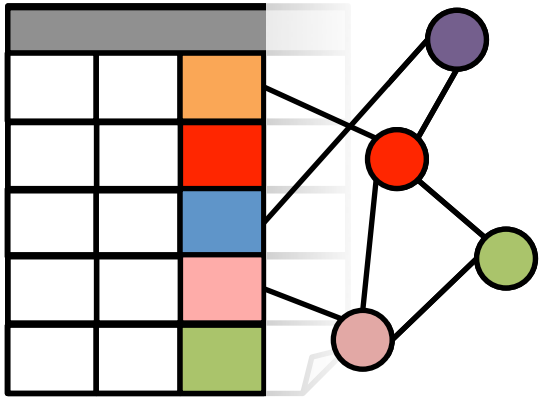
GraphX

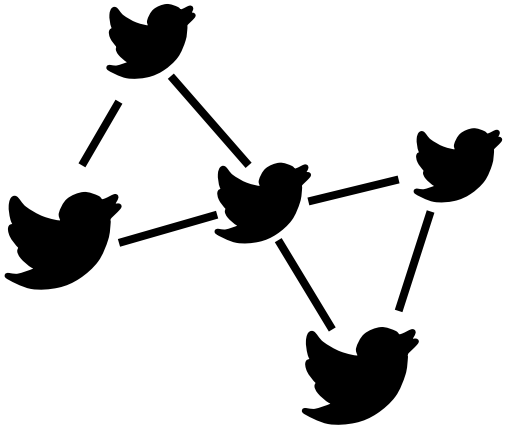


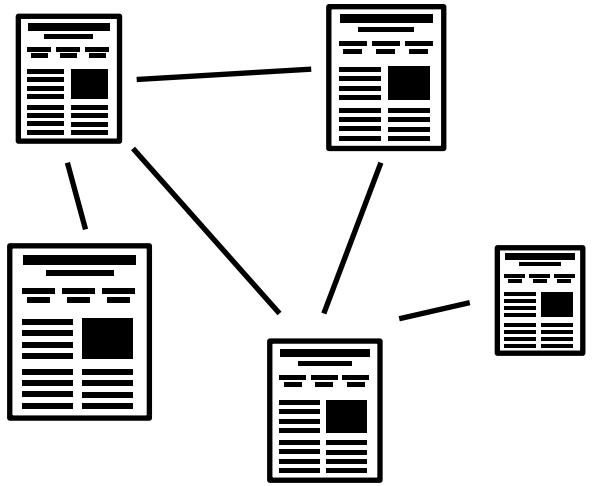
Graph Analytics in Spark

Ankur Dave
Graduate Student, UC Berkeley AMPLab

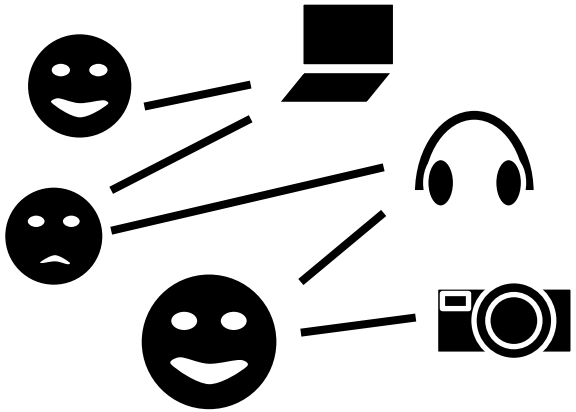
Joint work with Joseph Gonzalez, Reynold Xin, Daniel Crankshaw, Michael Franklin, and Ion Stoica

amplab
UC BERKELEY

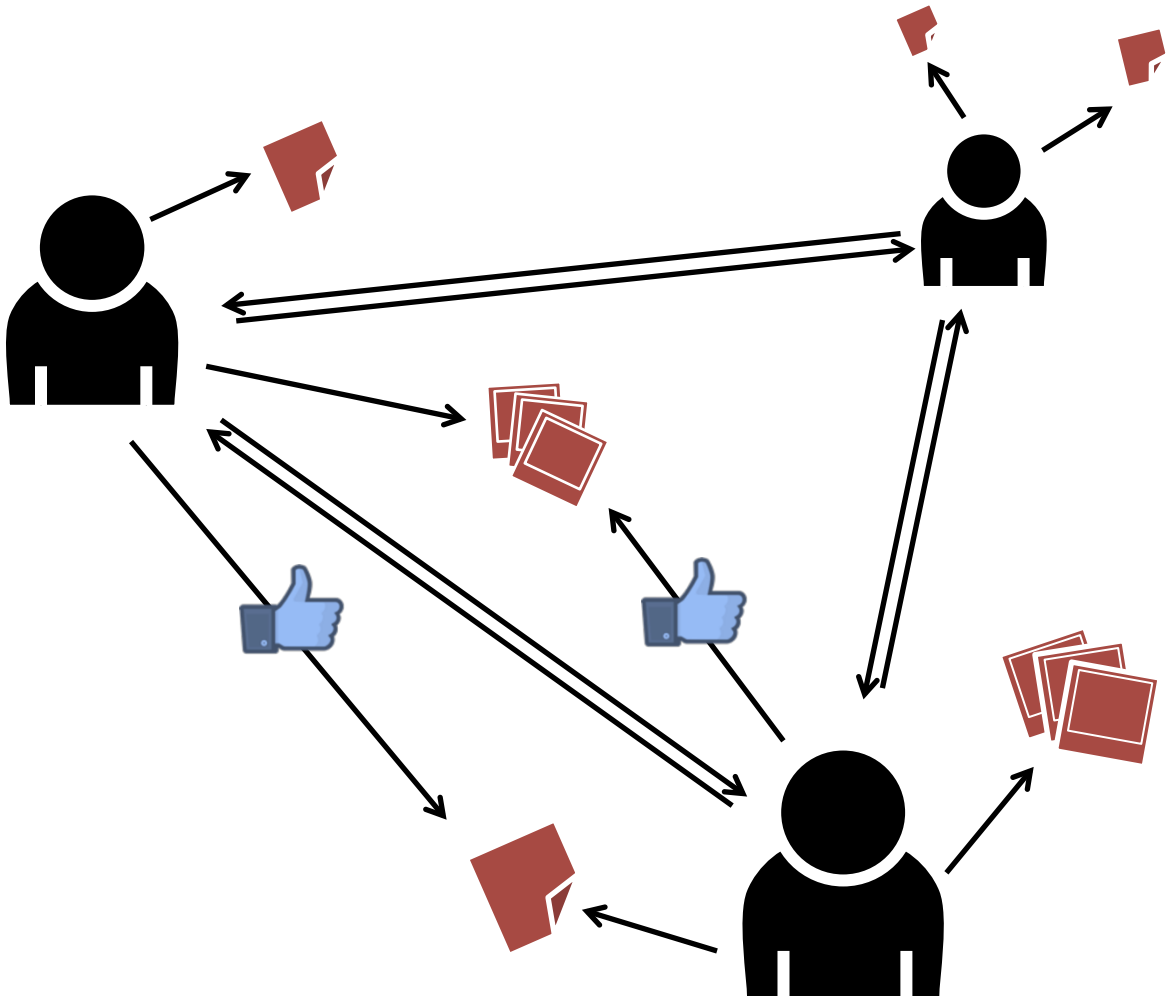




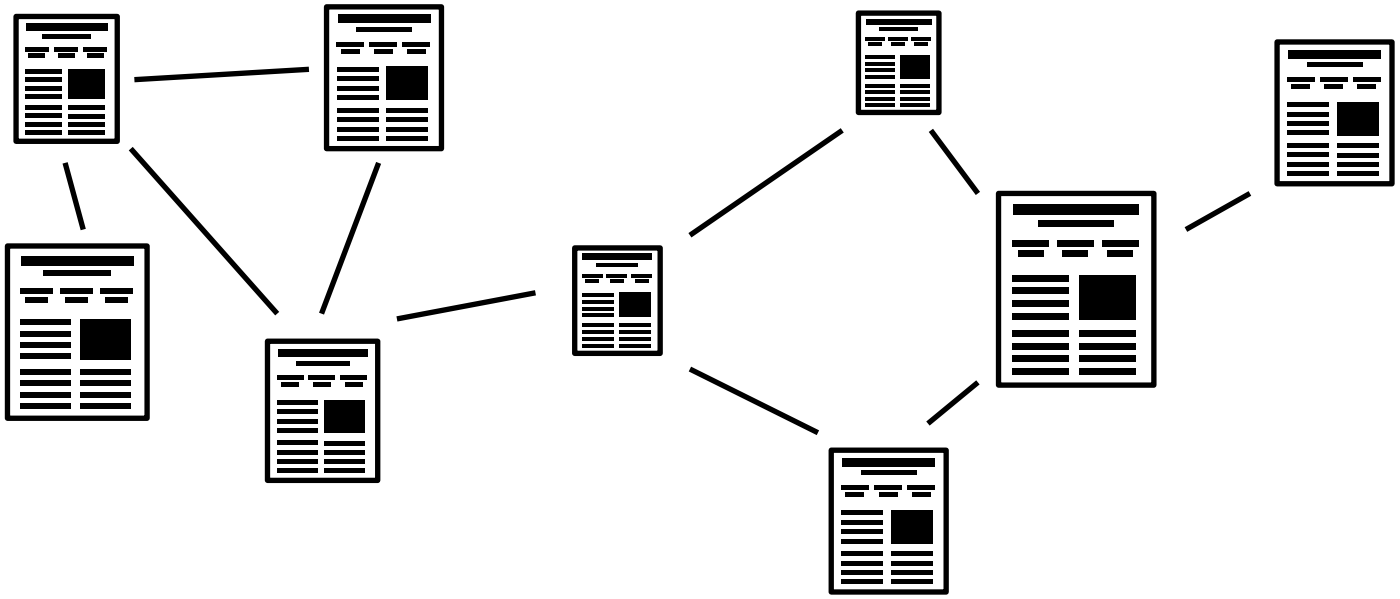
Graphs are Everywhere



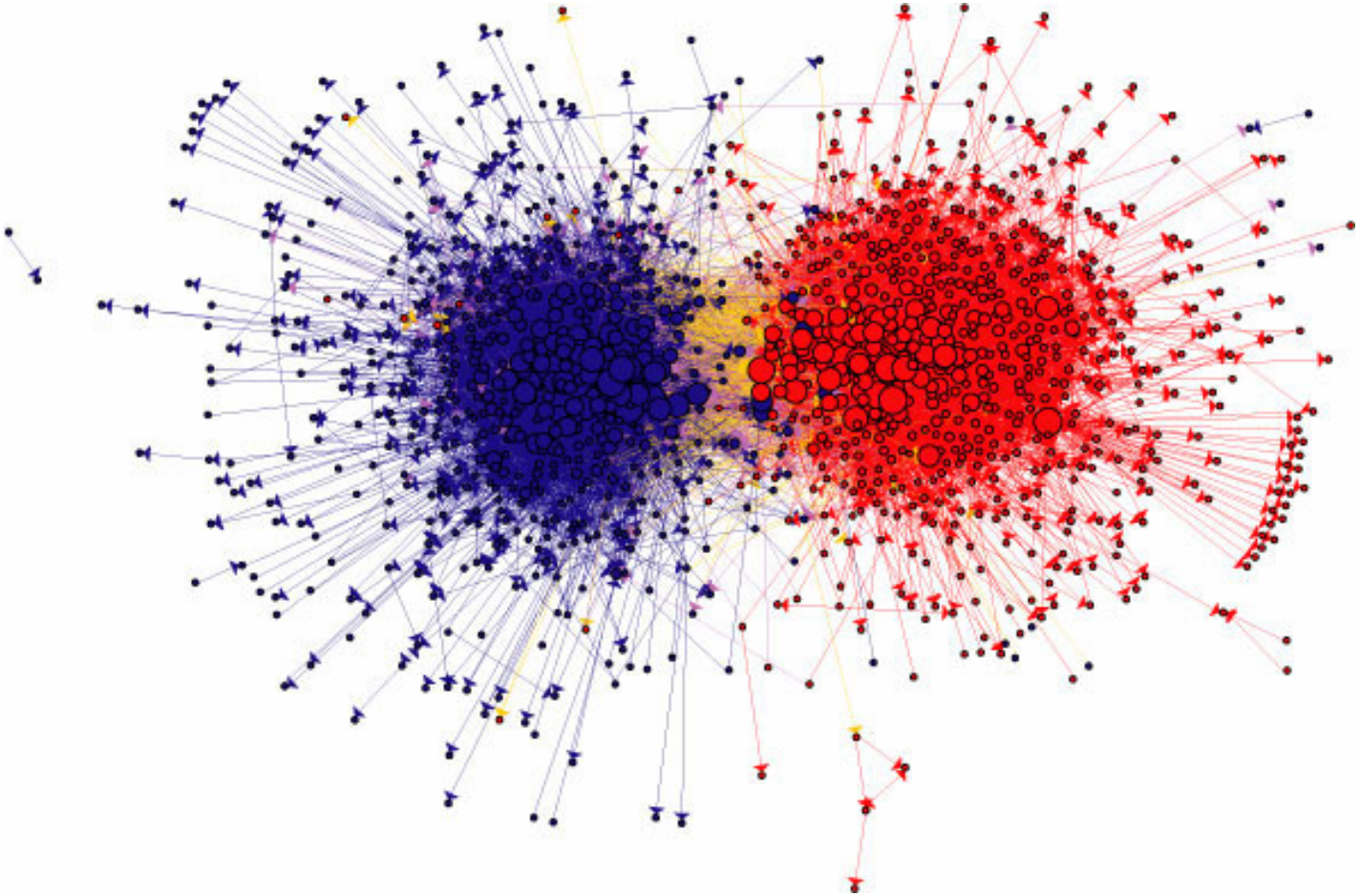
Social Networks



Web Graphs

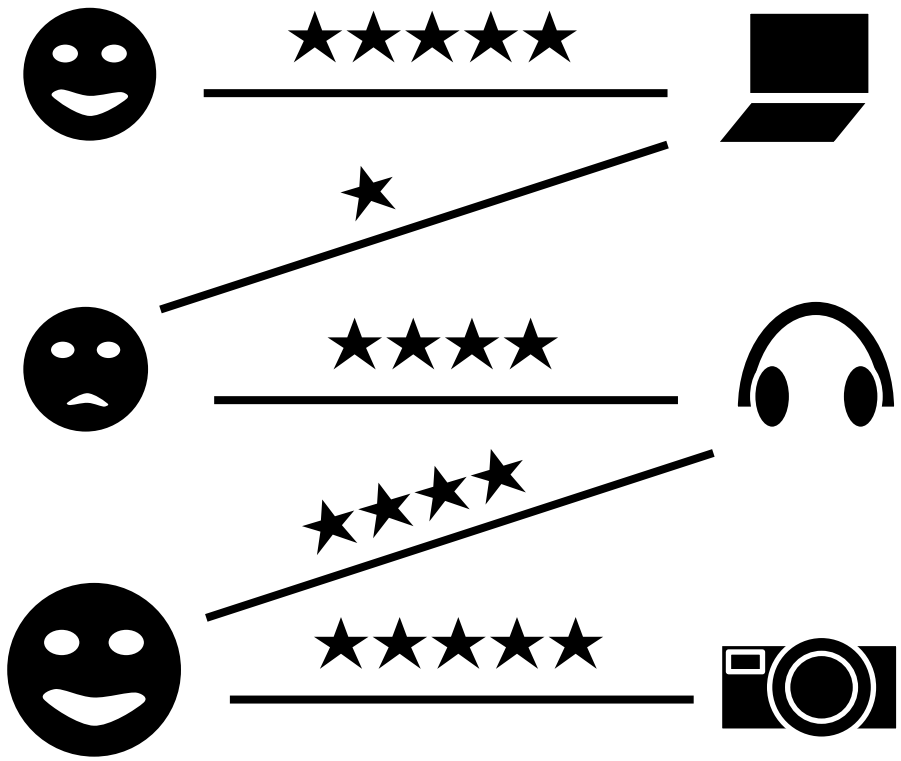


Web Graphs



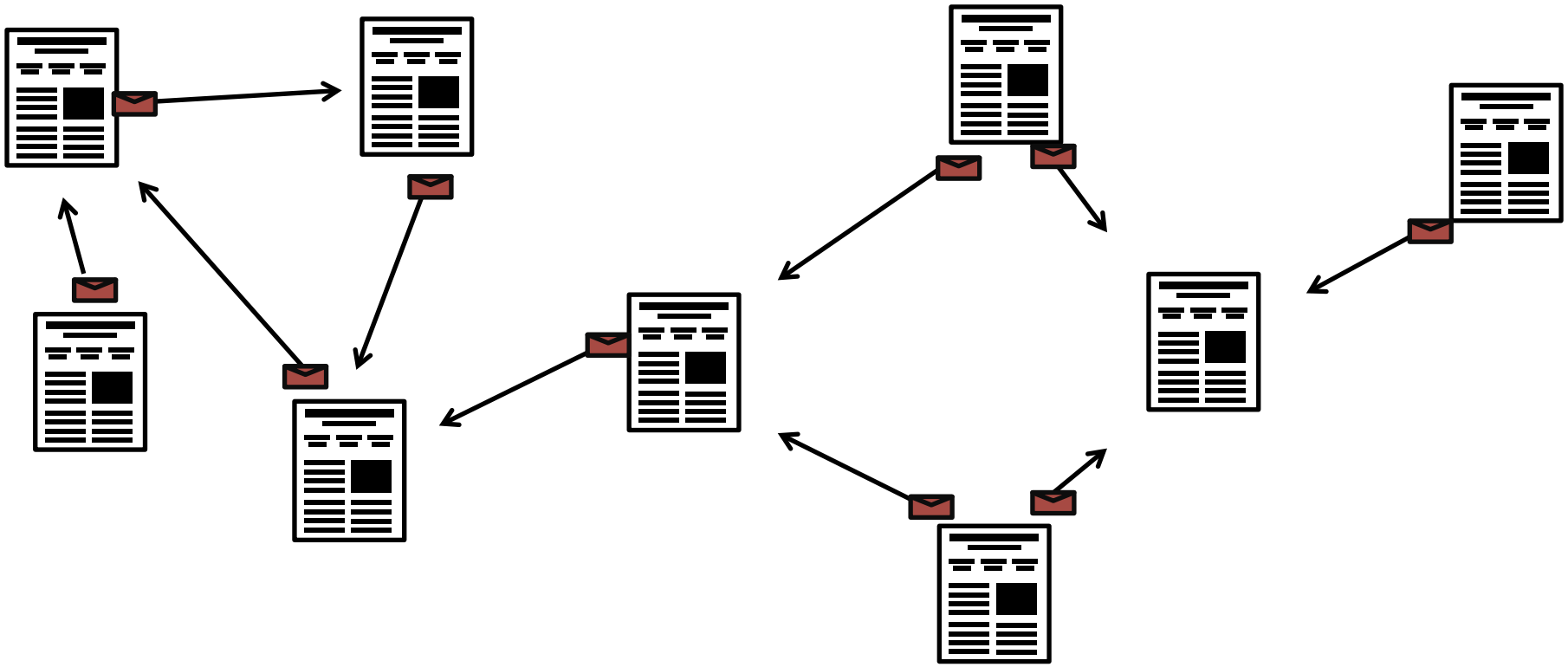
"The political blogosphere and the 2004 U.S. election: divided they blog." Adamic and Glance, 2005.

User-Item Graphs

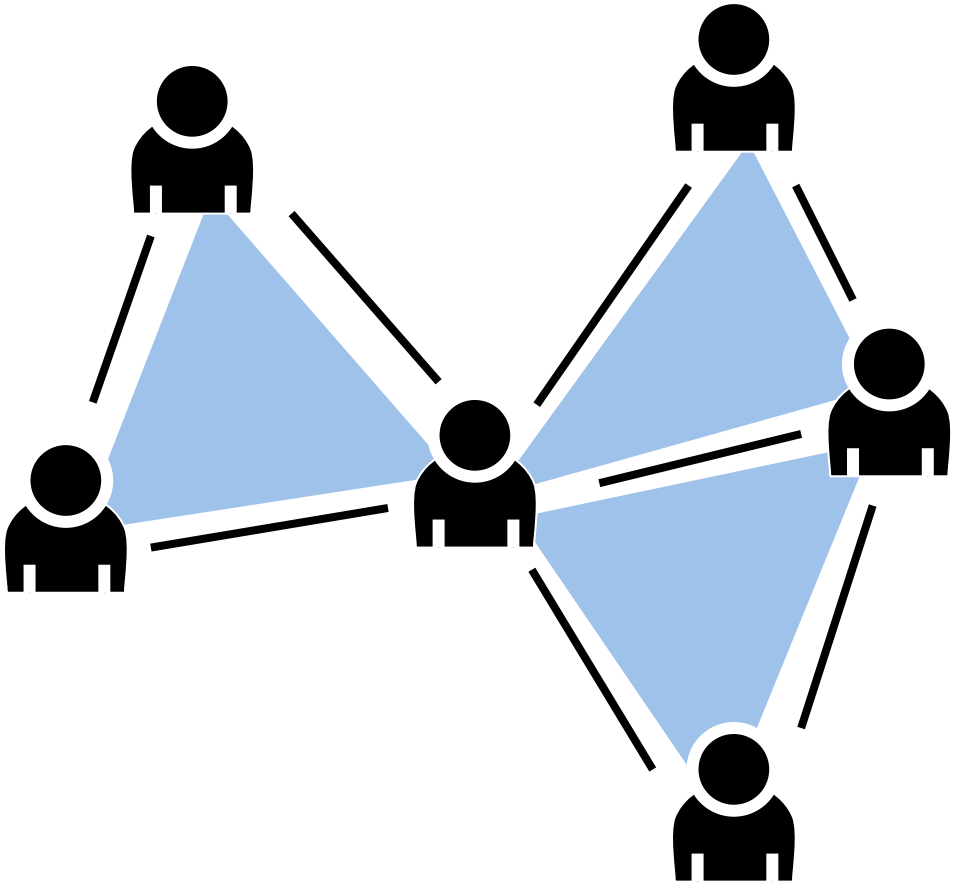


Graph Algorithms

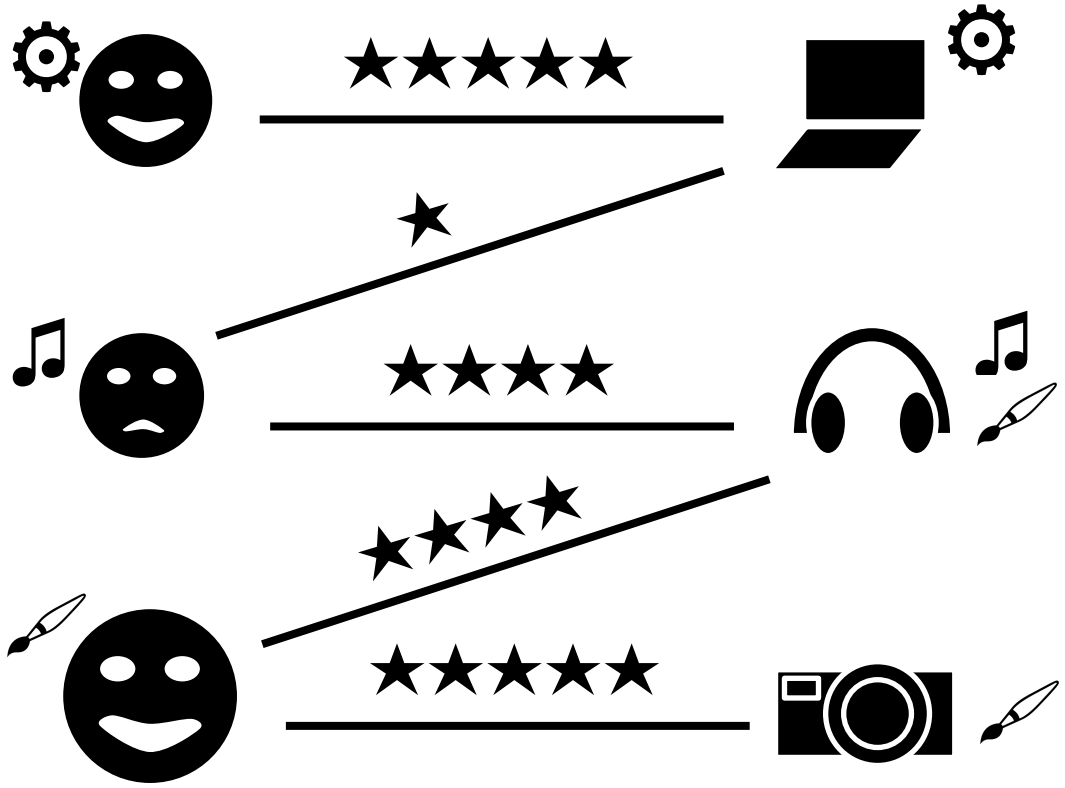
PageRank



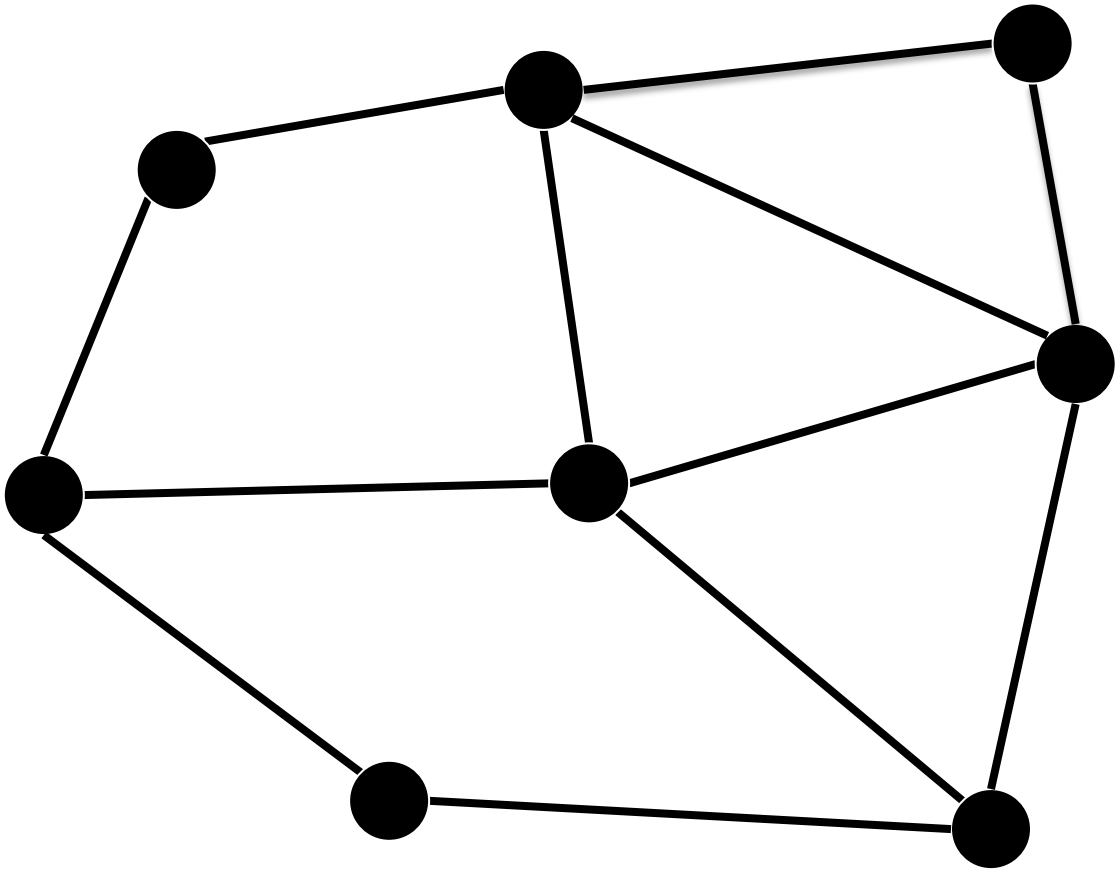
Triangle Counting



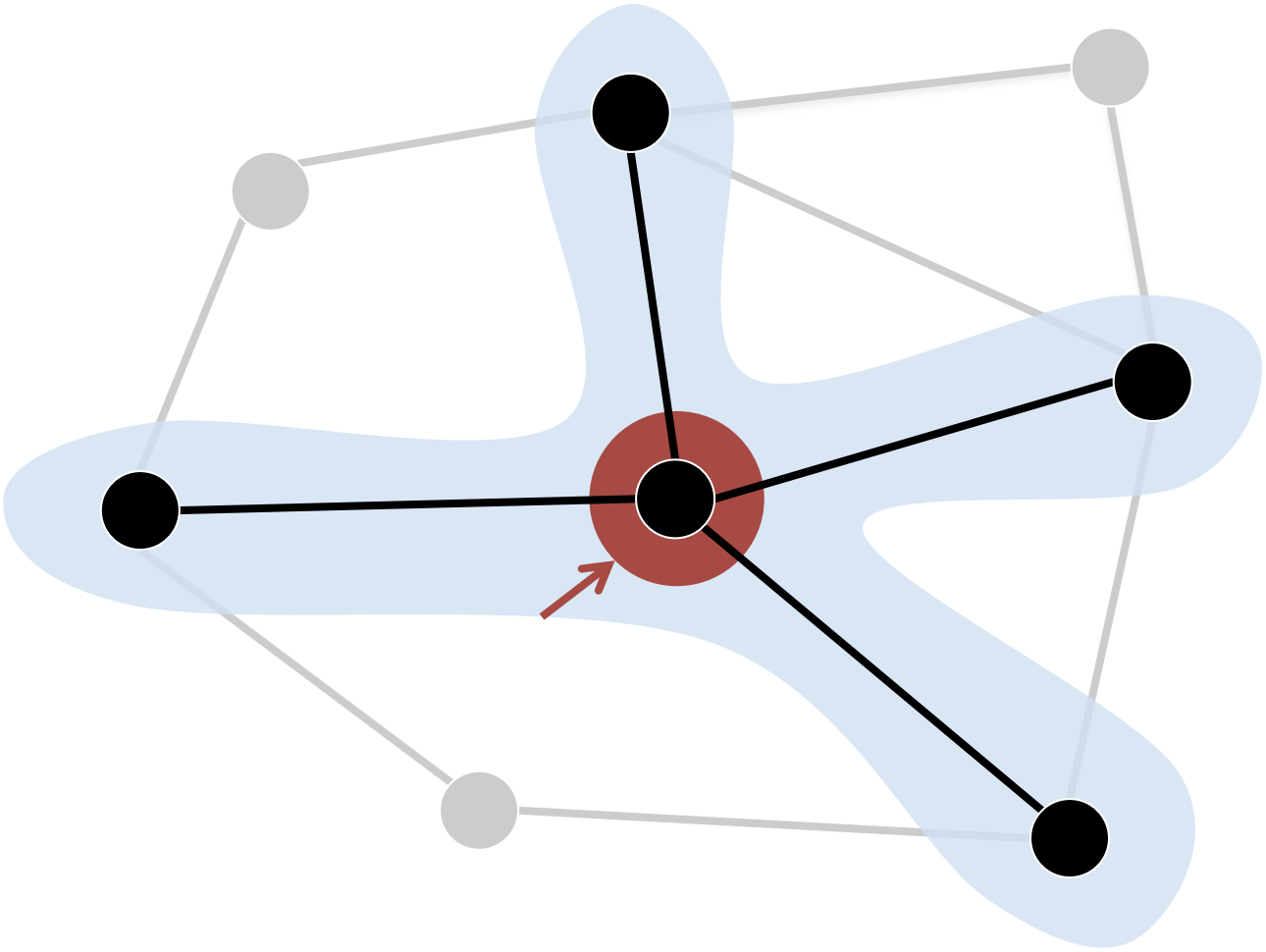
Collaborative Filtering



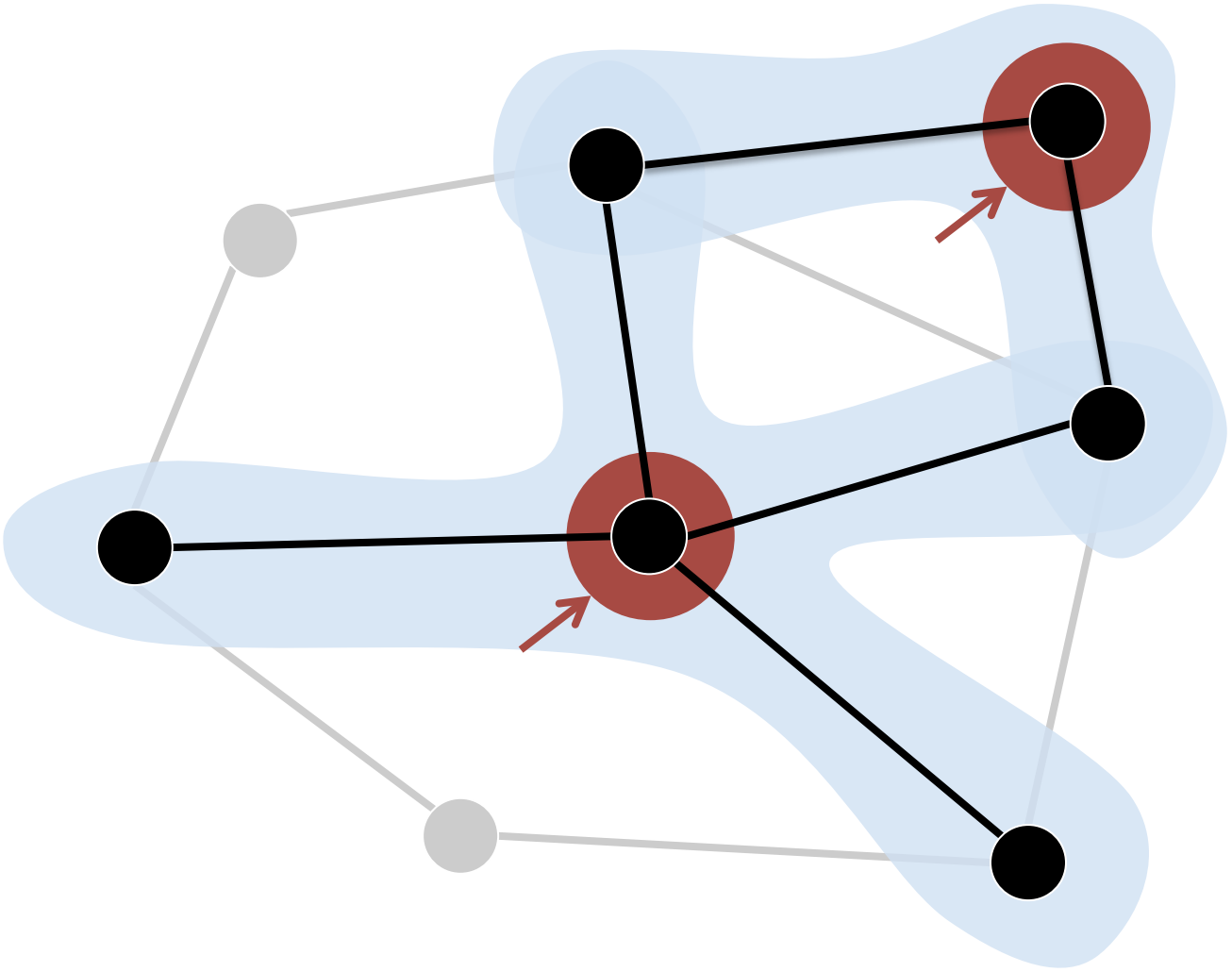
The Graph-Parallel Pattern



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

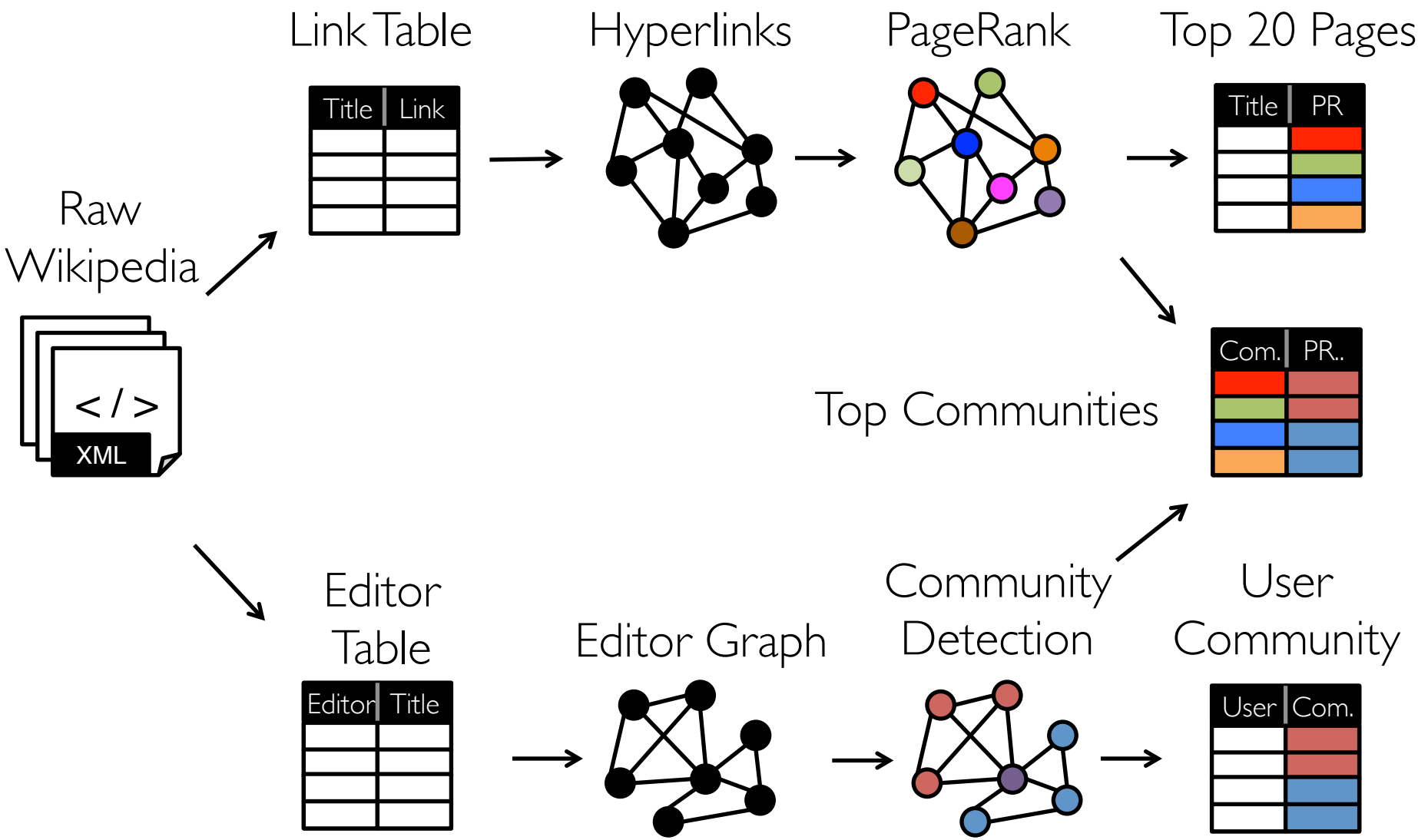
Semi-supervised ML
- » Graph SSL
- » CoEM

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

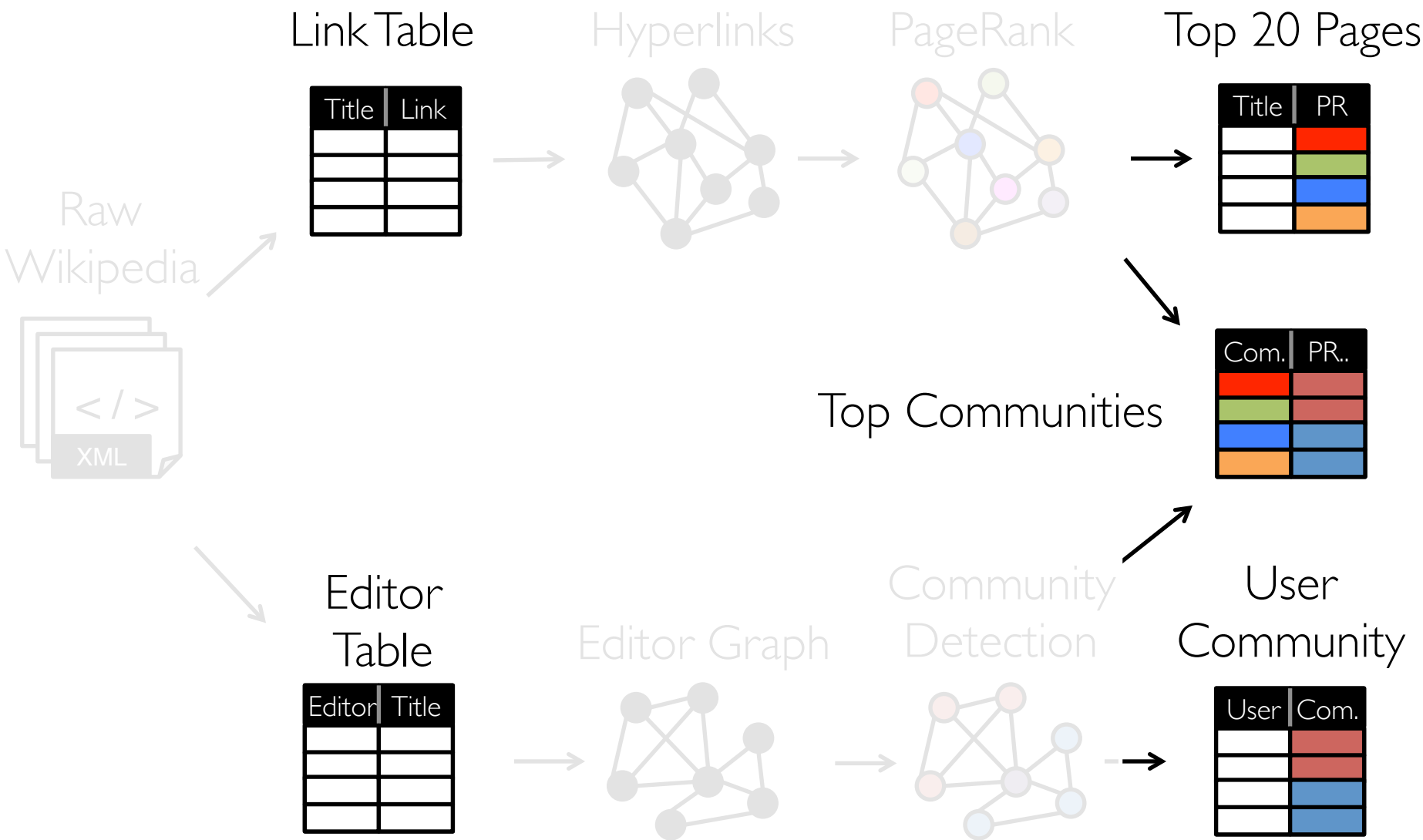
Graph Analytics
- » PageRank
- » Personalized PageRank
- » Shortest Path
- » Graph Coloring

Classification
- » Neural Networks

Modern Analytics



Tables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Hyperlinks
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Top 20 Pages
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PR
Raw
Wikipedia
XML
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Com.
PR..
Editor
Table
Editor Graph
Community
Detection
User
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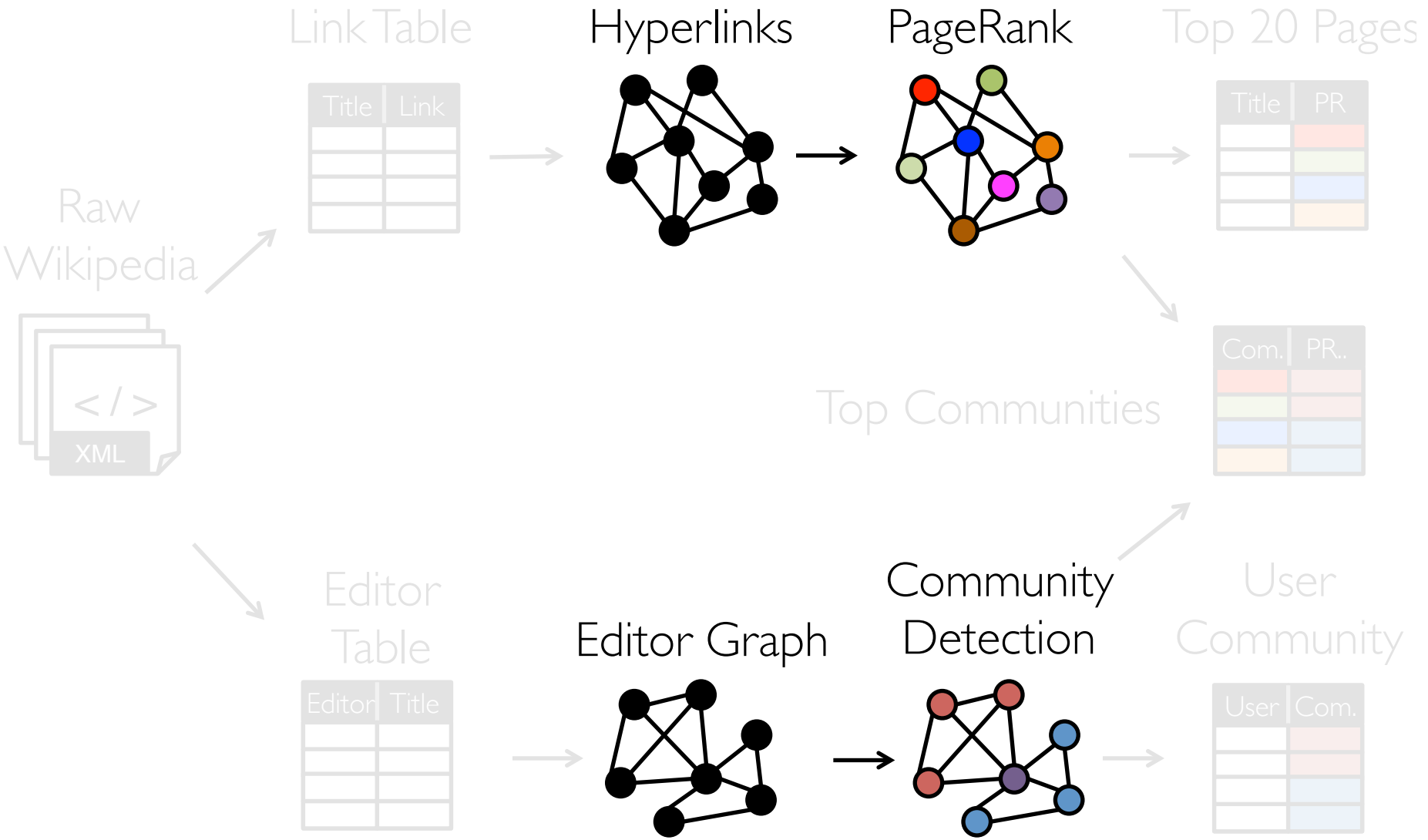
Title
User
Com.

Graphs


Link Table
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Top 20 Pages
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PR
Raw
Wikipedia
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Top Communities
Com.
PR..
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Table
Editor
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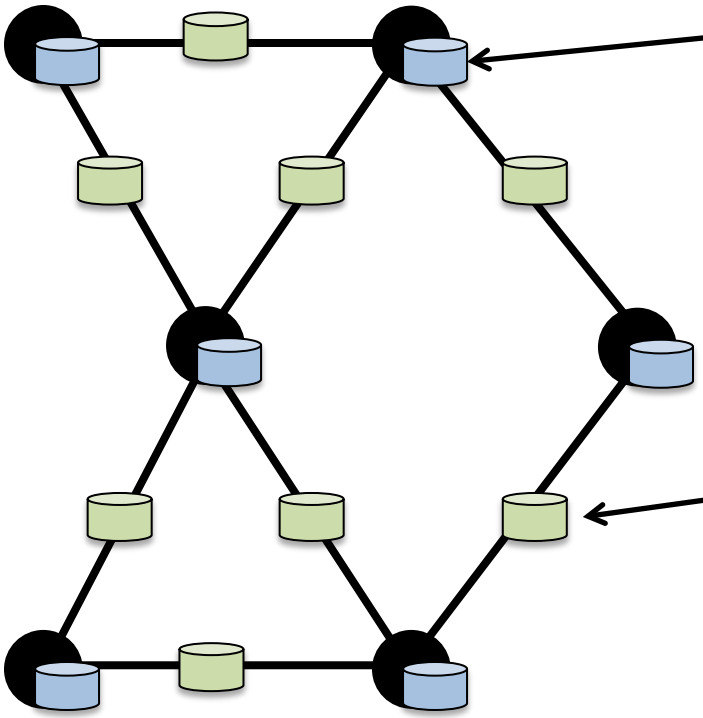
Com.

The GraphX API

Property Graphs



Vertex Property:

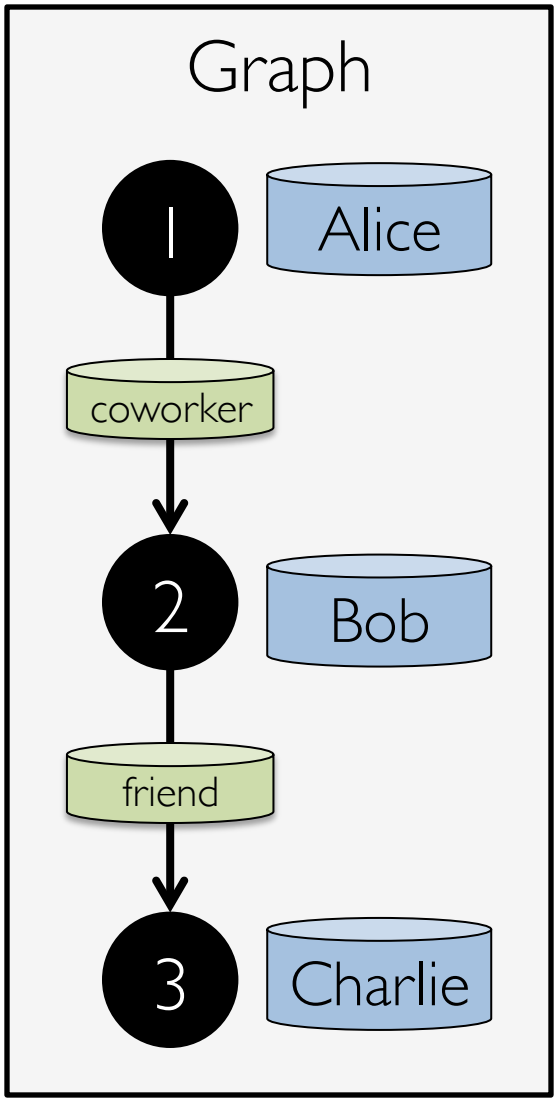
- User Profile
- Current PageRank Value

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)
```



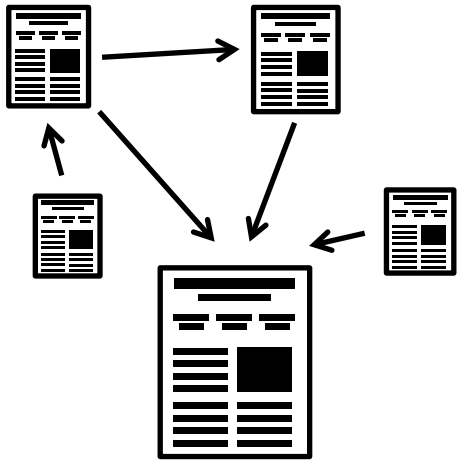
Graph Operations (Scala)

```
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)]
```

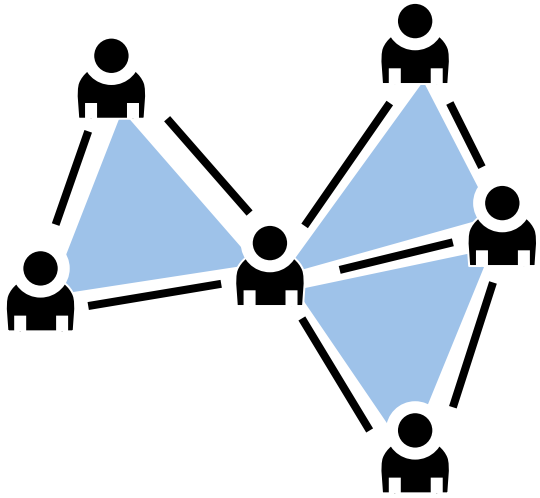
Built-in Algorithms (Scala)

```
    // 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
}
```

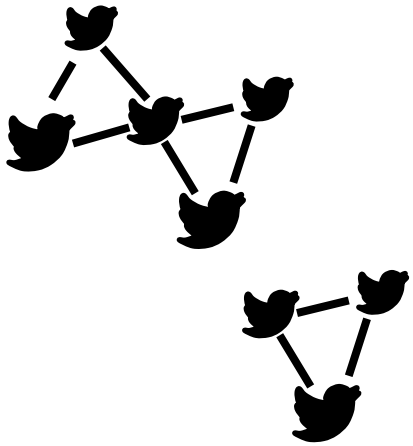
PageRank



Triangle Count

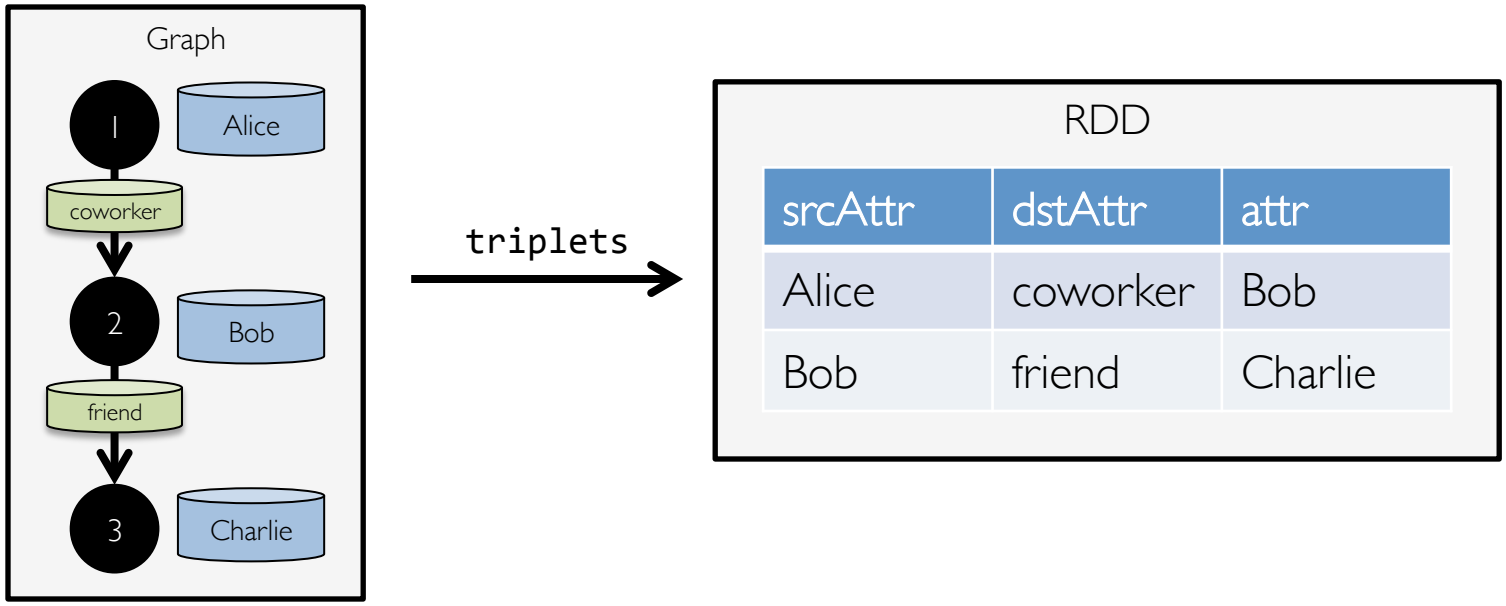


Connected Components



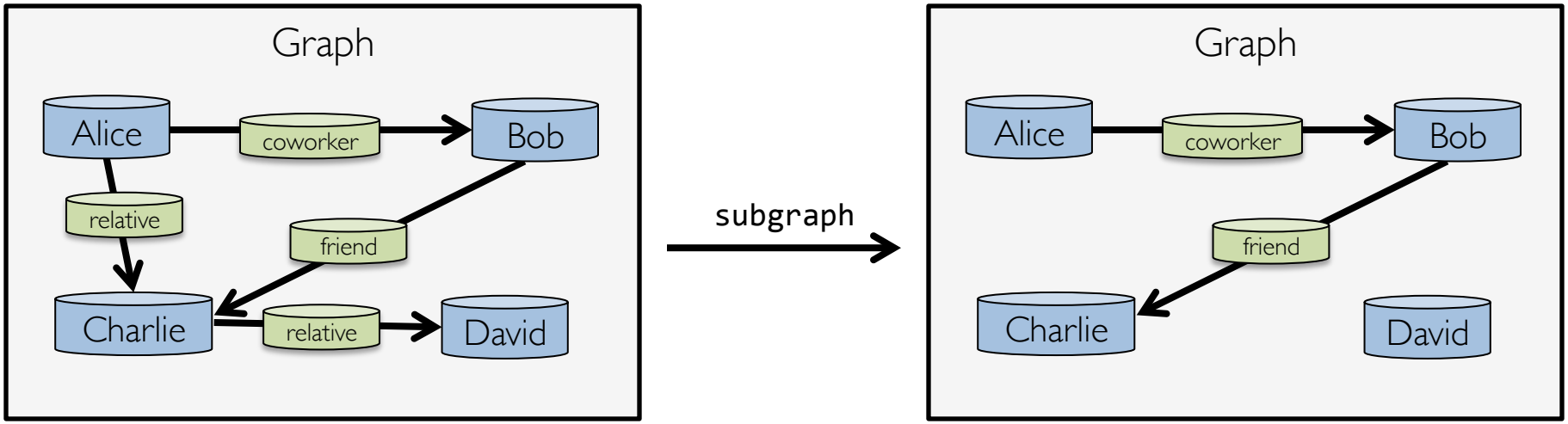
The `triplets` view

```
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)
```



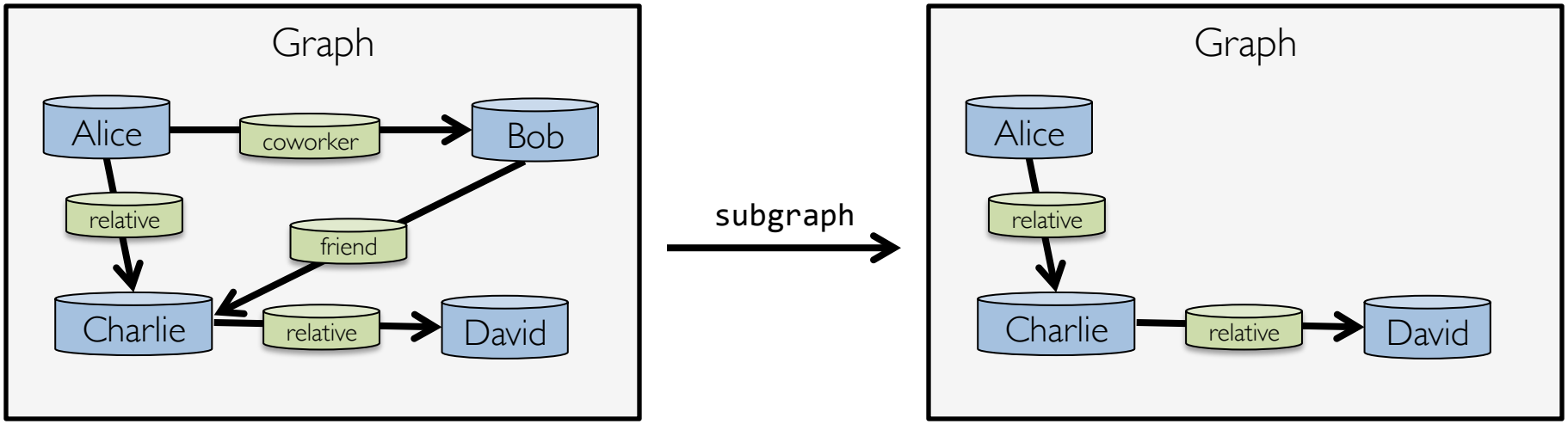
The **subgraph** transformation

```
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")
```

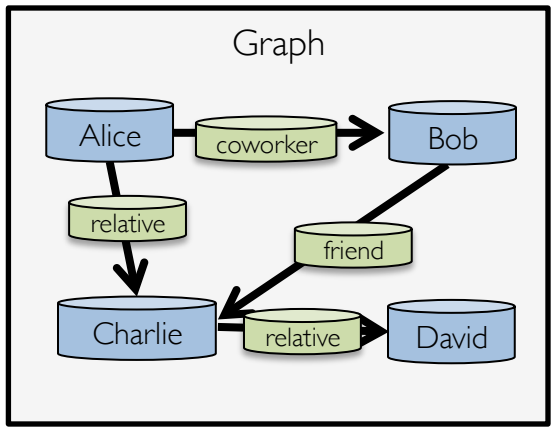


Computation with `mapReduceTriplets`

```
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)),
  _ + _)
```



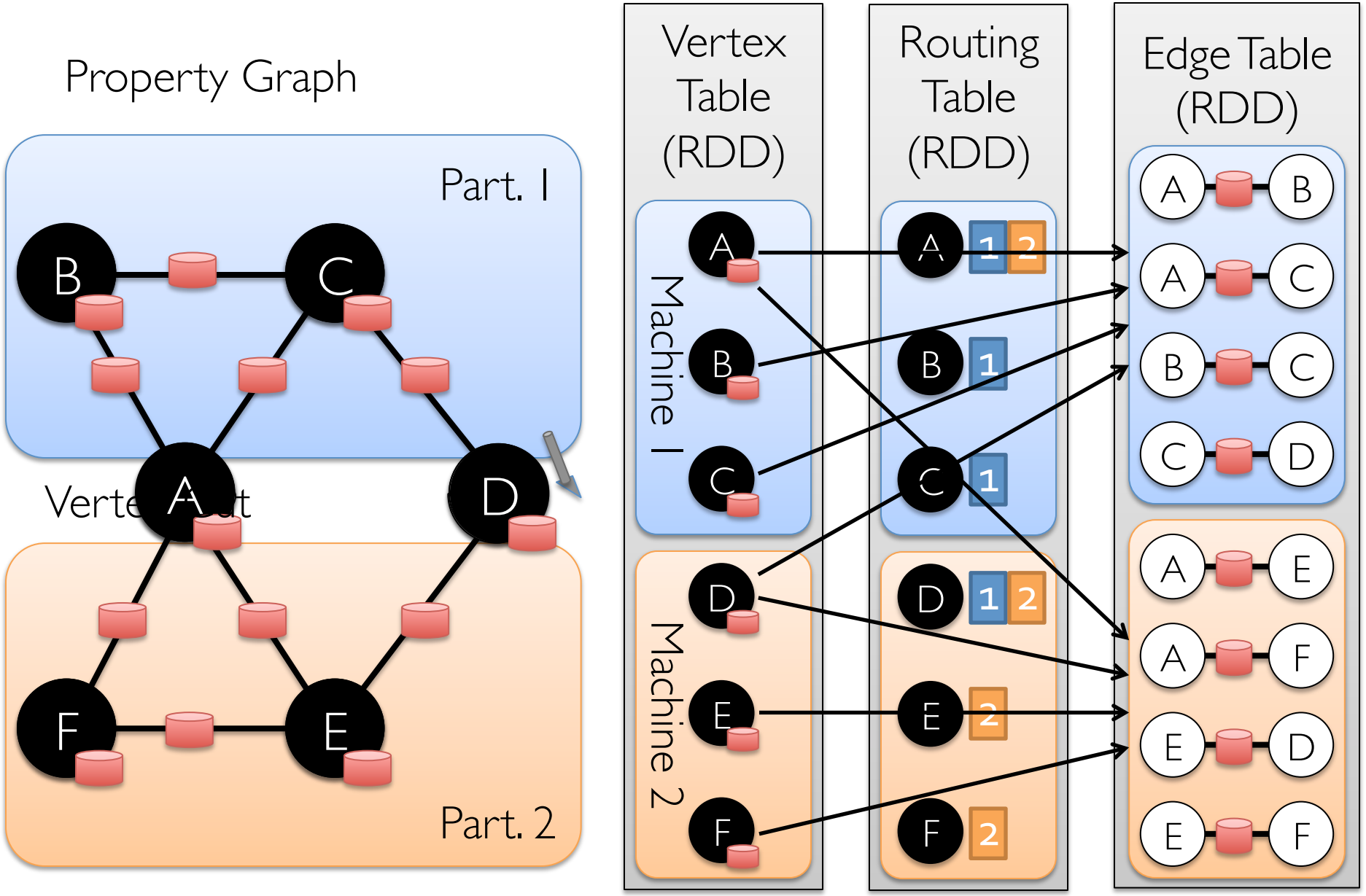
`mapReduceTriplets`

RDD

vertex id	degree
Alice	2
Bob	2
Charlie	3
David	1

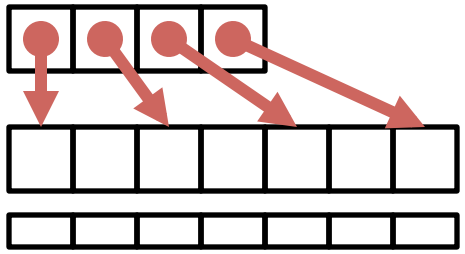
How GraphX Works

Encoding Property Graphs as RDDs

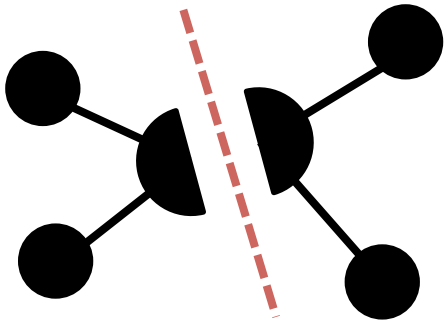


Graph System Optimizations

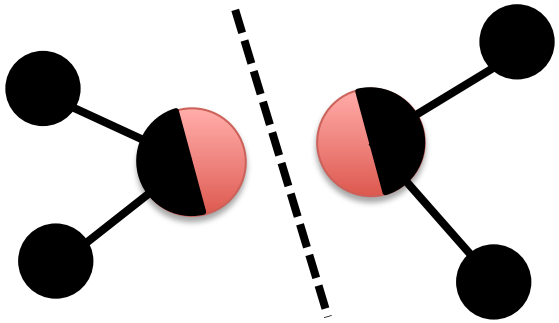
Specialized Data-Structures



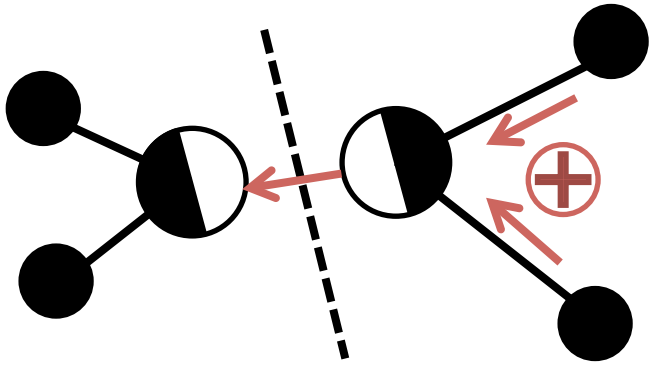
Vertex-Cuts Partitioning



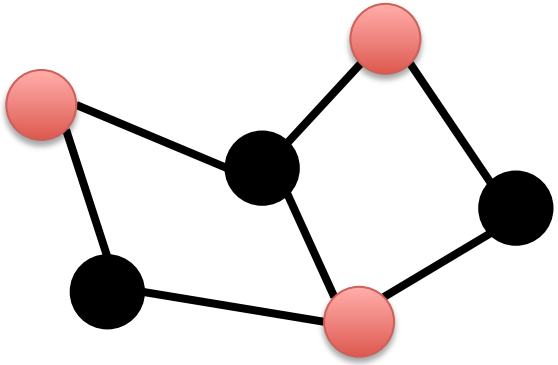
Remote Caching / Mirroring



Message Combiners

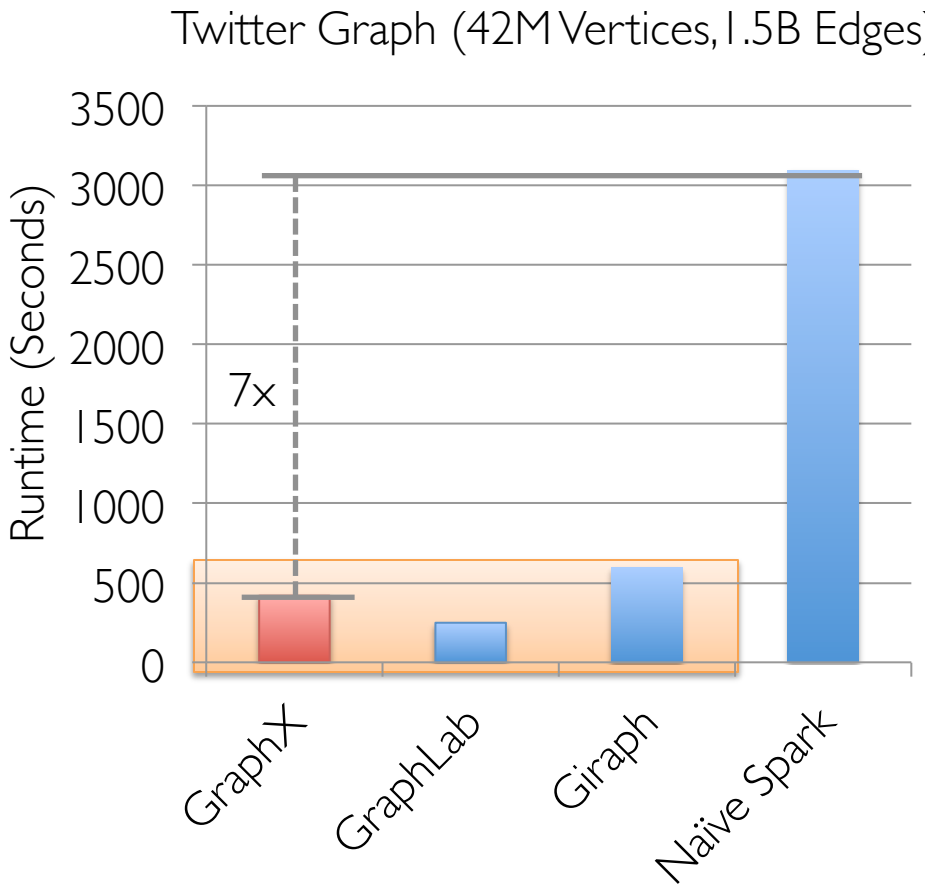


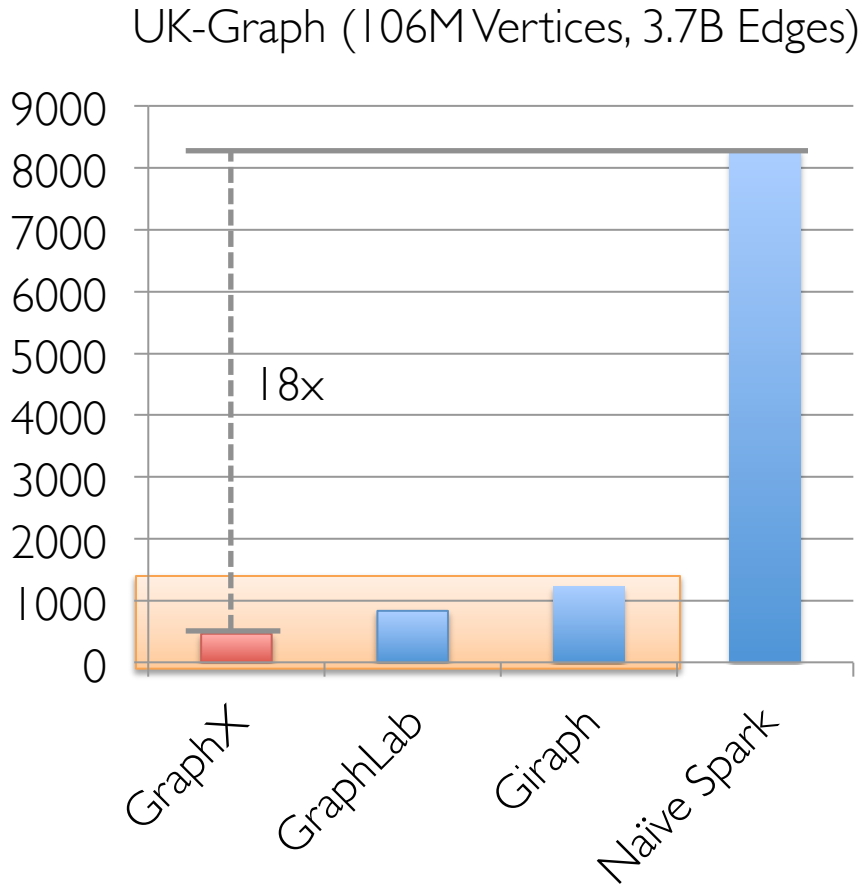
Active Set Tracking



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

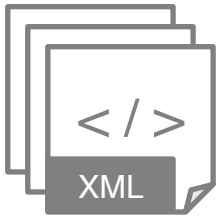
1. Language support
   a) Java API: PR #3234
   b) Python API: collaborating with Intel, SPARK-3789

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

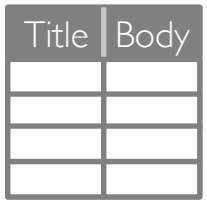
3. Speculative
   a) Streaming/time-varying graphs
   b) Graph database–like queries

Try GraphX Today

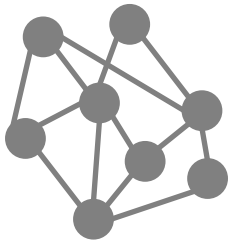
Raw Wikipedia



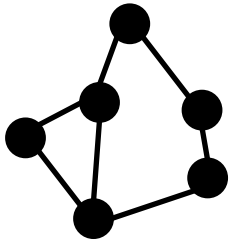
Text Table



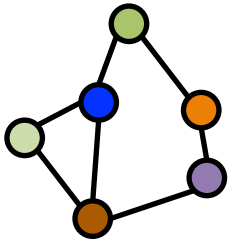
Hyperlinks



Berkeley subgraph



PageRank



Top 20 Pages

Thanks!

http://spark.apache.org/graphx

ankurd@eecs.berkeley.edu

jegonzal@eecs.berkeley.edu
rxin@eecs.berkeley.edu
crankshaw@eecs.berkeley.edu