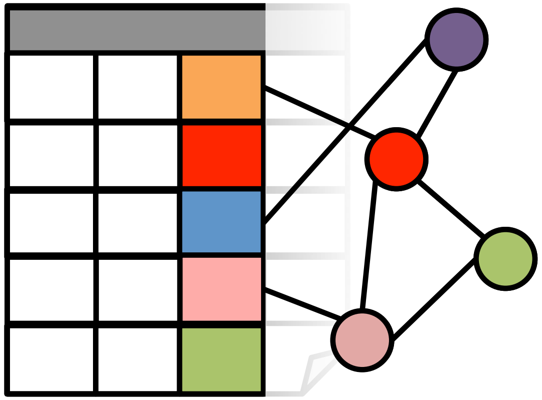
GraphX

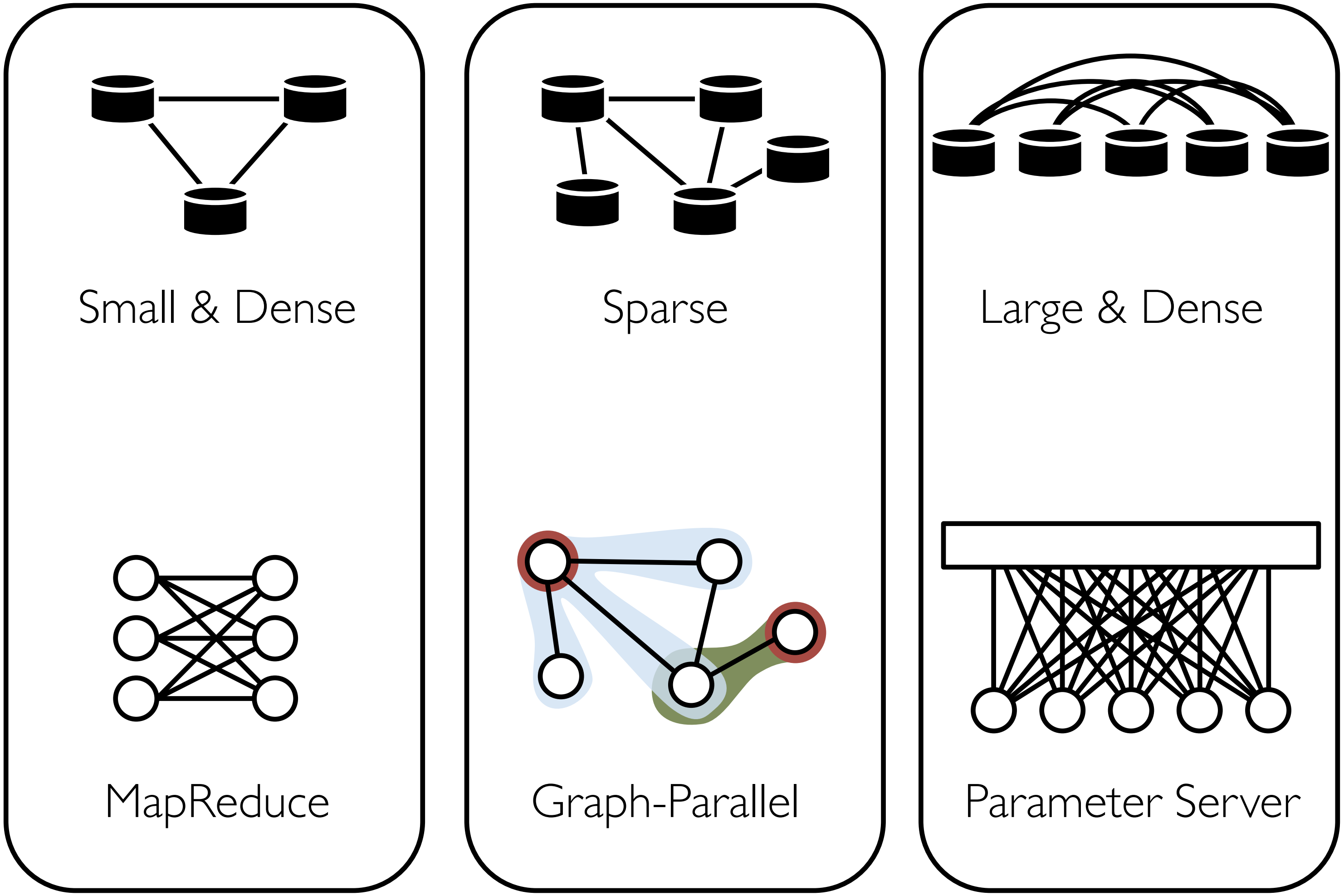


Graph Analytics in Spark

Ankur Dave
Graduate Student, UC Berkeley AMPLab

Joint work with Joseph Gonzalez, Reynold Xin, Daniel Crankshaw, Michael Franklin, and Ion Stoica

Machine Learning Landscape



Model & Dependencies

Small & Dense

Sparse

Large & Dense

Architecture

MapReduce

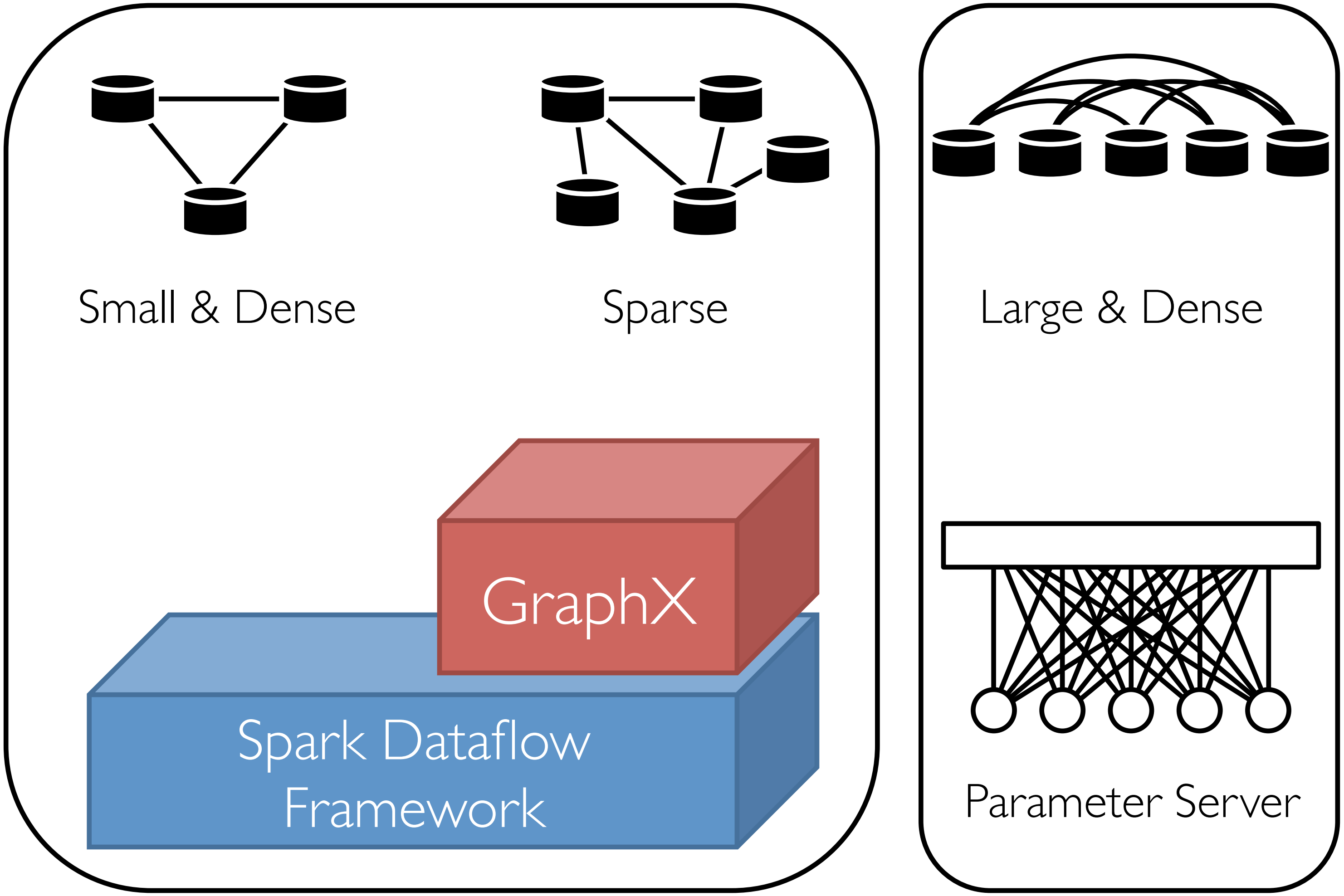
Graph-Parallel

Parameter Server

Machine Learning Landscape

Model & Dependencies

Architecture



Small & Dense

Sparse

Large & Dense

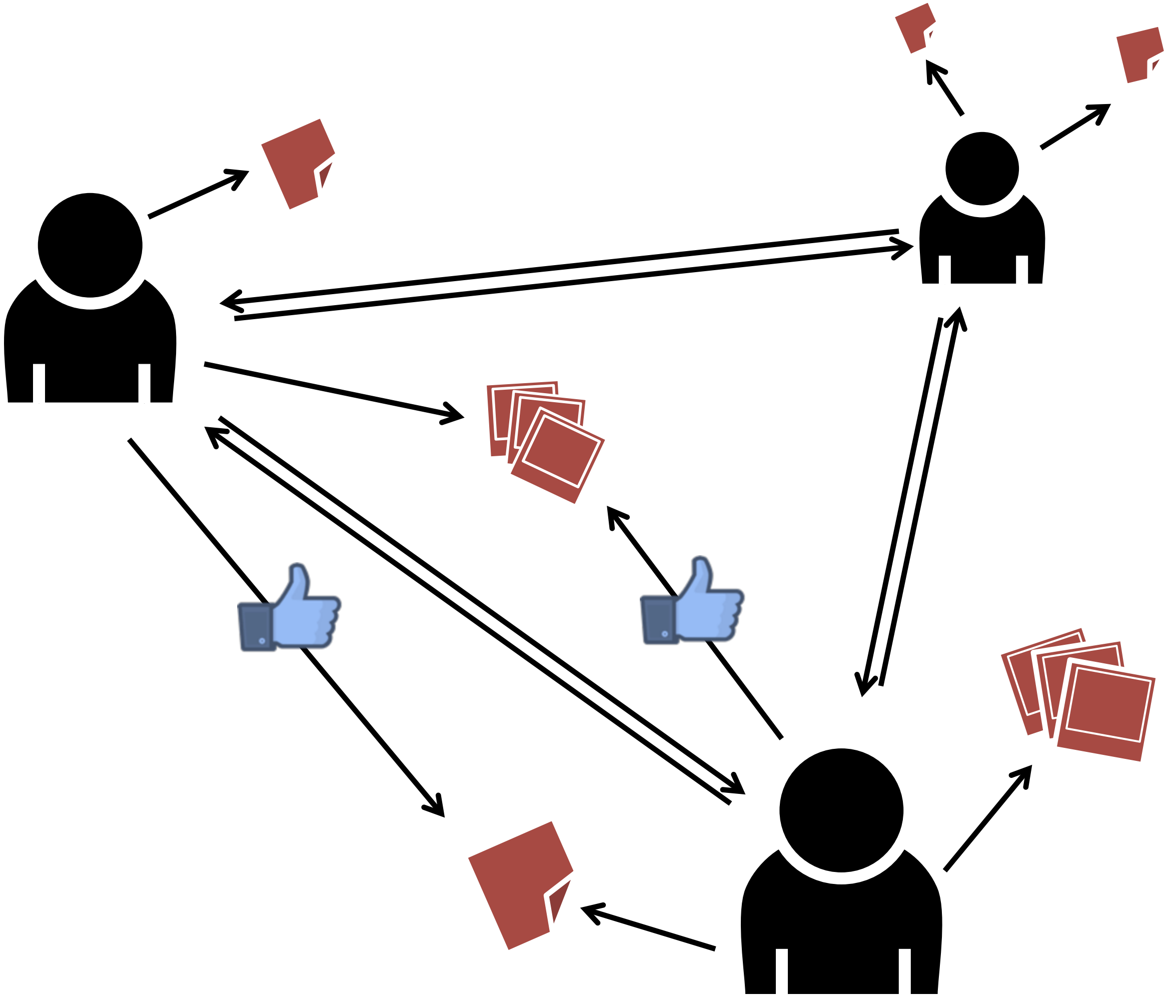
GraphX

Spark Dataflow Framework

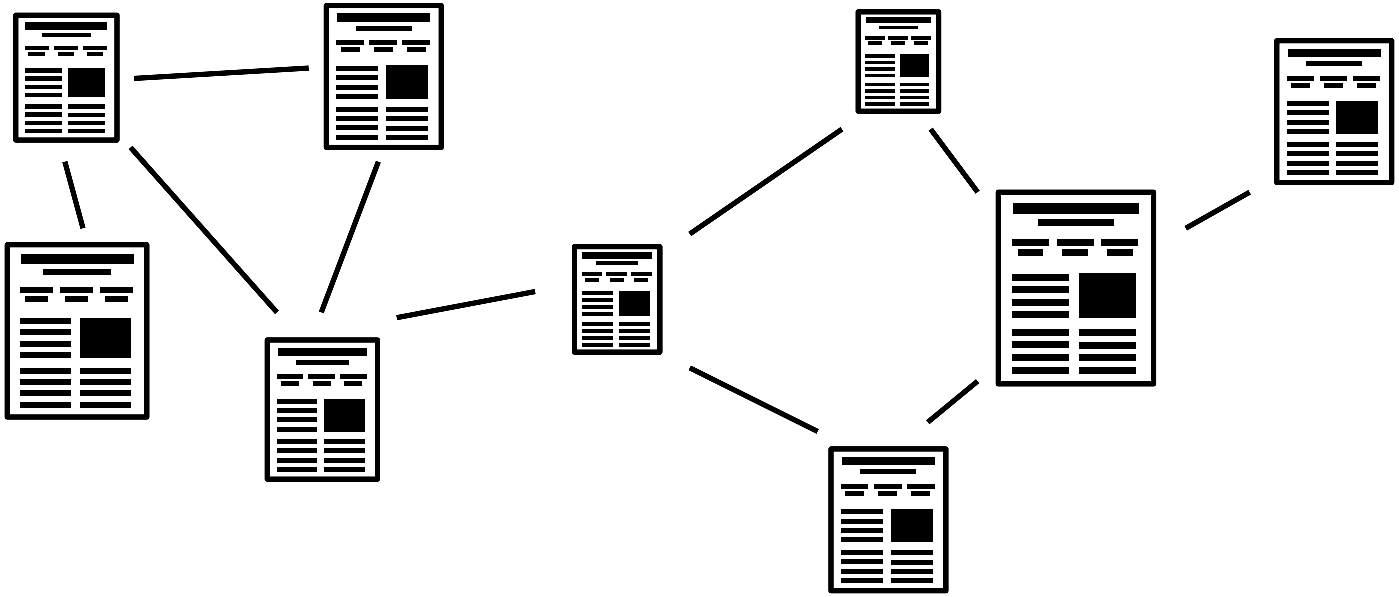
Parameter Server

Graphs

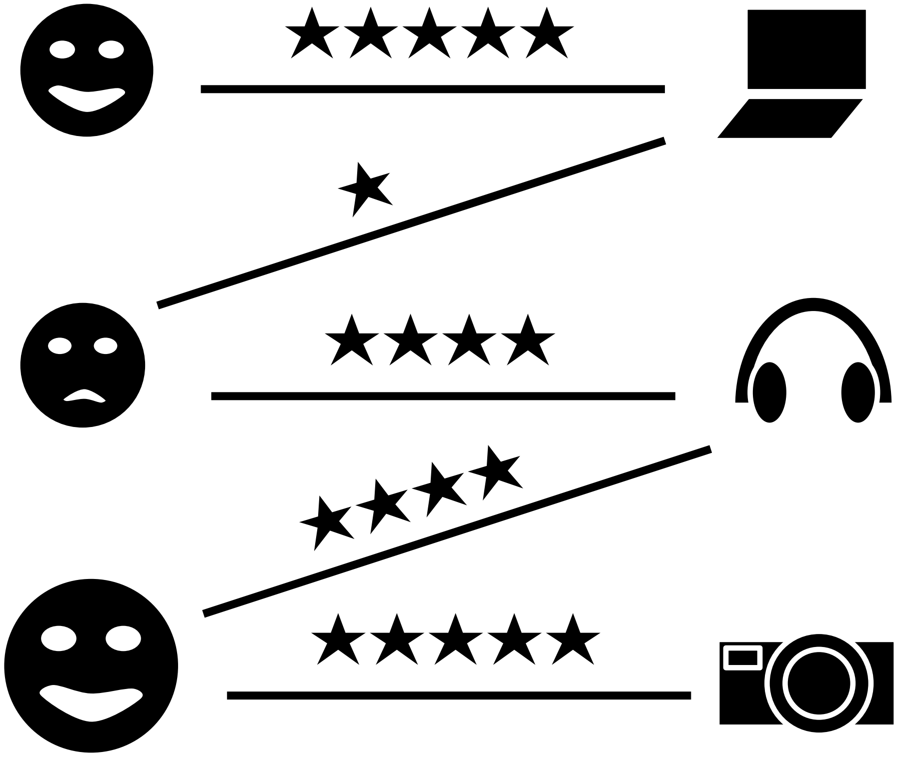
Social Networks



Web Graphs

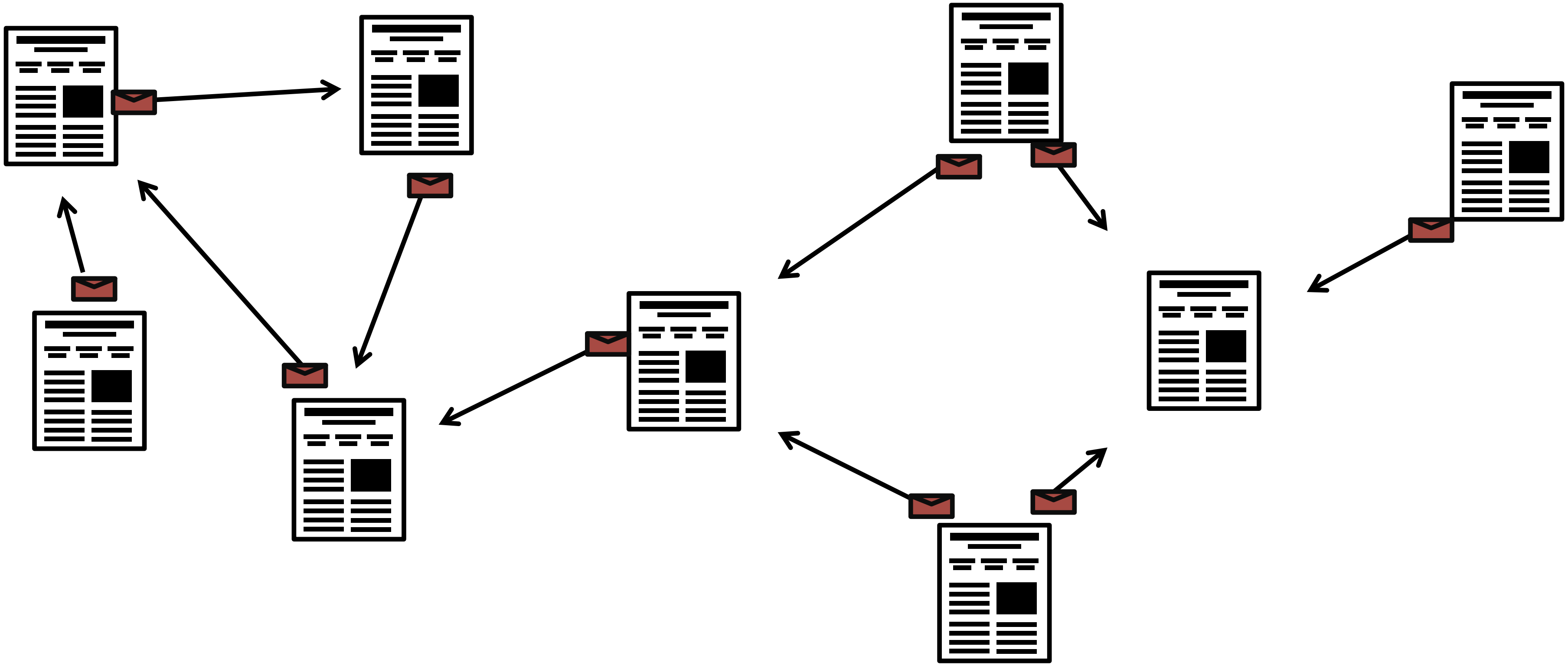


User-Item Graphs

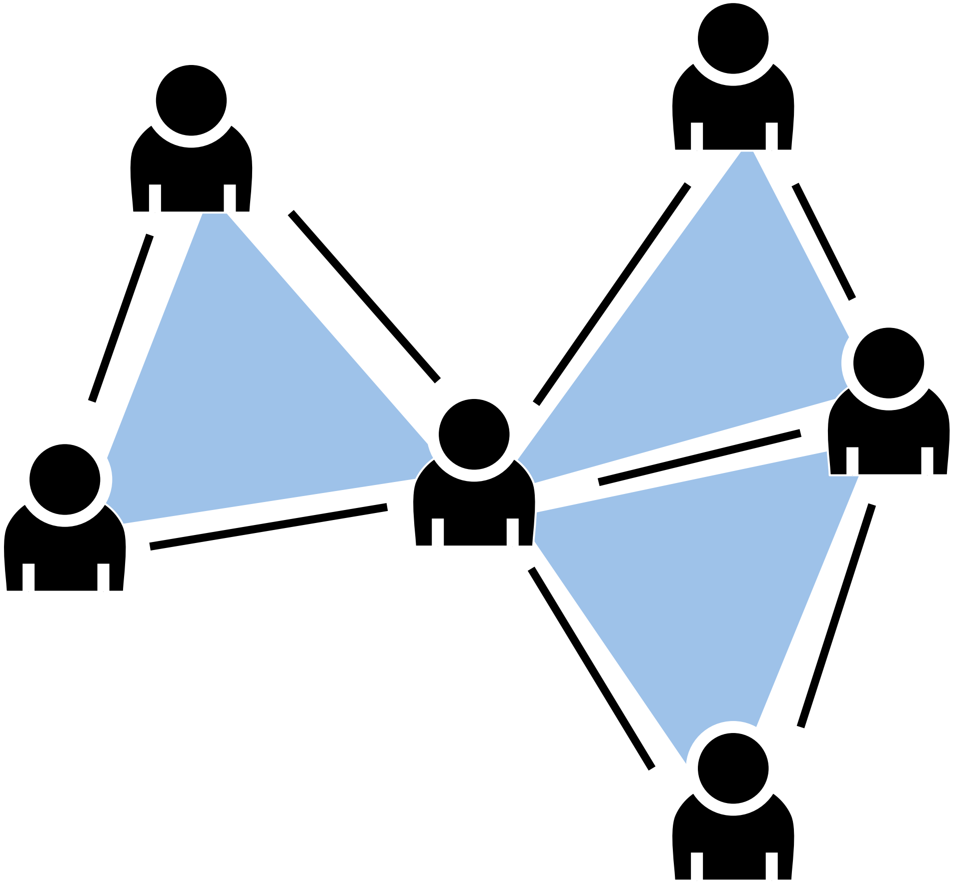


Graph Algorithms

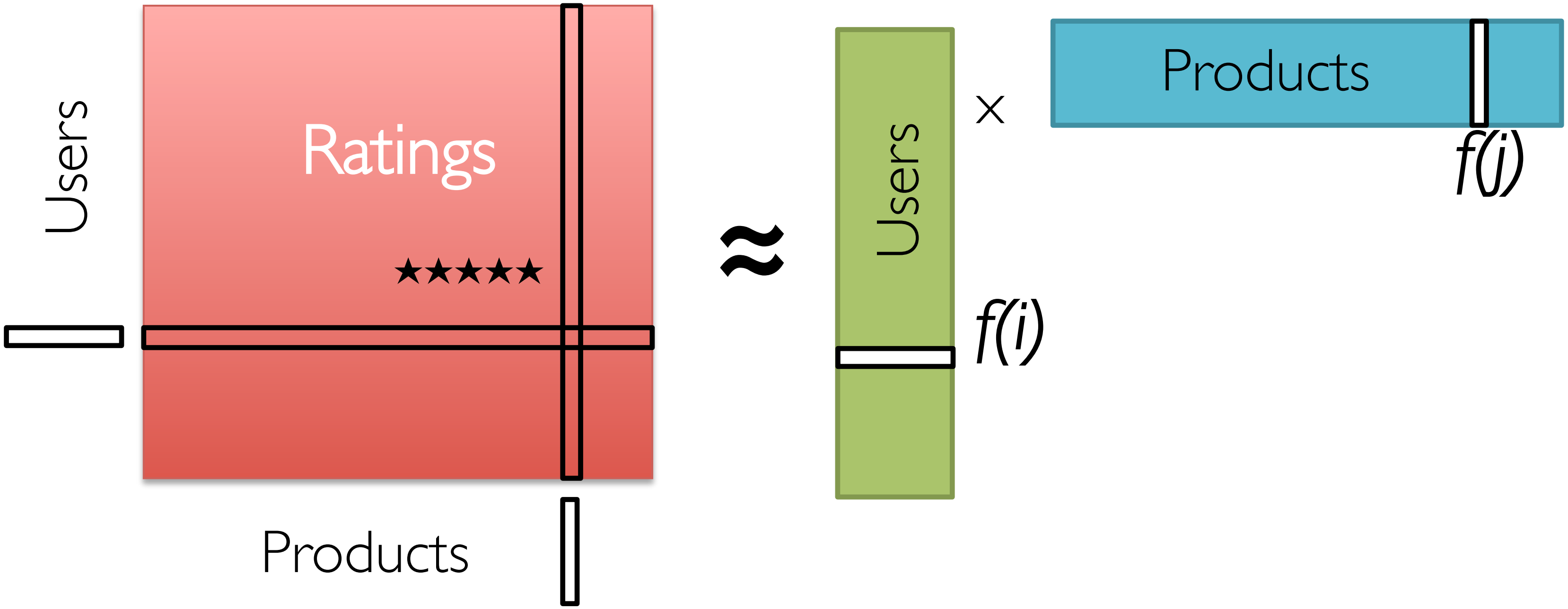
PageRank



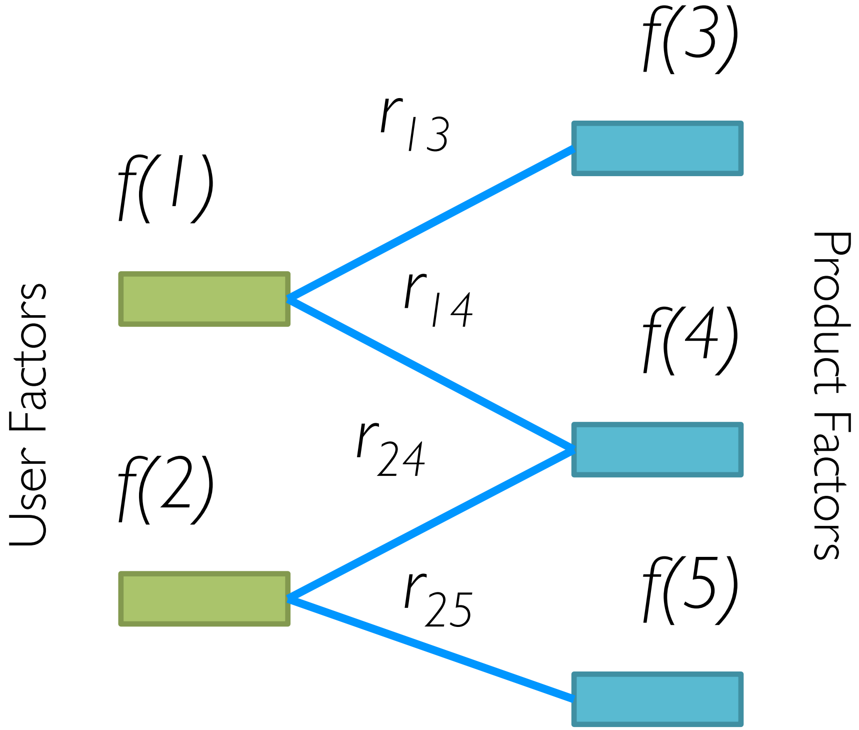
Triangle Counting



Collaborative Filtering

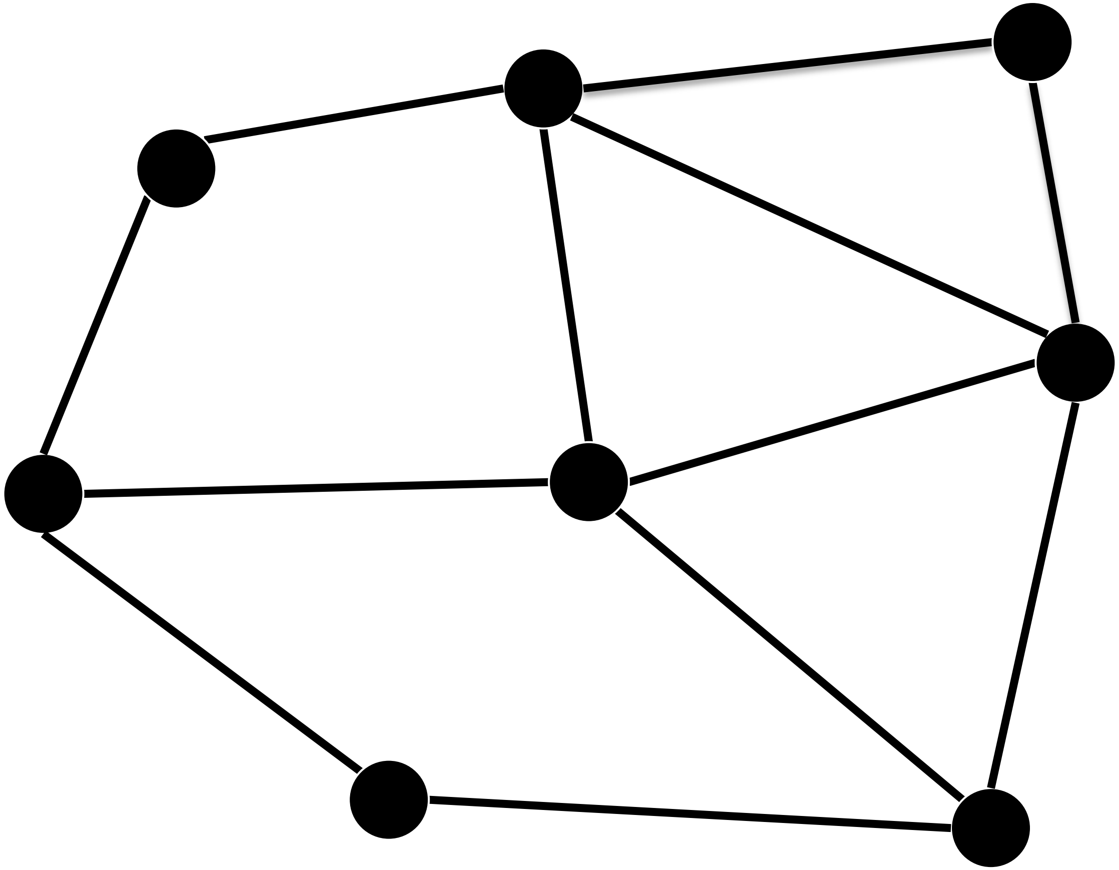


Collaborative Filtering

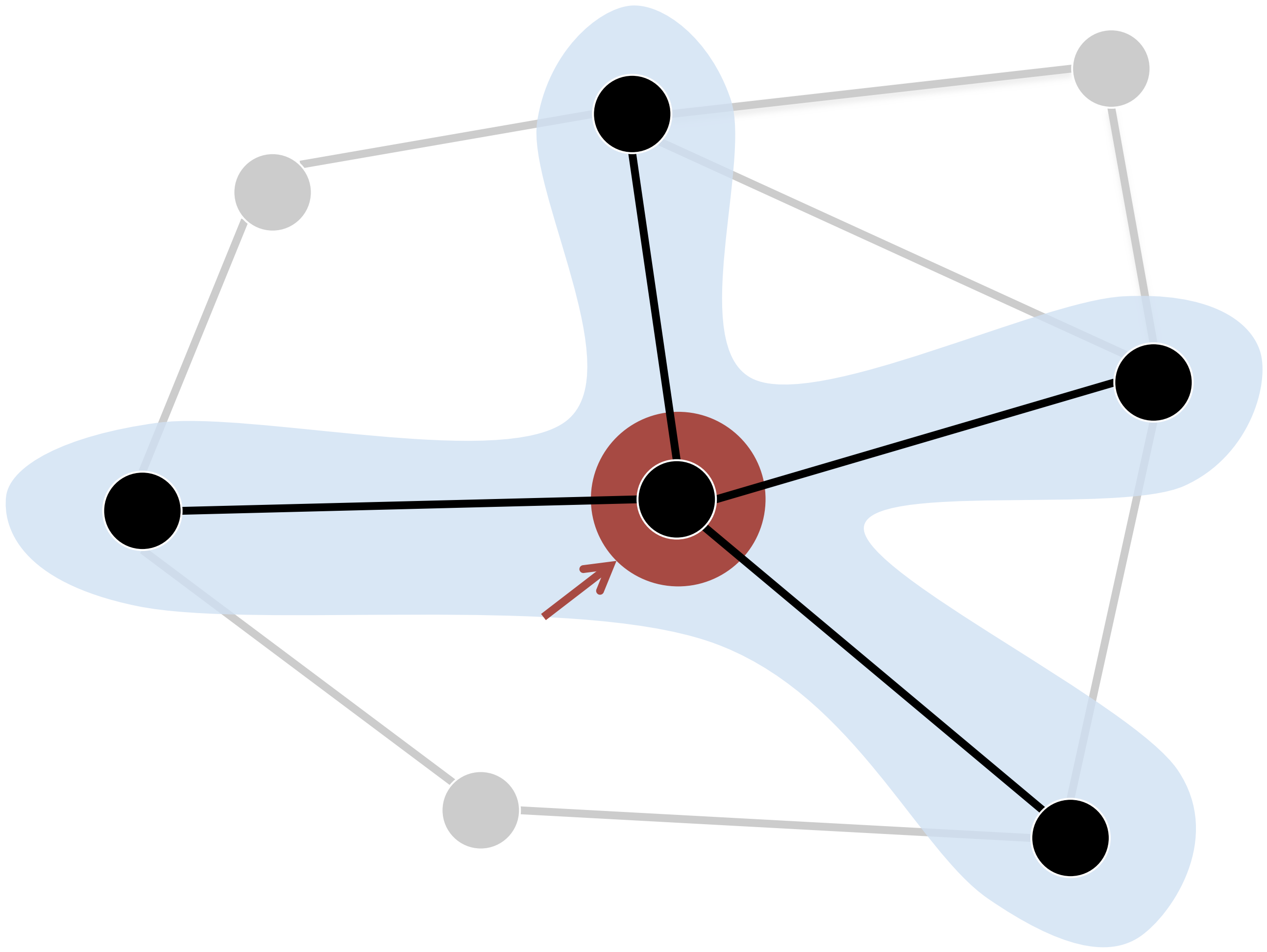


$$f[i] = \arg\min_{w \in \mathbb{R}^d} \sum_{j \in \mathrm{Nbrs}(i)} \left(r_{ij} - w^T f[j] \right)^2 + \lambda ||w||_2^2$$

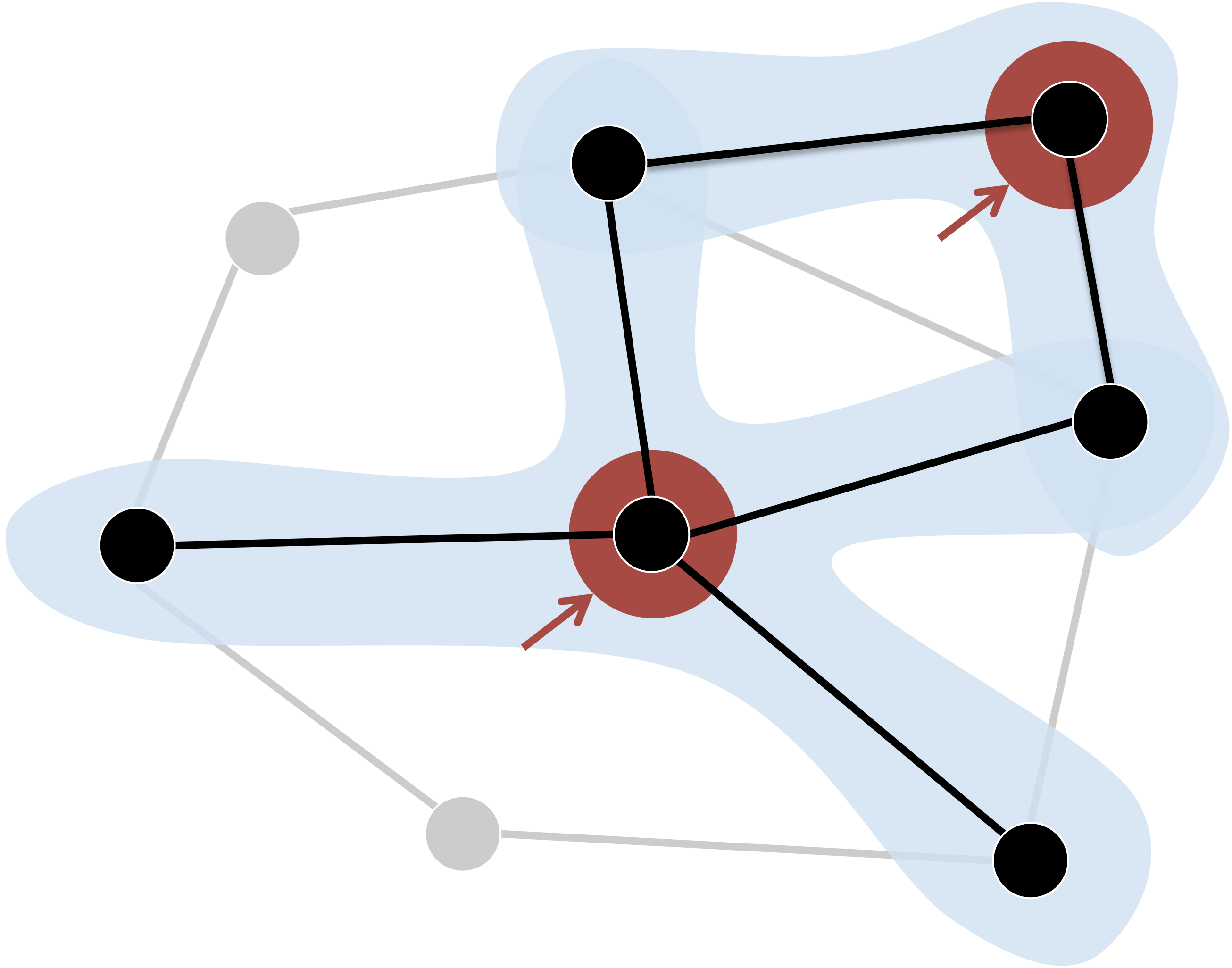
The Graph-Parallel Pattern



The Graph-Parallel Pattern



The Graph-Parallel Pattern



Many Graph-Parallel Algorithms

Collaborative Filtering

- » Alternating Least Squares
- » Stochastic Gradient Descent
- » Tensor Factorization

Structured Prediction

- » Loopy Belief Propagation
- » Max-Product Linear Programs
- » Gibbs Sampling

Semi-supervised ML

- » Graph SSL
- » CoEM

Community Detection

- » Triangle-Counting
- » K-core Decomposition
- » K-Truss

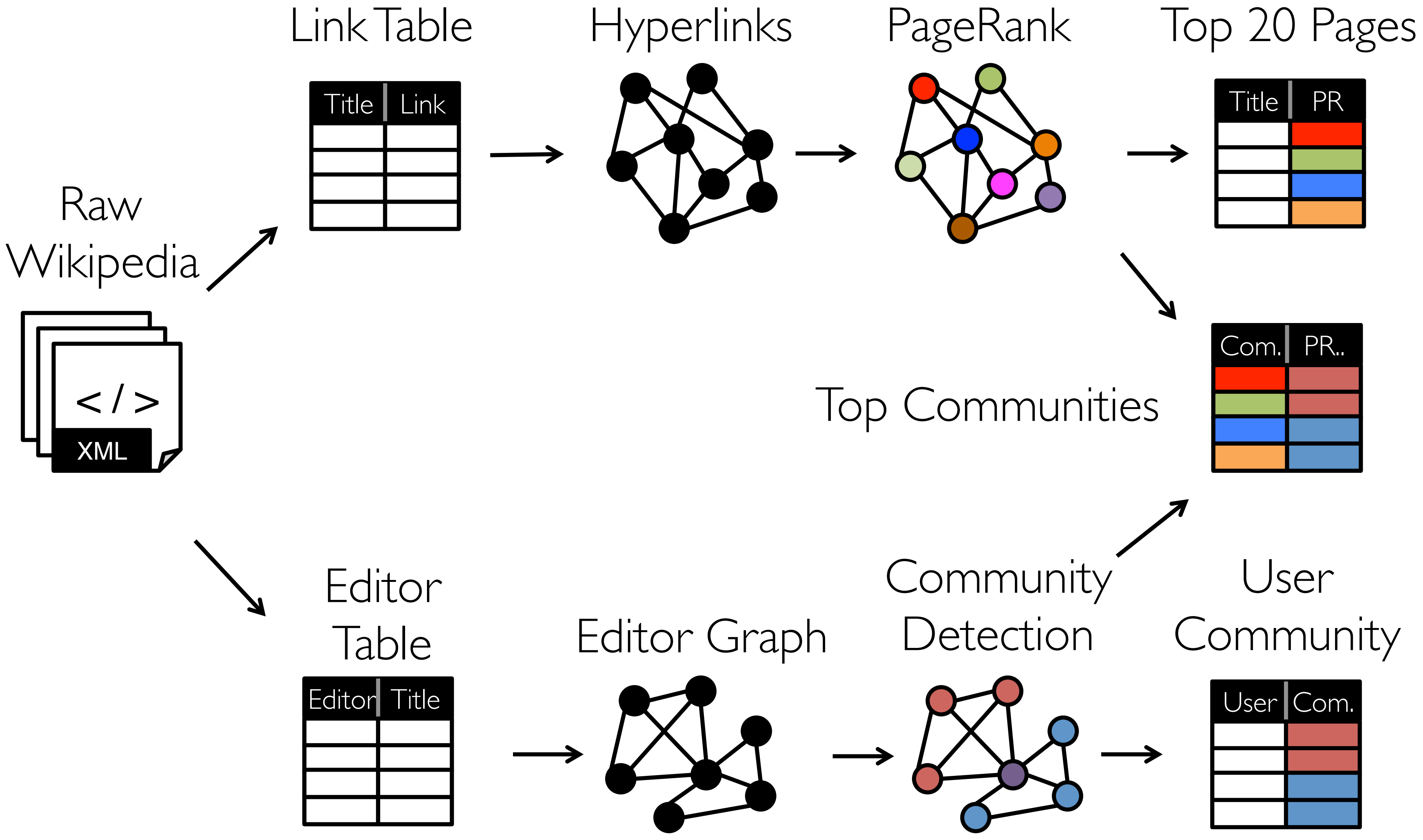
Graph Analytics

- » PageRank
- » Personalized PageRank
- » Shortest Path
- » Graph Coloring

Classification

- » Neural Networks

Modern Analytics



Raw Wikipedia

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XML

Link Table

Title Link

Hyperlinks

PageRank

Top 20 Pages

Title PR

Top Communities

Com. PR..

Editor Table

Editor Title

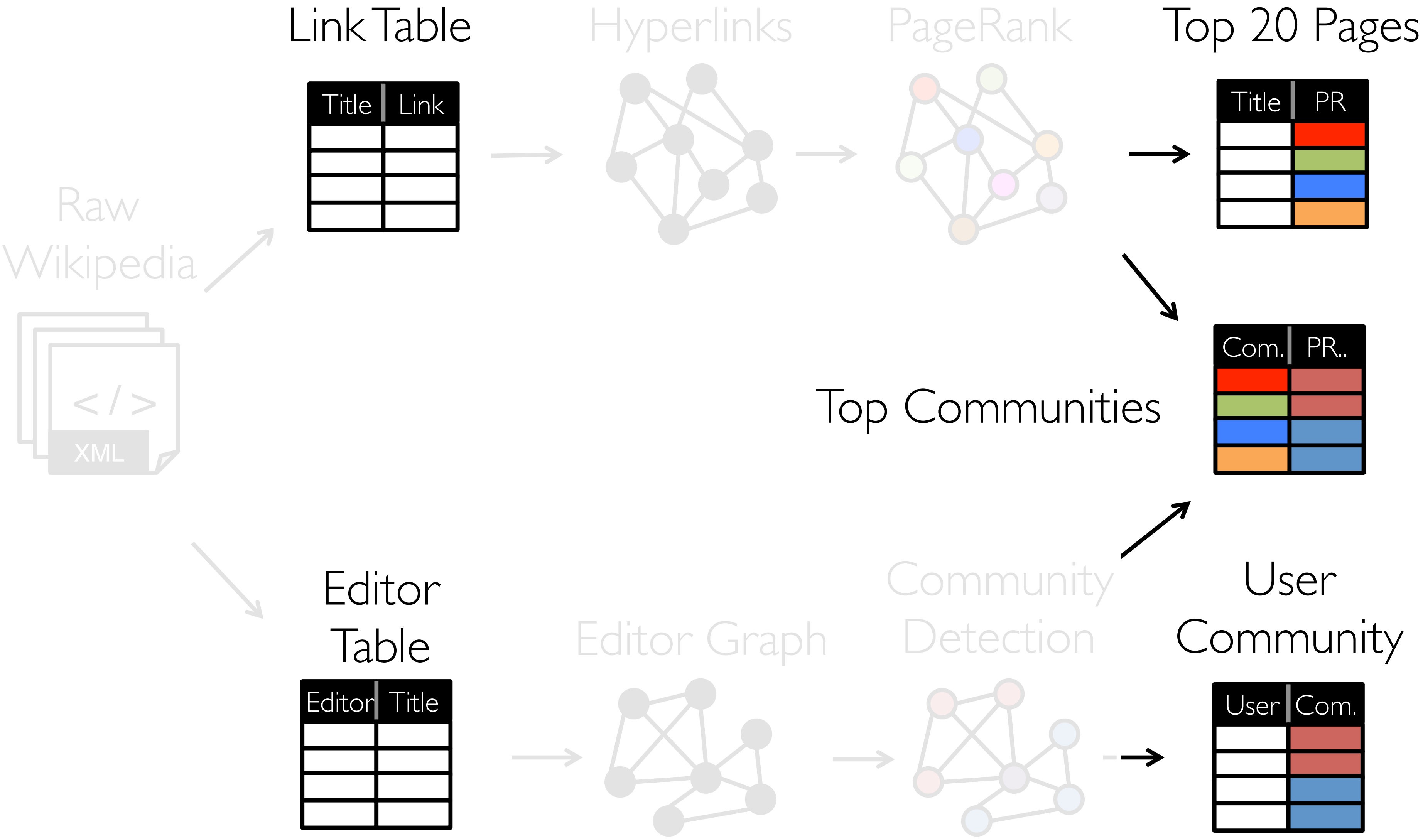
Editor Graph

Community Detection

User Community

User Com.

Tables



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Link Table

Title	Link

Hyperlinks

PageRank

Top 20 Pages

Title	PR
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Top Communities

Com.	PR..
🟥	🟥
🟩	🟥
🟦	🟦
🟧	🟦

Editor Table

Editor	Title

Editor Graph

Community Detection

User Community

User	Com.
	🟥
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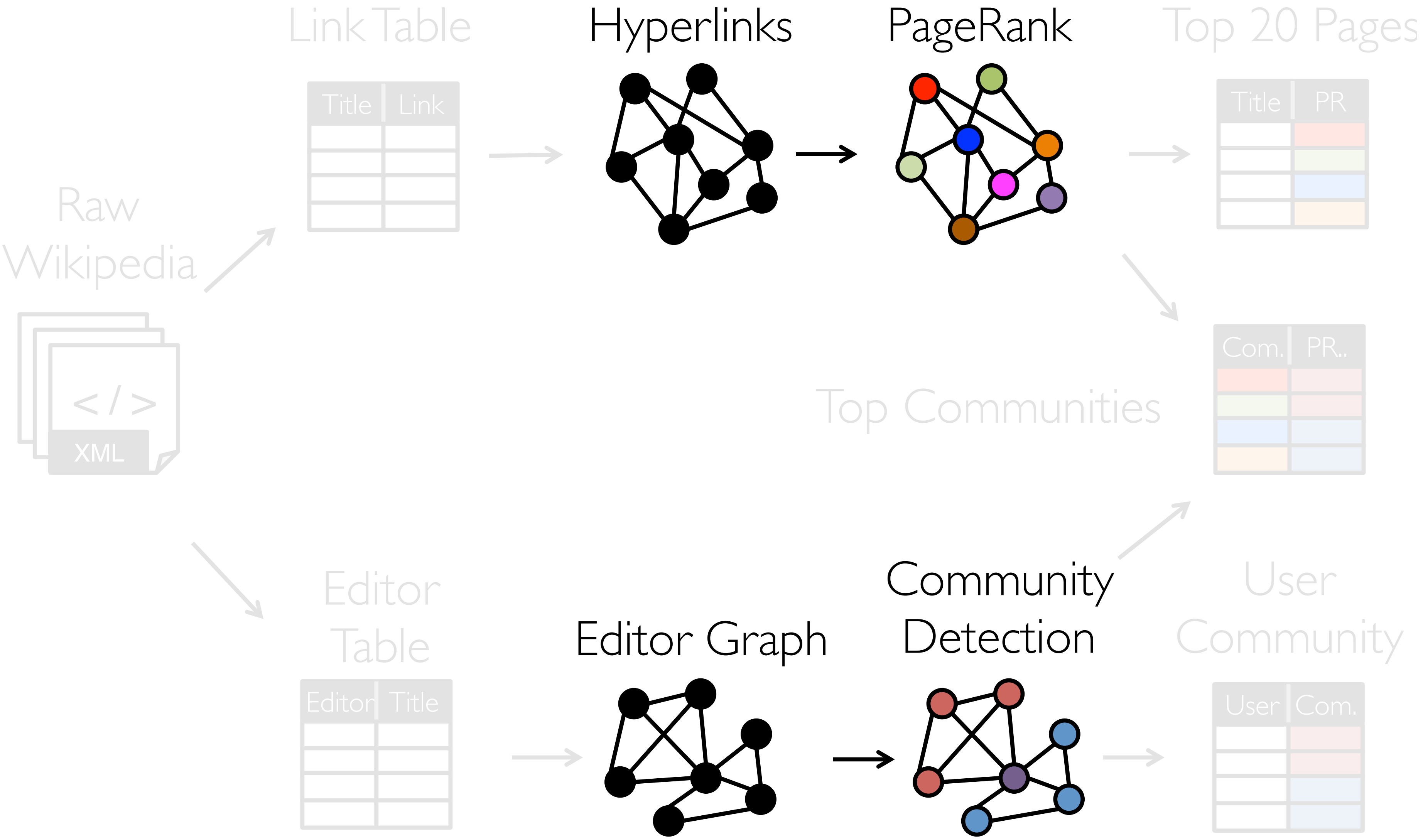
	🟦

Graphs



Raw Wikipedia

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Link Table

Title | Link

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PageRank

Top 20 Pages

Title | PR

Top Communities

Com. | PR..

Editor Table

Editor | Title

Editor Graph

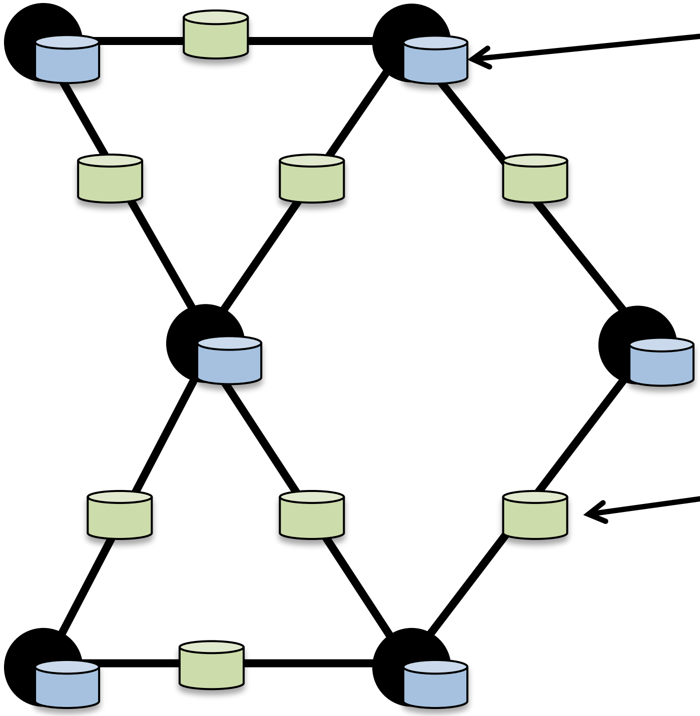
Community Detection

User Community

User | Com.

The GraphX API

Property Graphs



Vertex Property:

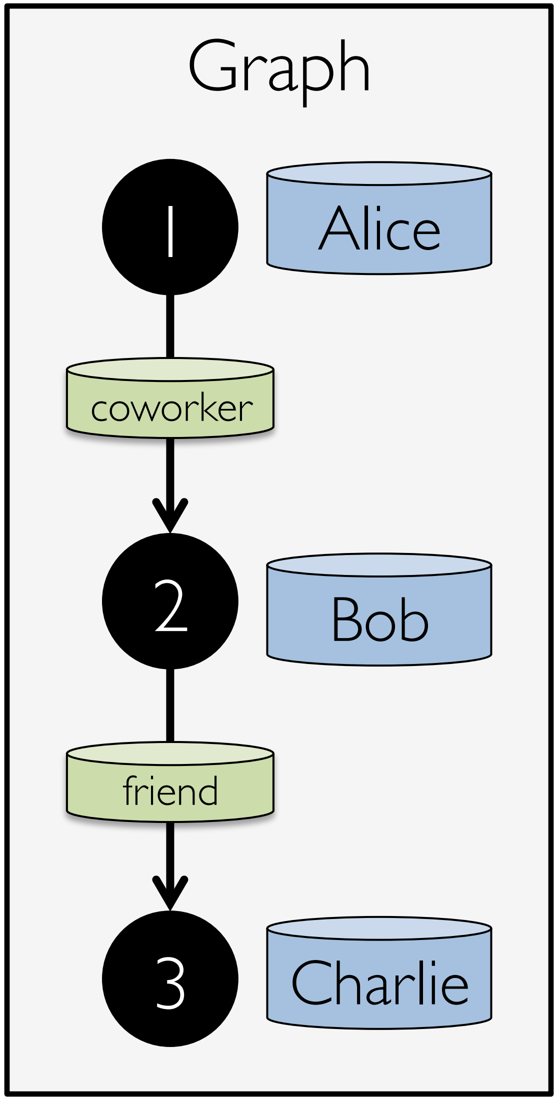
- User Profile
- Current PageRank Value

Edge Property:

- Weights
- Relationships
- Timestamps

Creating a Graph (Scala)

```
type VertexId = Long

val vertices: RDD[(VertexId, String)] =
  sc.parallelize(List(
    (1L, “Alice”),
    (2L, “Bob”),
    (3L, “Charlie”)))

class Edge[ED](
  val srcId: VertexId,
  val dstId: VertexId,
  val attr: ED)

val edges: RDD[Edge[String]] =
  sc.parallelize(List(
    Edge(1L, 2L, “coworker”),
    Edge(2L, 3L, “friend”)))

val graph = Graph(vertices, edges)
```



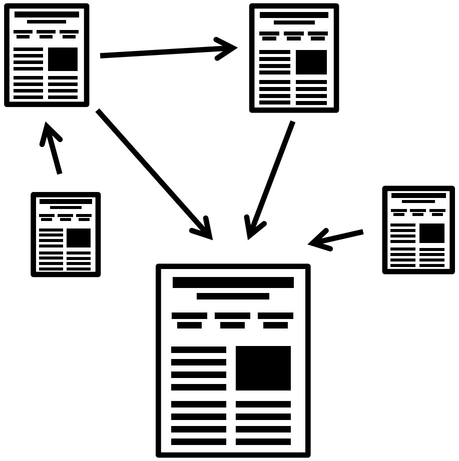
Graph Operations (Scala)

```scala
class Graph[VD, ED] {
    // Table Views -----------------------
    def vertices: RDD[(VertexId, VD)]
    def edges: RDD[Edge[ED]]
    def triplets: RDD[EdgeTriplet[VD, ED]]
    // Transformations ------------------------------------------
    def mapVertices[VD2](f: (VertexId, VD) => VD2): Graph[VD2, ED]
    def mapEdges[ED2](f: Edge[ED] => ED2): Graph[VD2, ED]
    def reverse: Graph[VD, ED]
    def subgraph(epred: EdgeTriplet[VD, ED] => Boolean,
                 vpred: (VertexId, VD) => Boolean): Graph[VD, ED]
    // Joins ----------------------------------------
    def outerJoinVertices[U, VD2]
        (tbl: RDD[(VertexId, U)])
        (f: (VertexId, VD, Option[U]) => VD2): Graph[VD2, ED]
    // Computation ----------------------------------
    def mapReduceTriplets[A](
        sendMsg: EdgeTriplet[VD, ED] => Iterator[(VertexId, A)],
        mergeMsg: (A, A) => A): RDD[(VertexId, A)]
```

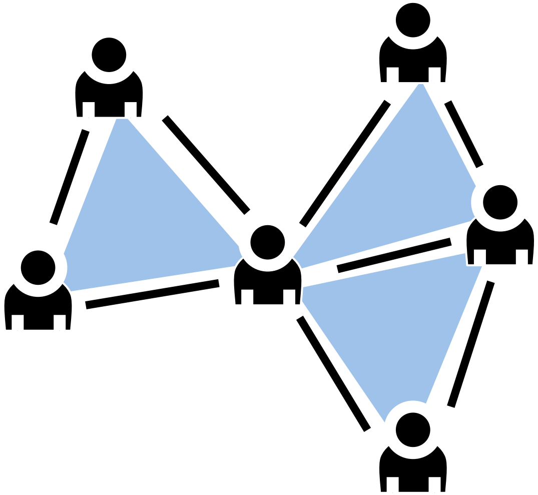
Built-in Algorithms (Scala)

```
    // Continued from previous slide
    def pageRank(tol: Double): Graph[Double, Double]
    def triangleCount(): Graph[Int, ED]
    def connectedComponents(): Graph[VertexId, ED]
    // ...and more: org.apache.spark.graphx.lib
}
```

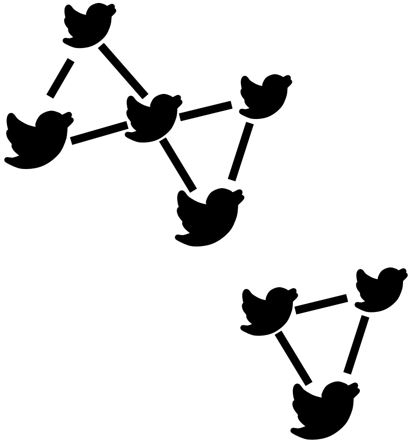
PageRank



Triangle Count

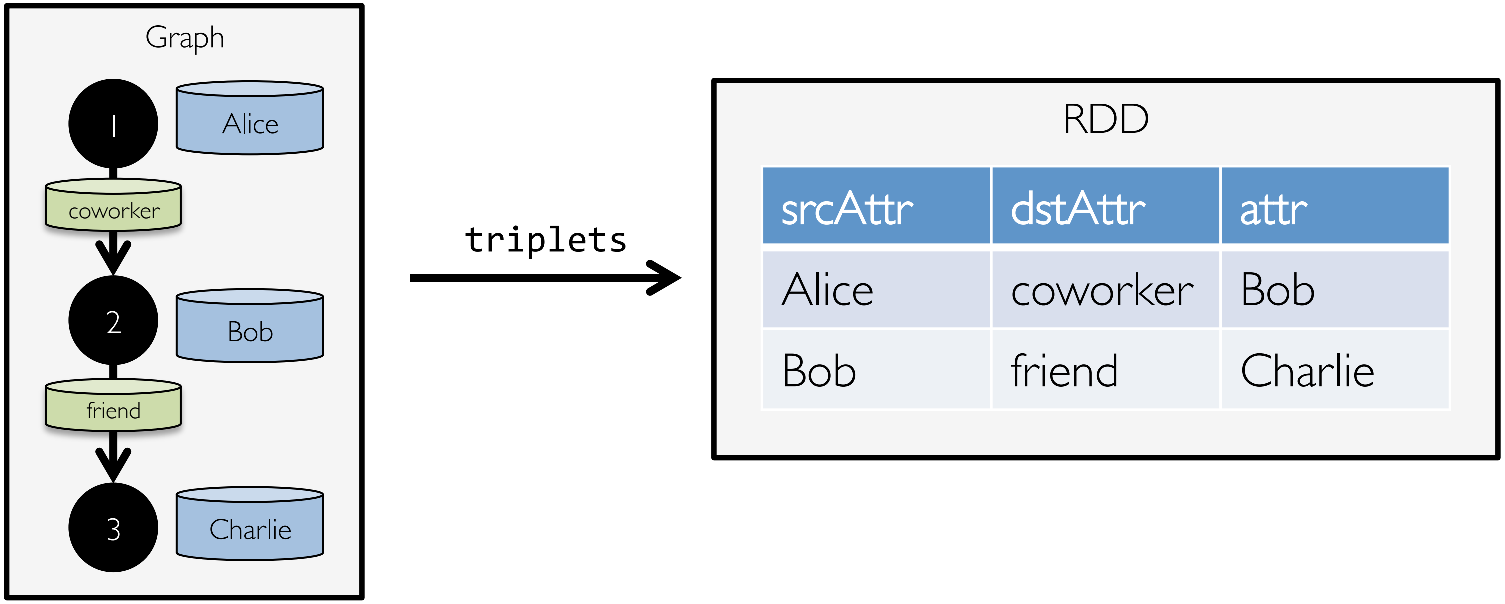


Connected Components



The triplets view

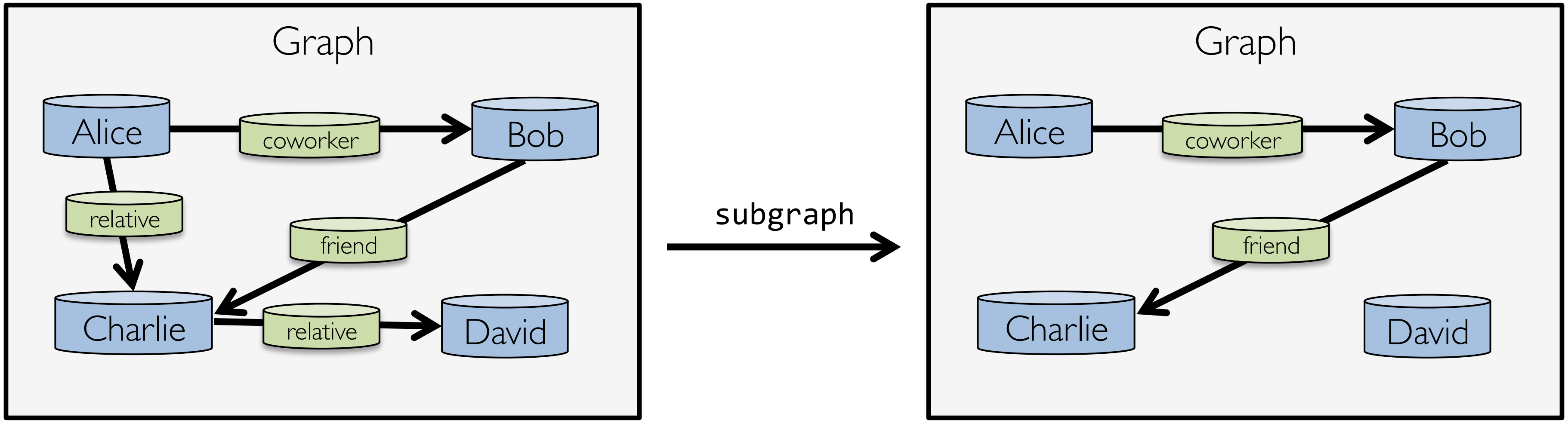
```
class Graph[VD, ED] {
    def triplets: RDD[EdgeTriplet[VD, ED]]
}

class EdgeTriplet[VD, ED](
  val srcId: VertexId, val dstId: VertexId, val attr: ED,
  val srcAttr: VD, val dstAttr: VD)
```



srcAttr	dstAttr	attr
Alice	coworker	Bob
Bob	friend	Charlie

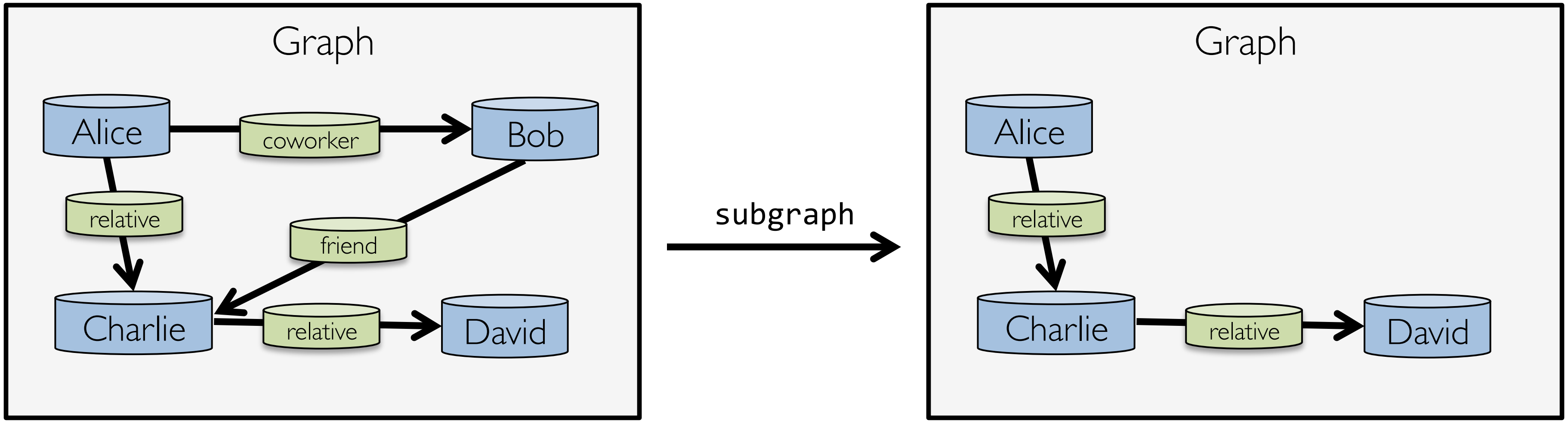
The **subgraph** transformation

```
class Graph[VD, ED] {
    def subgraph(epred: EdgeTriplet[VD, ED] => Boolean,
                 vpred: (VertexId, VD) => Boolean): Graph[VD, ED]
}

graph.subgraph(epred = (edge) => edge.attr != “relative”)
```



The **subgraph** transformation

```
class Graph[VD, ED] {
    def subgraph(epred: EdgeTriplet[VD, ED] => Boolean,
                 vpred: (VertexId, VD) => Boolean): Graph[VD, ED]
}

graph.subgraph(vpred = (id, name) => name != “Bob”)
```

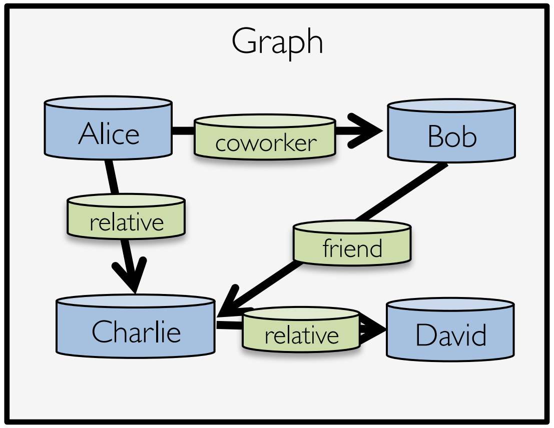


Computation with `mapReduceTriplets`

```
class Graph[VD, ED] {
  def mapReduceTriplets[A](
    sendMsg: EdgeTriplet[VD, ED] => Iterator[(VertexId, A)],
    mergeMsg: (A, A) => A): RDD[(VertexId, A)]
}
```

⚠ upgrade to `aggregateMessages` in Spark 1.2.0

```
graph.mapReduceTriplets(
  edge => Iterator(
    (edge.srcId, 1),
    (edge.dstId, 1)),
  _ + _)
```



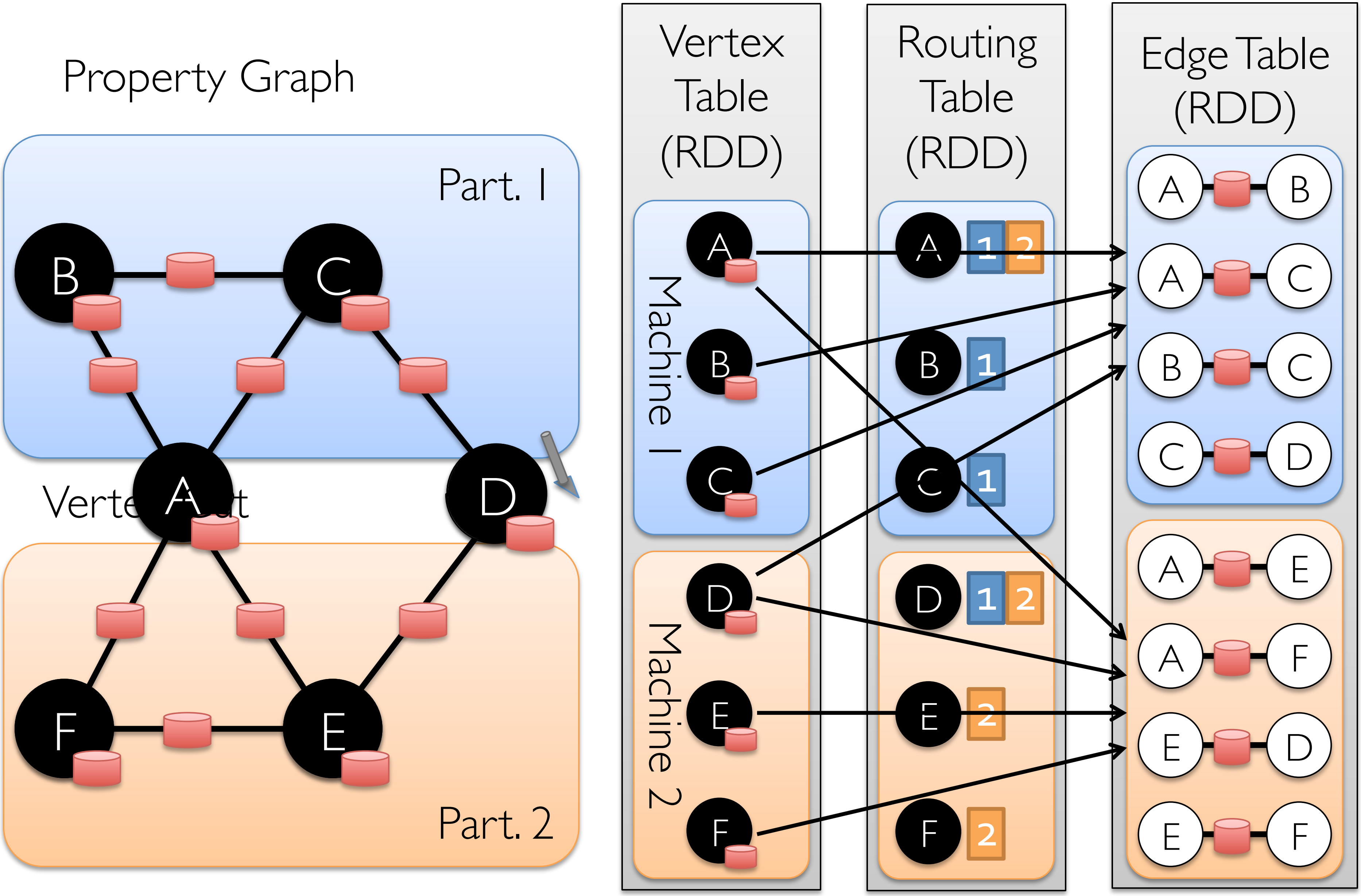
`mapReduceTriplets` →

RDD

vertex id	degree
Alice	2
Bob	2
Charlie	3
David	1

How GraphX Works

Encoding Property Graphs as RDDs



Property Graph

Part. 1

Vertex Cut

Part. 2

Vertex Table (RDD)

Machine 1

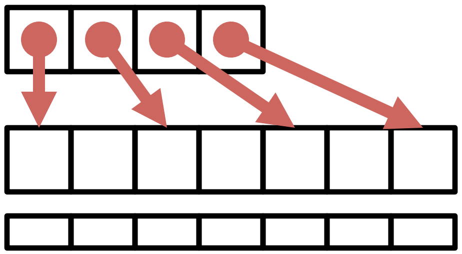
Machine 2

Routing Table (RDD)

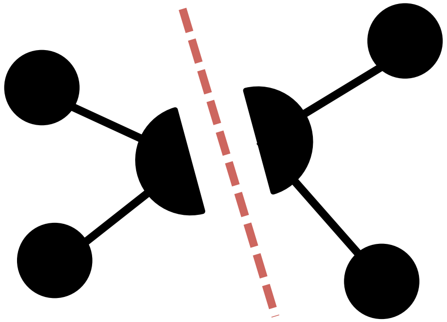
Edge Table (RDD)

Graph System Optimizations

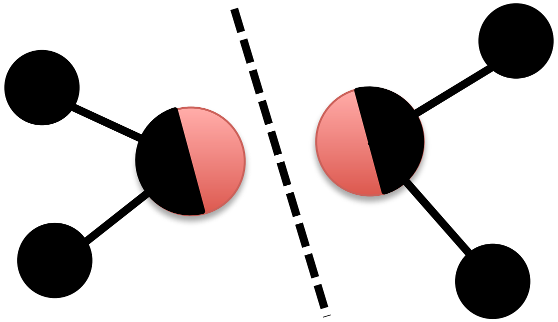
Specialized
Data-Structures



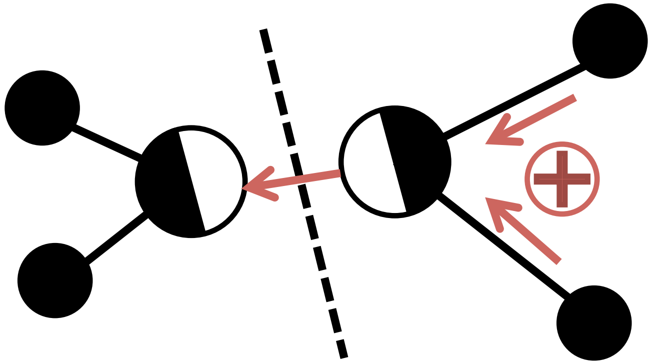
Vertex-Cuts
Partitioning



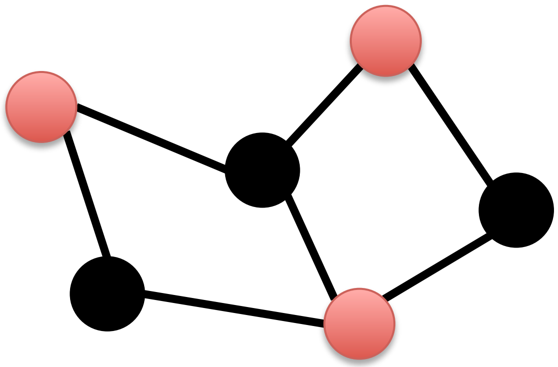
Remote
Caching / Mirroring



Message Combiners

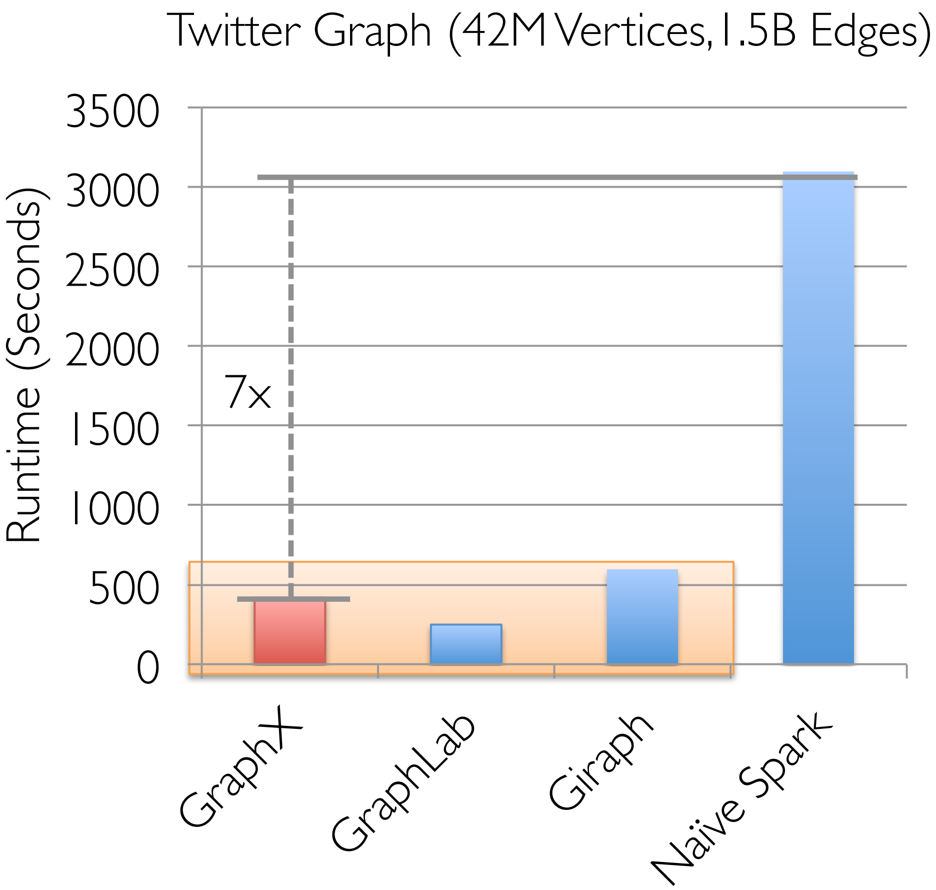


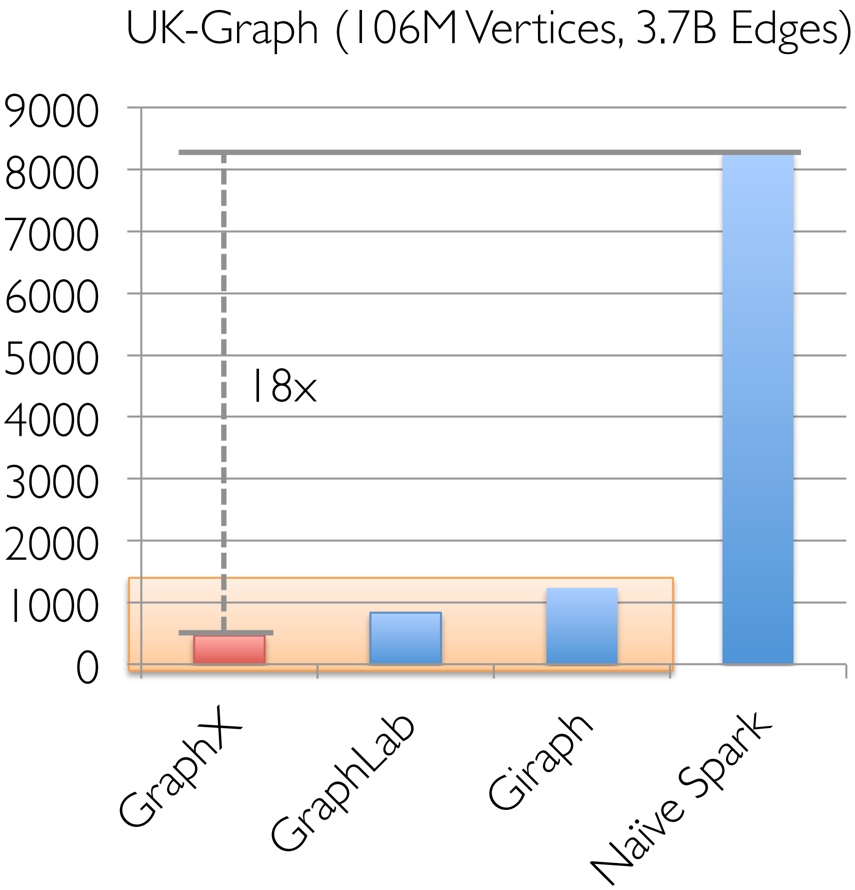
Active Set Tracking



PageRank Benchmark

EC2 Cluster of 16 x m2.4xLarge (8 cores) + 1GigE





GraphX performs comparably to state-of-the-art graph processing systems.

Future of GraphX

1. Language support
   a) Java API: PR #3234
   b) Python API: collaborating with Intel, SPARK-3789

2. More algorithms
   a) LDA (topic modeling): PR #2388
   b) Correlation clustering
   c) Your algorithm here?

3. Speculative
   a) Streaming/time-varying graphs
   b) Graph database–like queries

Thanks!

http://spark.apache.org/graphx

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