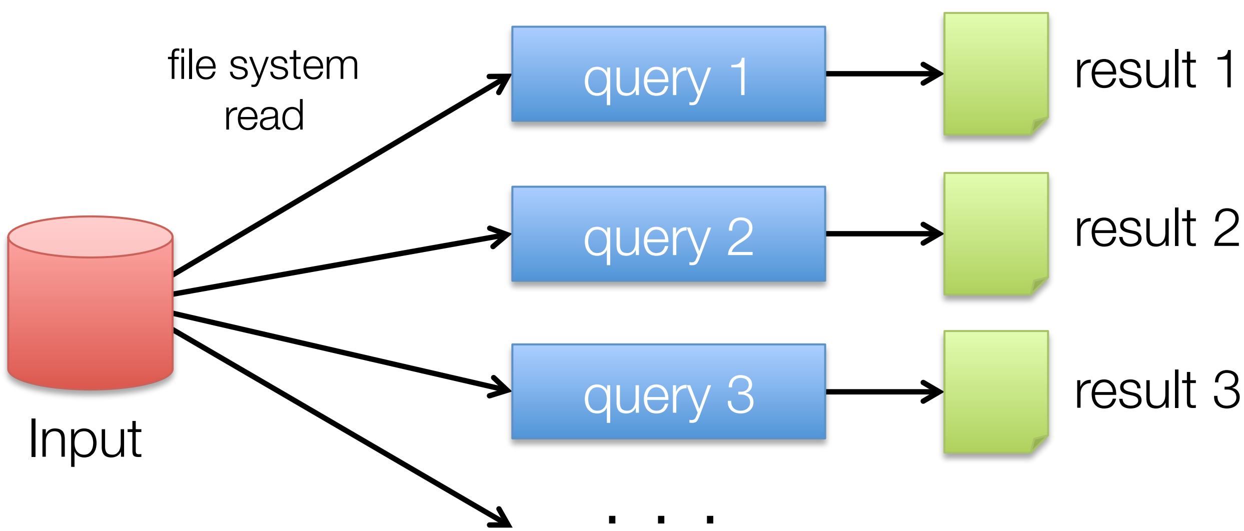
MapReduce is great at one-pass computation, but inefficient for *multi-pass* algorithms

No efficient primitives for data sharing

- State between steps goes to distributed file system
- Slow due to replication & disk storage

Example: Iterative Apps



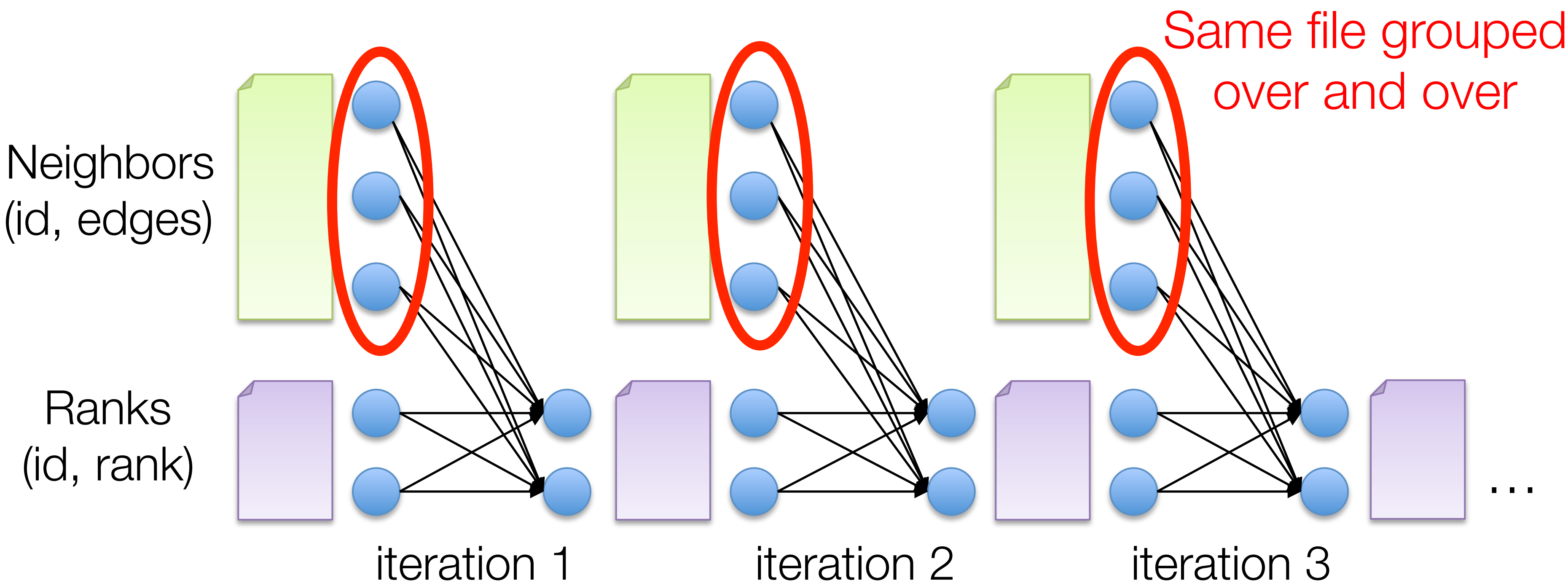


Commonly spend 90% of time doing I/O

Example: PageRank

Repeatedly multiply sparse matrix and vector

Requires repeatedly hashing together page adjacency lists and rank vector



Result

While MapReduce is simple, it can require *asymptotically* more communication or I/O

Verdict

MapReduce algorithms research doesn’t go to waste, it just gets sped up and easier to use

Still useful to study as an algorithmic framework, silly to use directly

Spark computing engine

Spark Computing Engine

Extends a programming language with a distributed collection data-structure

- » "Resilient distributed datasets" (RDD)

Open source at Apache

- » Most active community in big data, with 50+ companies contributing

Clean APIs in Java, Scala, Python, R

Resilient Distributed Datasets (RDDs)

Main idea: Resilient Distributed Datasets

» Immutable collections of objects, spread across cluster

» Statically typed: RDD[T] has objects of type T

```
val sc = new SparkContext()
val lines = sc.textFile("log.txt")   // RDD[String]

// Transform using standard collection operations
val errors = lines.filter(_.startsWith("ERROR"))
val messages = errors.map(_.split('\t')(2))

messages.saveAsTextFile("errors.txt")
```

→ lazily evaluated

→ kicks off a computation

Key Idea

Resilient Distributed Datasets (RDDs)

» Collections of objects across a cluster with user controlled partitioning & storage (memory, disk, ...)
» Built via parallel transformations (map, filter, …)
» The world only lets you make make RDDs such that they can be:

Automatically rebuilt on failure

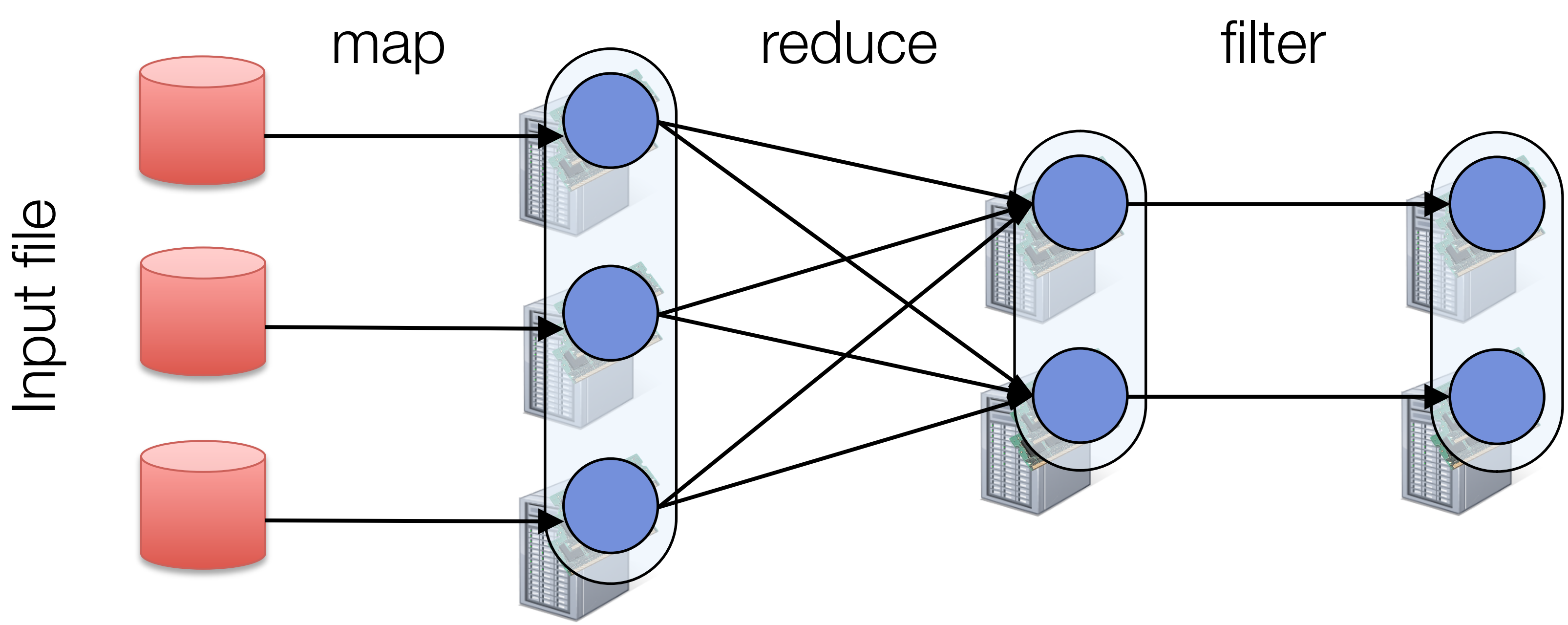
Python, Java, Scala, R

```
// Scala:

val lines = sc.textFile(...)
lines.filter(x => x.contains(“ERROR”)).count()


// Java (better in java8!):

JavaRDD<String> lines = sc.textFile(...);
lines.filter(new Function<String, Boolean>() {
  Boolean call(String s) {
    return s.contains(“error”);
  }
}).count();
```

Fault Tolerance

RDDs track *lineage* info to rebuild lost data

```
file.map(lambda rec: (rec.type, 1))
    .reduceByKey(lambda x, y: x + y)
    .filter(lambda (type, count): count > 10)
```



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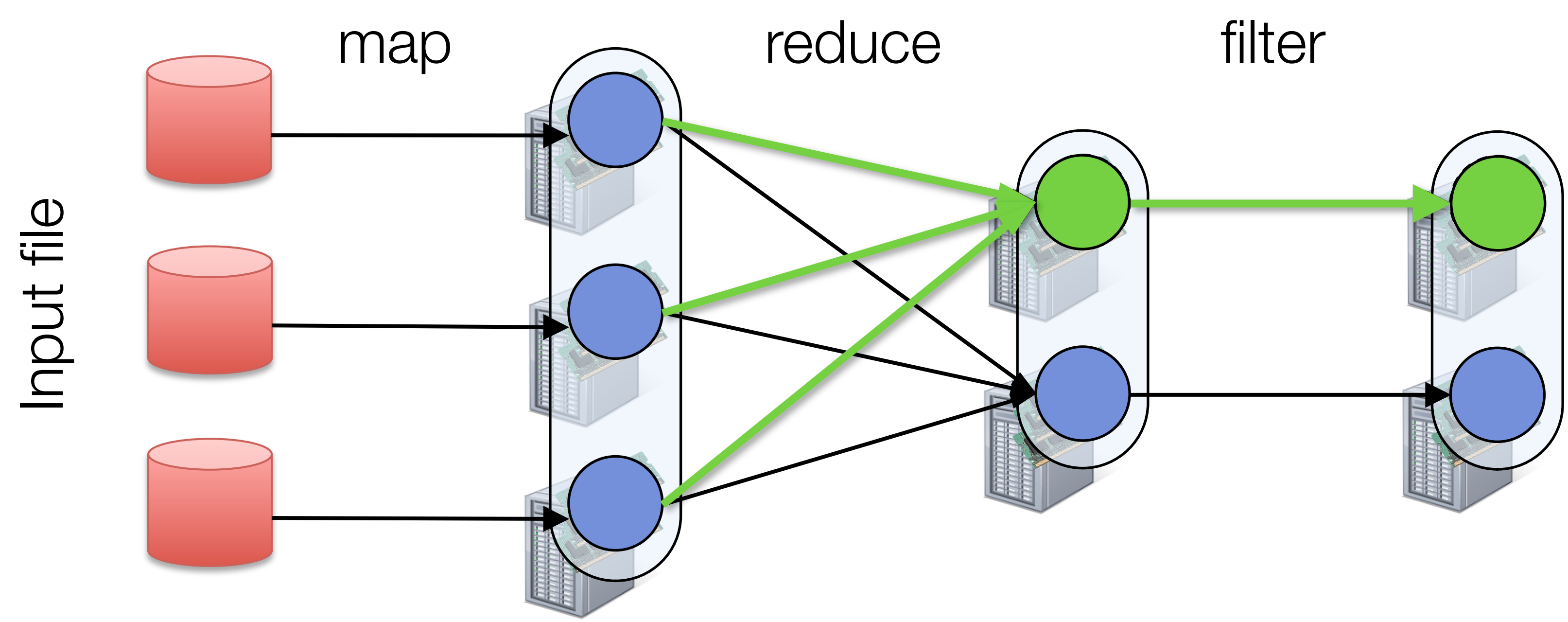

Partitioning

RDDs know their partitioning functions

```
file.map(lambda rec: (rec.type, 1))
    .reduceByKey(lambda x, y: x + y)
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```
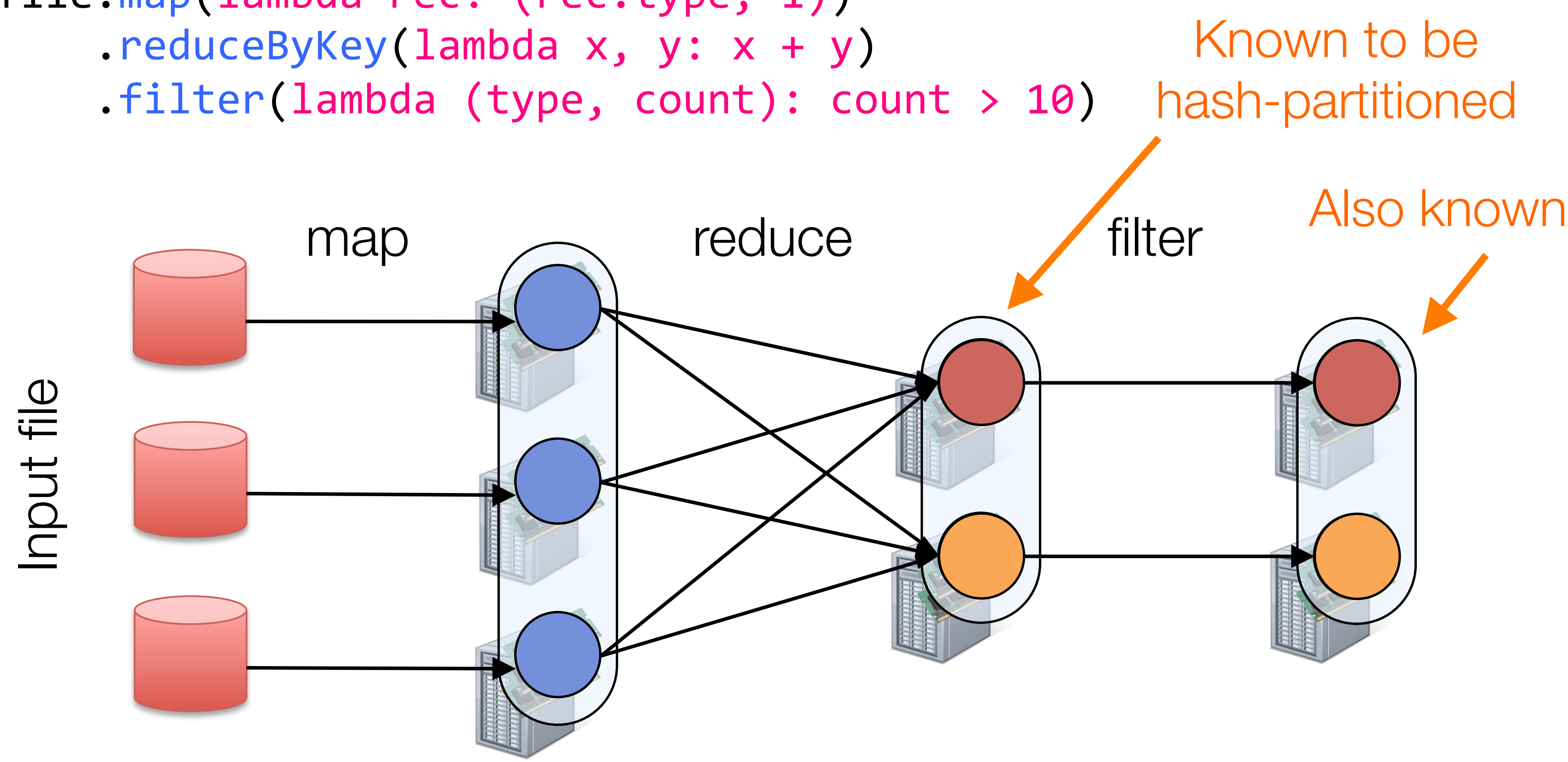



Spark in this class

Training distribution and data in first homework, also on class webpage

Databricks Cloud to try a real cluster, third week, handing out clusters to all of you

Download it yourself! spark.apache.org

Other Data-flow

Graph Computations: Pregel, GraphLab

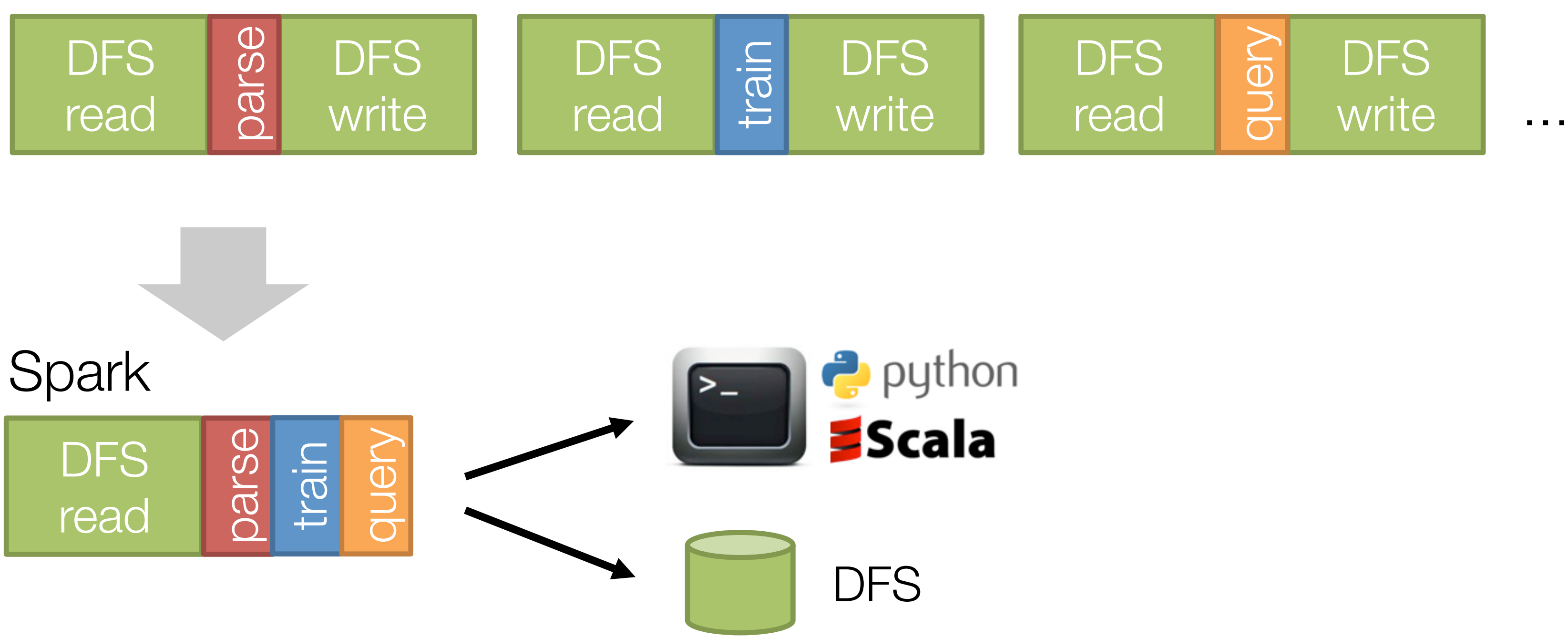
SQL based engines: Hive, Pig, …

… jury still out?

Benefit for Users

Same engine performs data extraction, model training and interactive queries

Separate engines



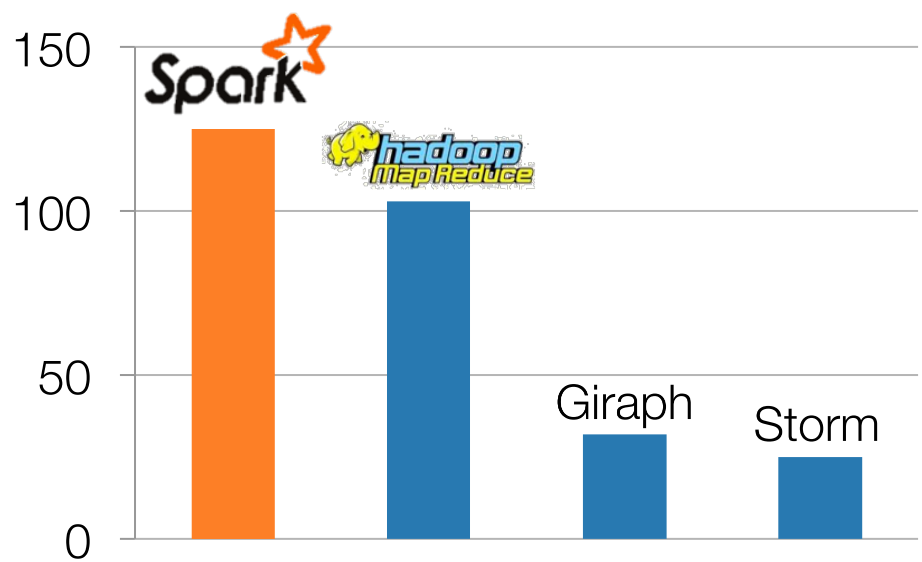
State of the Spark ecosystem

Spark Community

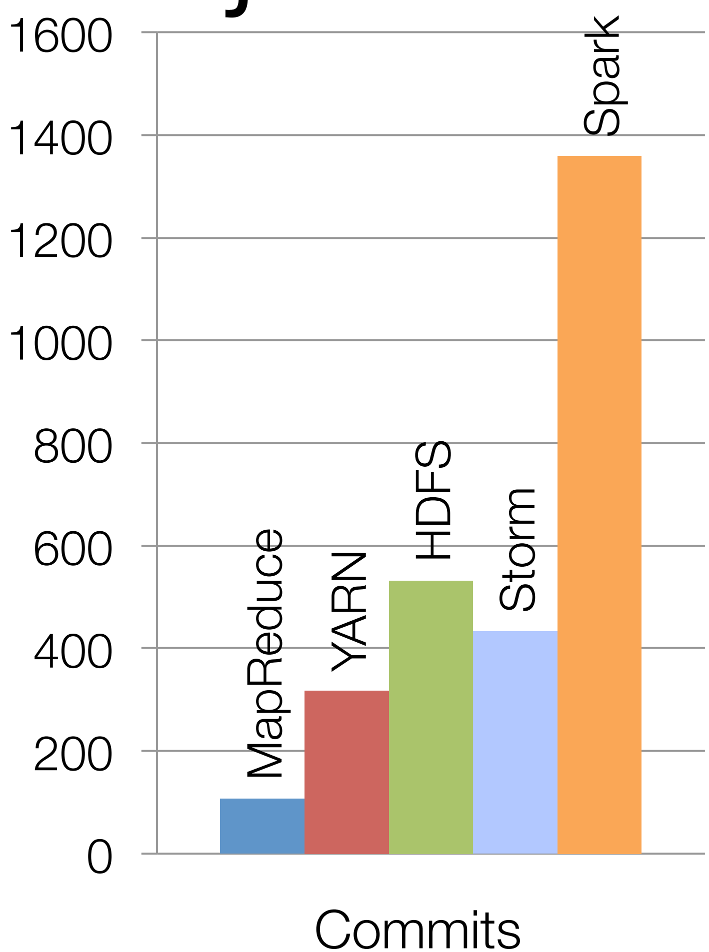
Most active open source community in big data

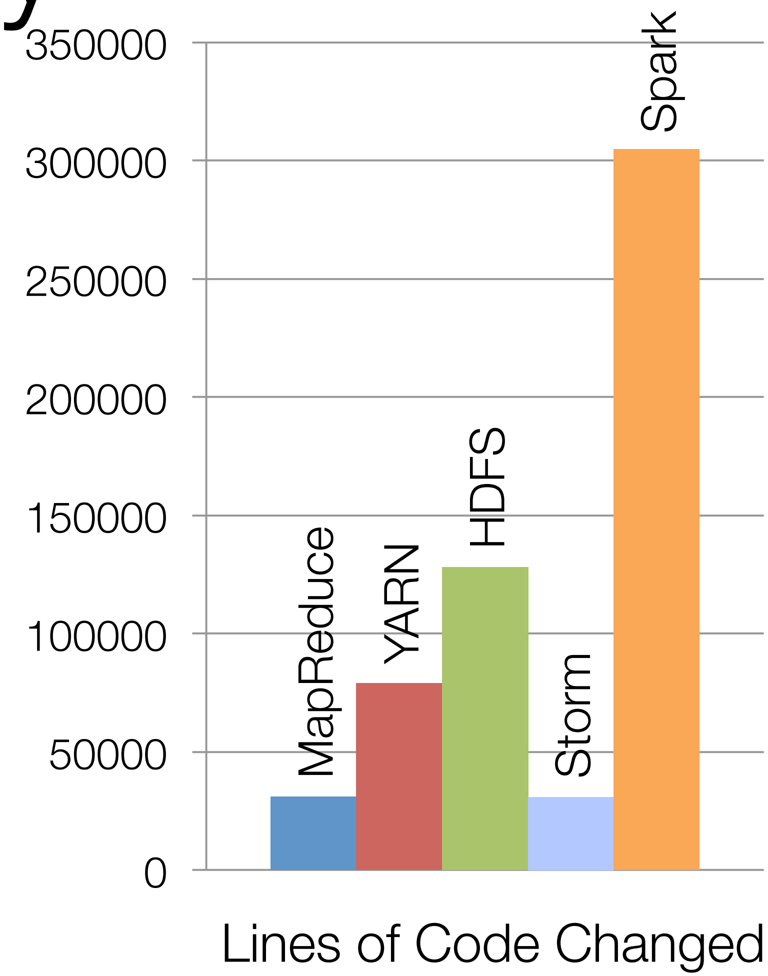
200+ developers, **50+** companies contributing

Contributors in past year



Project Activity





Activity in past 6 months

Continuing Growth

Contributors per month to Spark

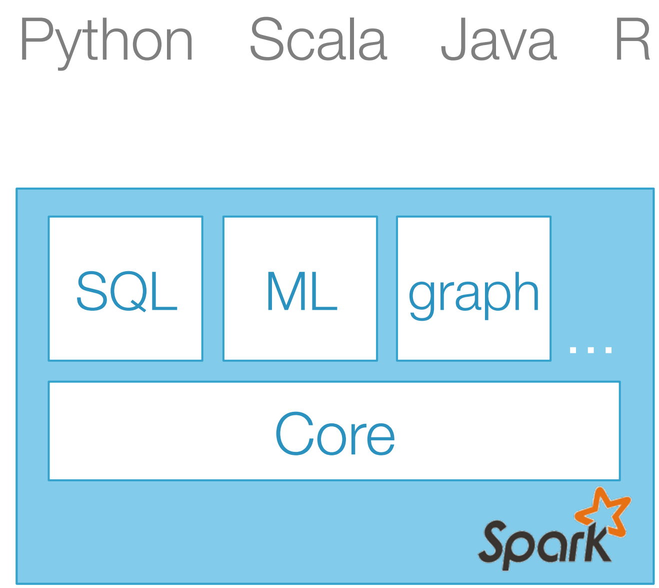
source: ohloh.net

Built-in libraries

Standard Library for Big Data

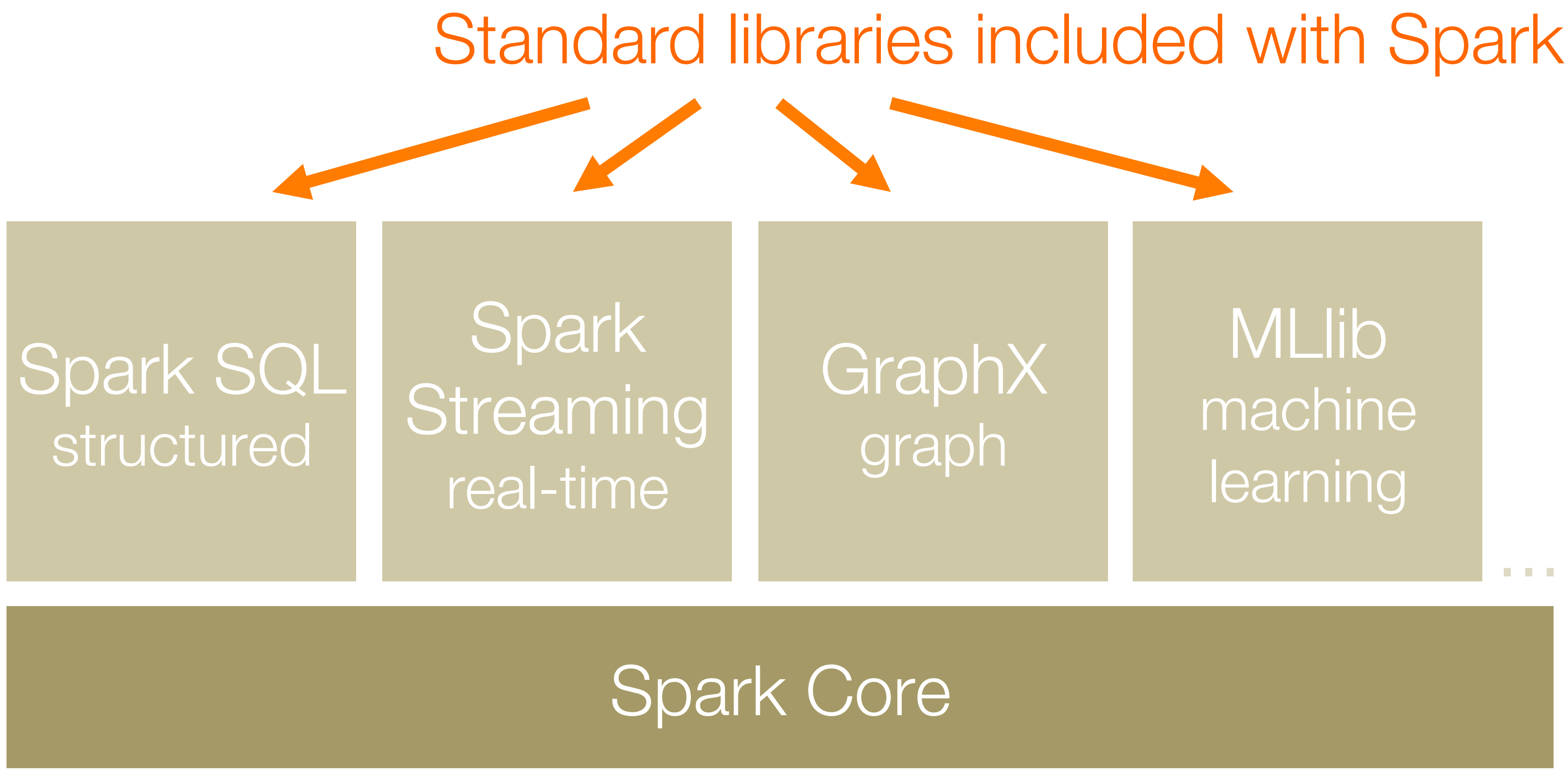
Big data apps lack libraries of common algorithms

Spark's generality + support for multiple languages make suitable to offer this



Much of future activity will be in these libraries

A General Platform



Machine Learning Library (MLlib)

```
points = context.sql("select latitude, longitude from tweets")
model = KMeans.train(points, 10)
```

40 contributors in past year

MLlib algorithms

classification: logistic regression, linear SVM, naïve Bayes, classification tree

regression: generalized linear models (GLMs), regression tree

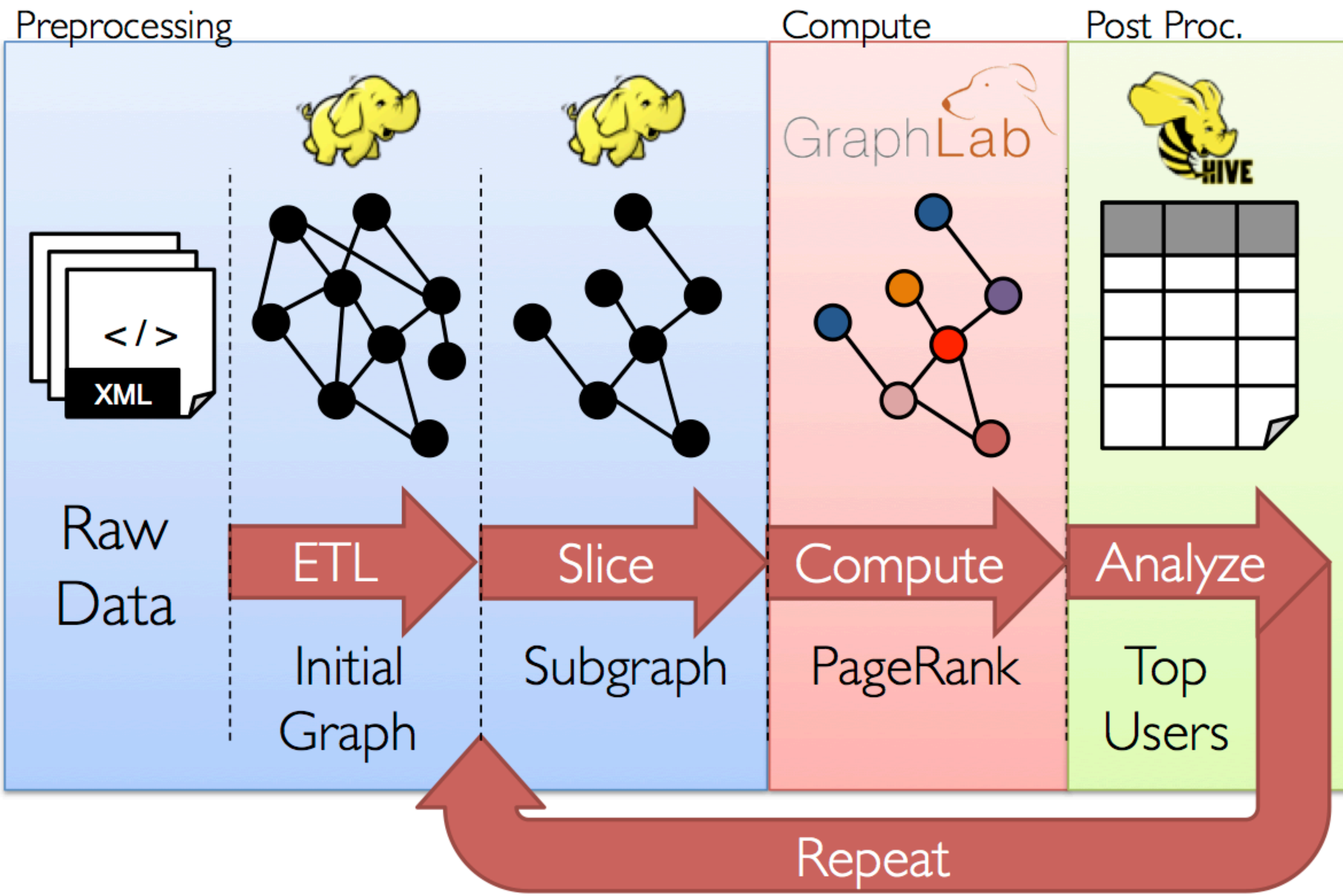
collaborative filtering: alternating least squares (ALS), non-negative matrix factorization (NMF)

clustering: k-means||

decomposition: SVD, PCA

optimization: stochastic gradient descent, L-BFGS

GraphX



Preprocessing
Compute
Post Proc.
GraphLab
HIVE
</>
XML
Raw Data
ETL
Slice
Compute
Analyze
Initial Graph
Subgraph
PageRank
Top Users
Repeat

GraphX

General graph processing library

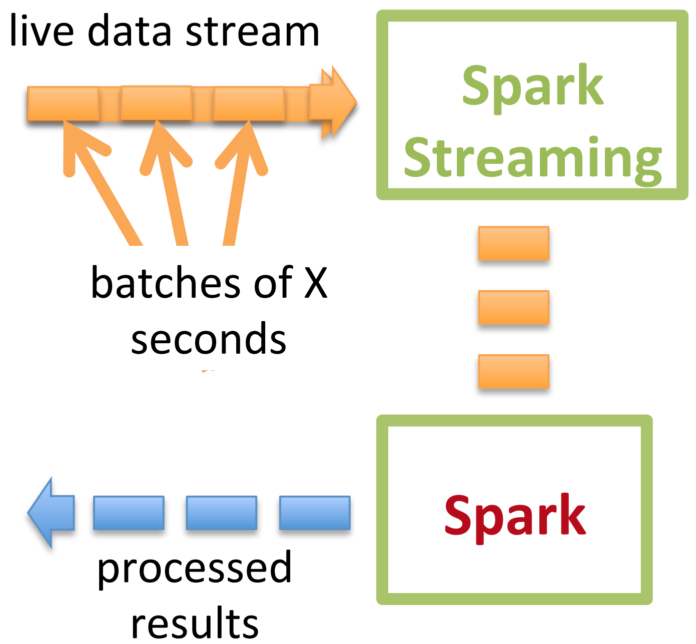
Build graph using RDDs of nodes and edges

Large library of graph algorithms with composable steps

Spark Streaming

Run a streaming computation as a **series of very small, deterministic batch jobs**

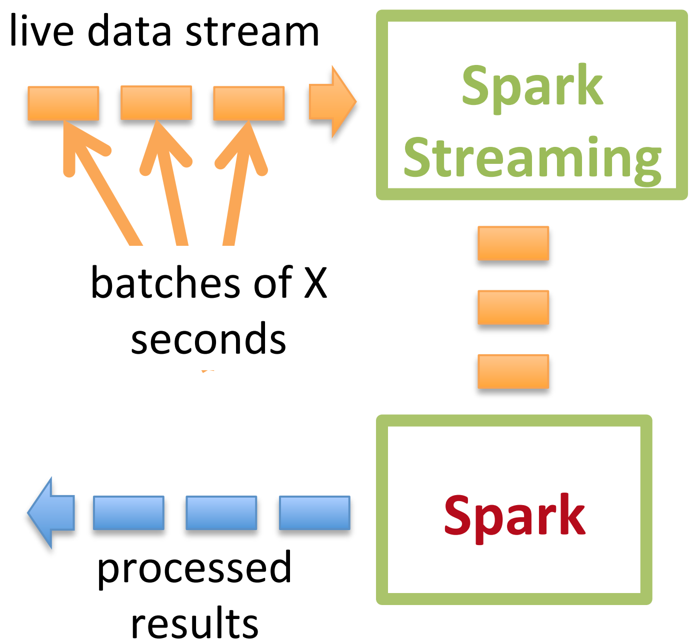
- Chop up the live stream into batches of X seconds
- Spark treats each batch of data as RDDs and processes them using RDD operations
- Finally, the processed results of the RDD operations are returned in batches



Spark Streaming

Run a streaming computation as a **series of very small, deterministic batch jobs**

- Batch sizes as low as ½ second, latency ~ 1 second
- Potential for combining batch processing and streaming processing in the same system



Spark SQL

```
// Run SQL statements
val teenagers = context.sql(
  "SELECT name FROM people WHERE age >= 13 AND age <= 19")


// The results of SQL queries are RDDs of Row objects
val names = teenagers.map(t => "Name: " + t(0)).collect()
```

Spark SQL

Enables loading & querying structured data in Spark

From Hive:

```
c = HiveContext(sc)
rows = c.sql("select text, year from hivetable")
rows.filter(lambda r: r.year > 2013).collect()
```

From JSON:

```
c.jsonFile("tweets.json").registerAsTable("tweets")
c.sql("select text, user.name from tweets")
```

tweets.json

```
{"text": "hi",
 "user": {
  "name": "matei",
  "id": 123
}}
```