Graph Mining with Spark

Distributed Big Data Analytics Seminar – Tim Draeger, Ricarda Schüler

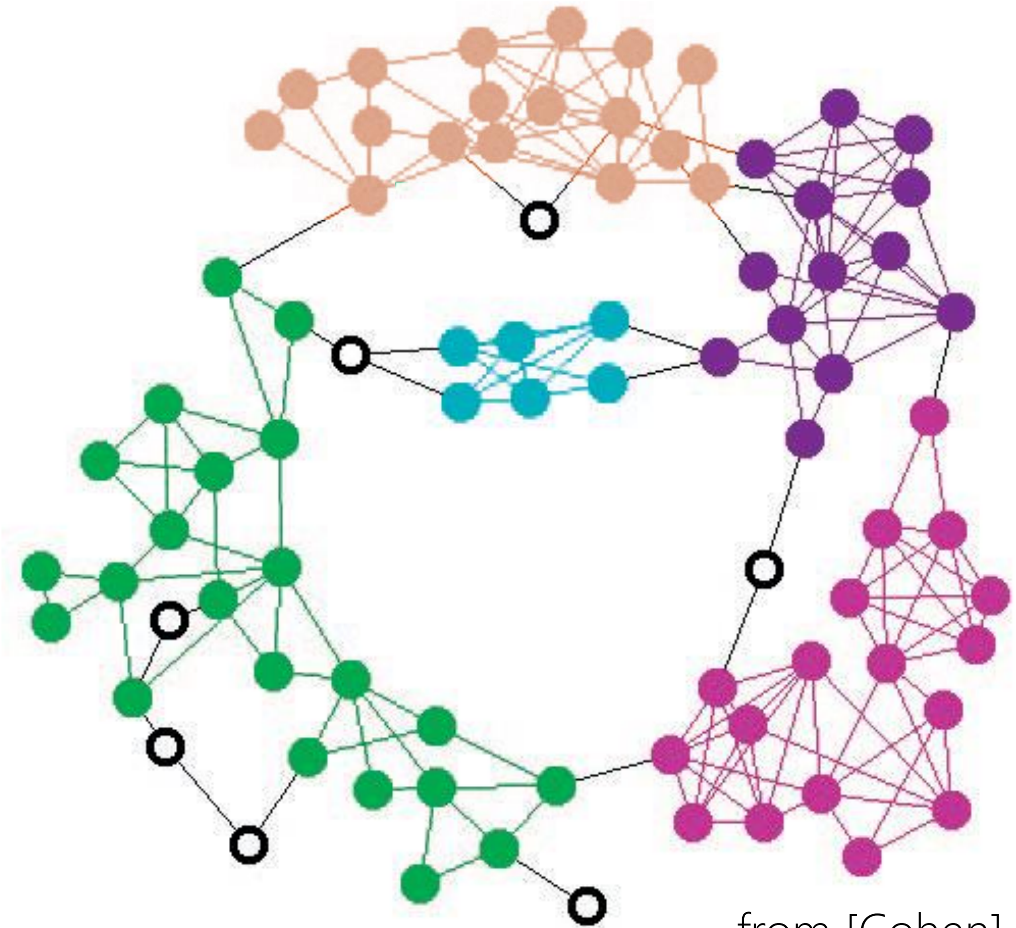
Hasso Plattner Institut

Problem

Finding highly connected sub-graphs

- Why is this important?
  - Social media graphs: groups of friends/family/co-workers
  - Website interliking

- Why is this difficult?
  - Possible solution set size: $2^{|V|}$
  - → Exponential run time for naive approach
  - Often millions of vertices
  - → ☹



from [Cohen]

The Data

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Wikipedia

- Directed graph of English Wikipedia page interlinks from 2007
- ~1.9 million vertices, ~40 million edges, 1 GB size on disc

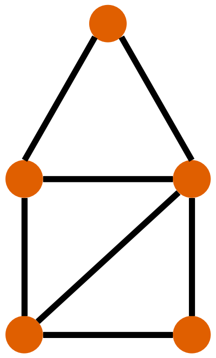
Twitter

- Directed graph of anonymous Twitter follower/following data from 2009
- ~41 million vertices, ~1.6 billion edges, 25.5 GB size on disc

k-Trusses

k-Truss

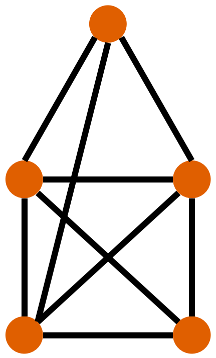
- **Definition**: a maximal subgraph so that every edge is part of at least k-2 triangles
- Indicates a high connectivity between its nodes
- Can be seen as a relaxation of the clique problem (= fully connected subgraph)



a 3-truss

How?

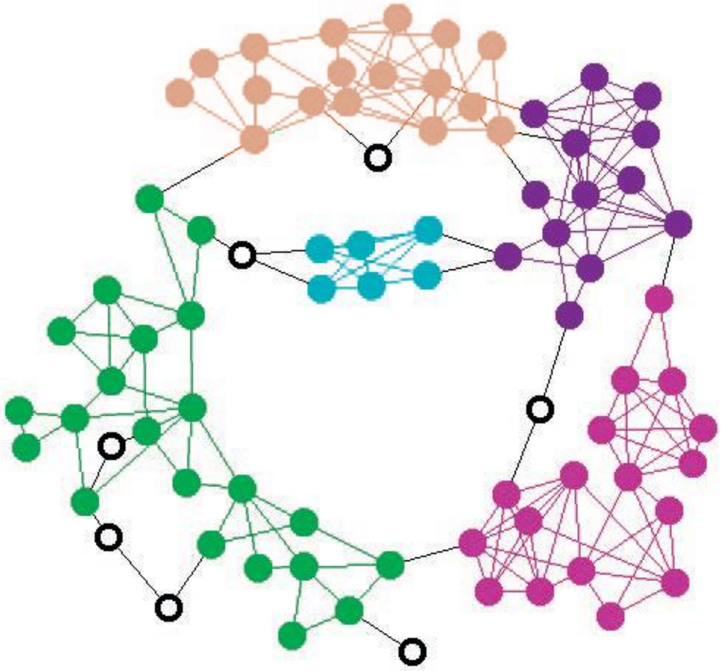
- Find all triangles in the graph
- Recursively remove all edges that are in <k-2 triangles
- Return sets of nodes that are still connected



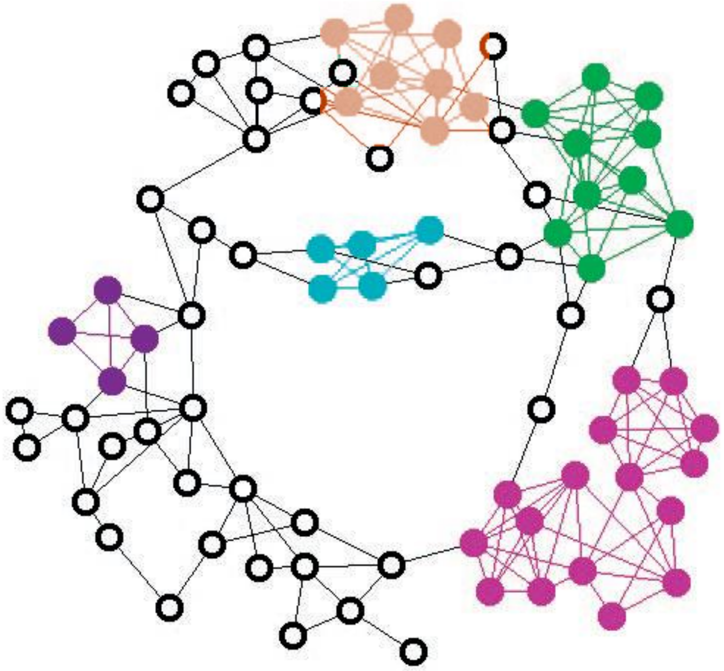
a 4-truss

k-Trusses

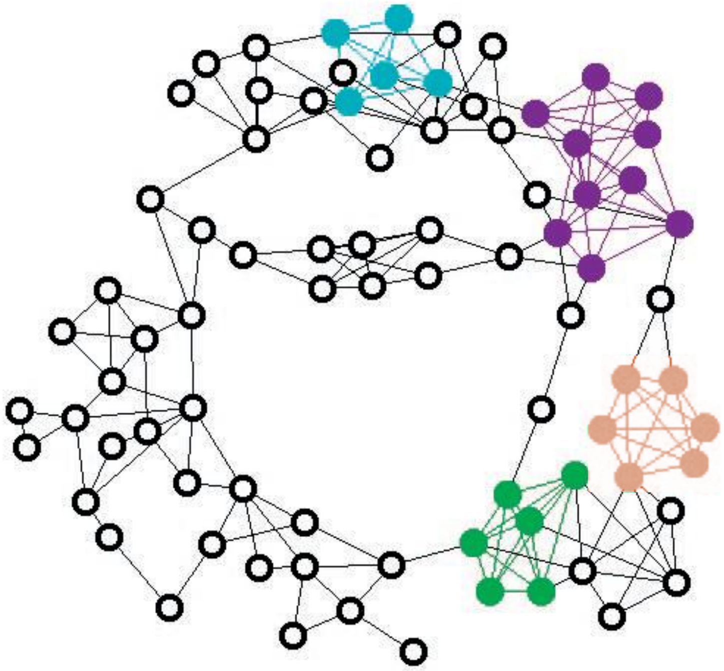
k = 3



k = 4



k = 5

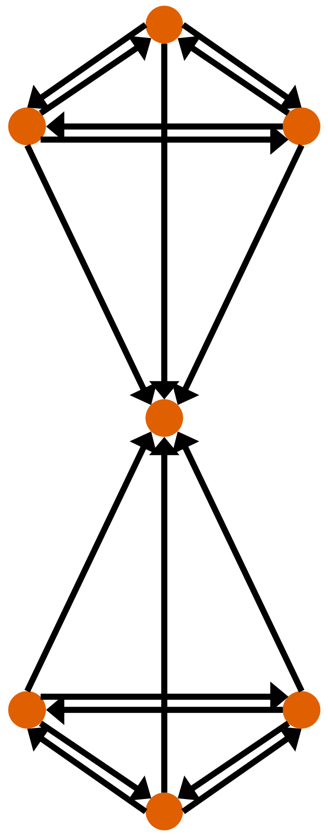


from [Cohen]

Direction?

Two possibilities

- Any direction
  - Accept trusses where either direction of an edge exists
- Both directions
  - Accept trusses only when both directions of an edge exist



Direction?

Two possibilities

- Any direction
  - Accept trusses where either direction of an edge exists
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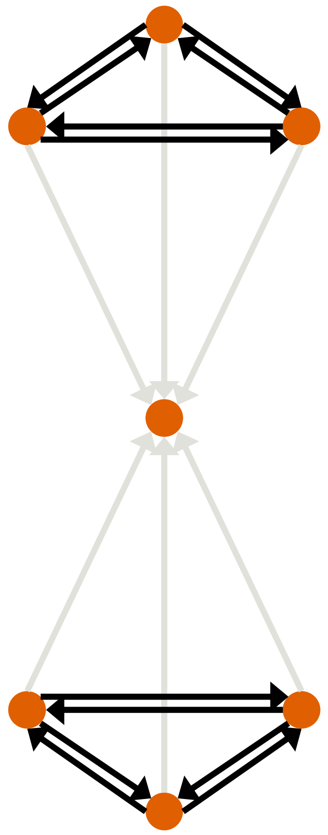
Decision

- Bidirectional edges only
- Only nodes that actually interact with one another should form a truss

→ Can use pre-processing step to create graph with bidirectional edges only



Finding the maximum Truss

1. Create new graph from bidirectional edges only
2. Set k = arbitrary value, subraphs = (fullGraph)
3. Find all k-trusses for each subgraph *after [Cohen]*
4. If none exist:
5. Reduce k, go to 3.
6. Set subgraphs =(truss1, truss2, …)
7. Increase k, go to 3.

Abort if k has already been seen before

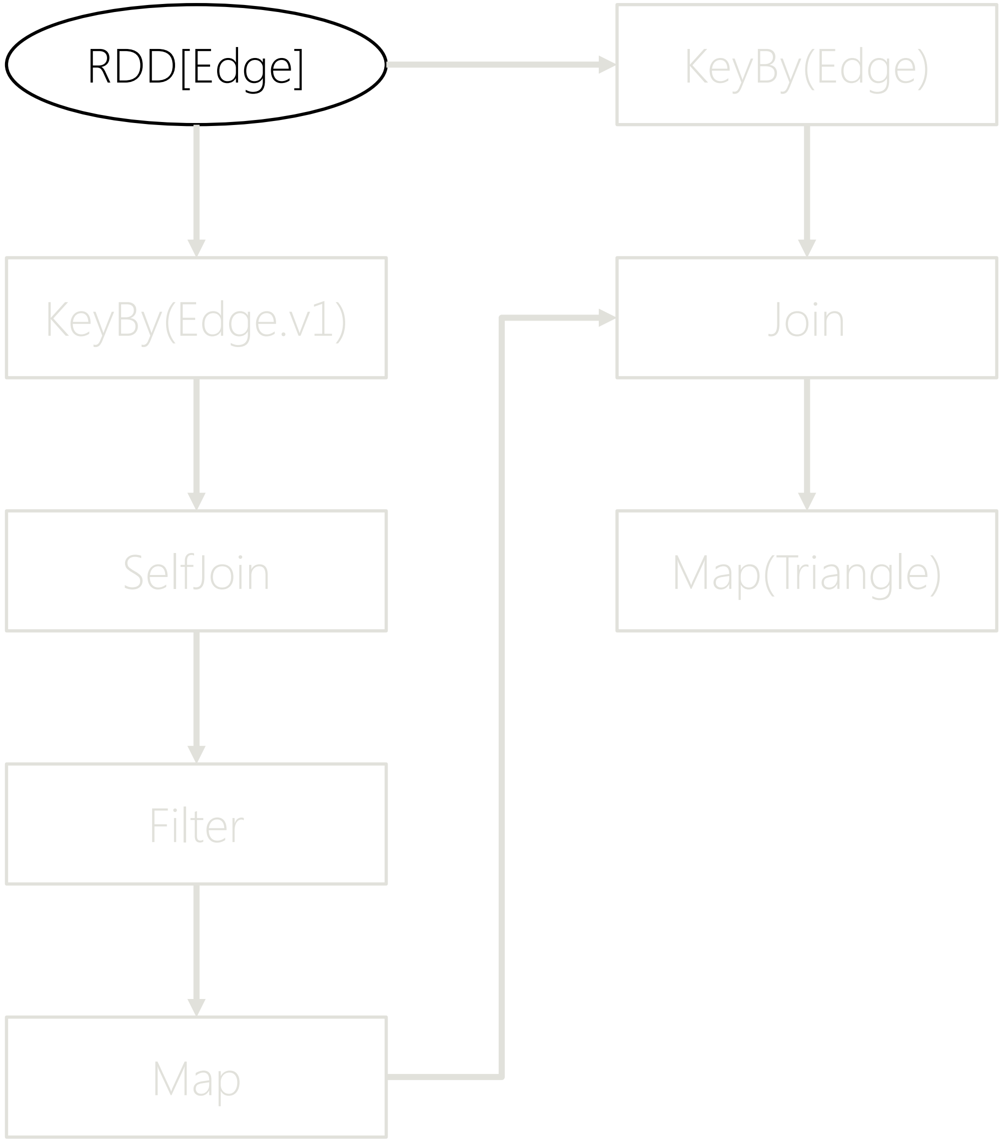
(Increase or reduce k according to a binary search strategy)

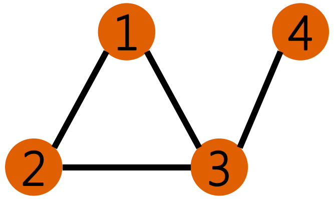
Evaluation – starting k

real maxTrussSize = 28

- k = 10 – 17 minutes
  - k values tried: 10, 20, 40, 30, 25, 27, 28, 29, 28
- k = 20 – 11 minutes
  - k values tried: 20, 40, 30, 25, 27, 28, 29, 28
- k = 28 – 10 minutes
  - k values tried: 28, 56, 42, 35, 31, 29
- k = 40 – 20 minutes
  - k values tried: 40, 21, 30, 25, 27, 28, 29, 28

Implementation – Triangle Generation





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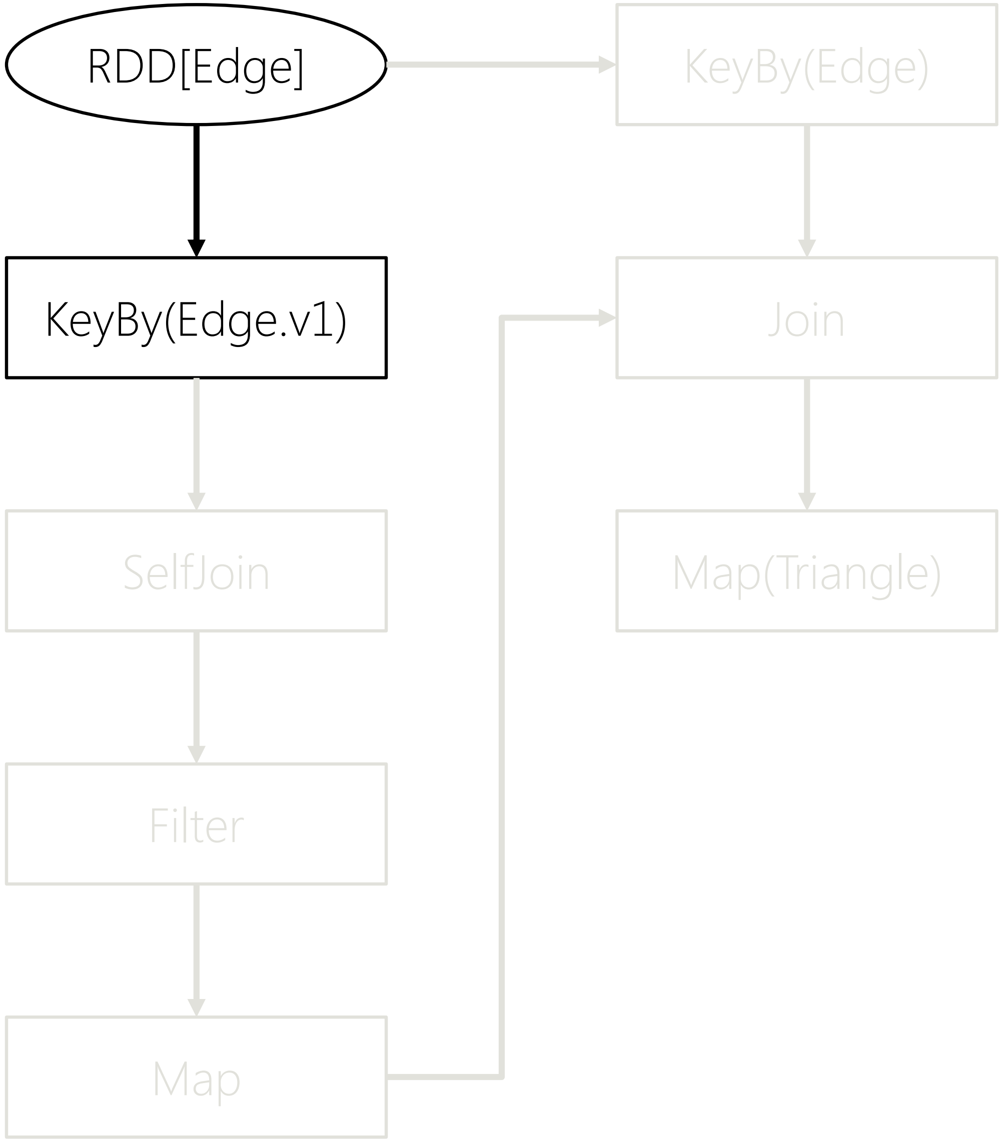

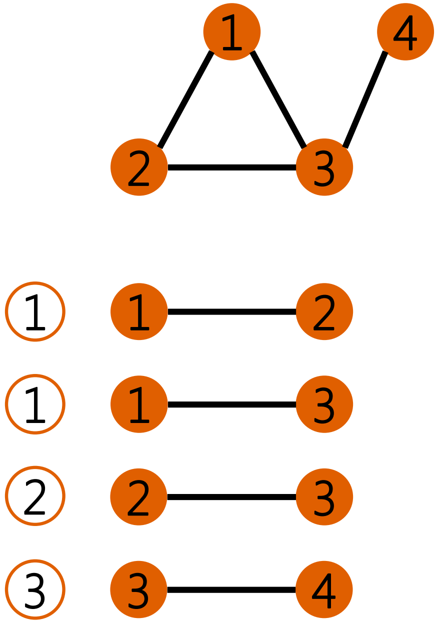

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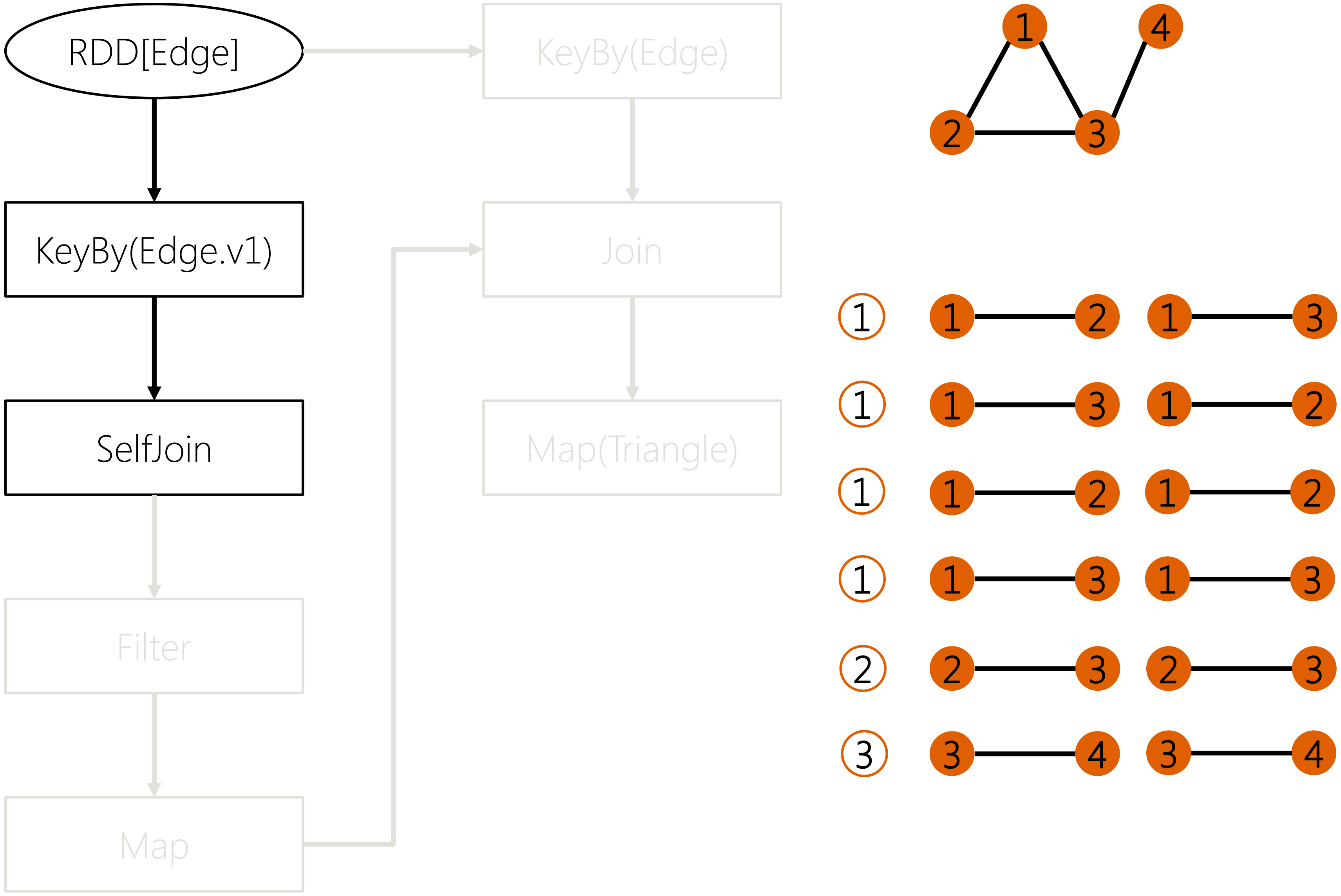

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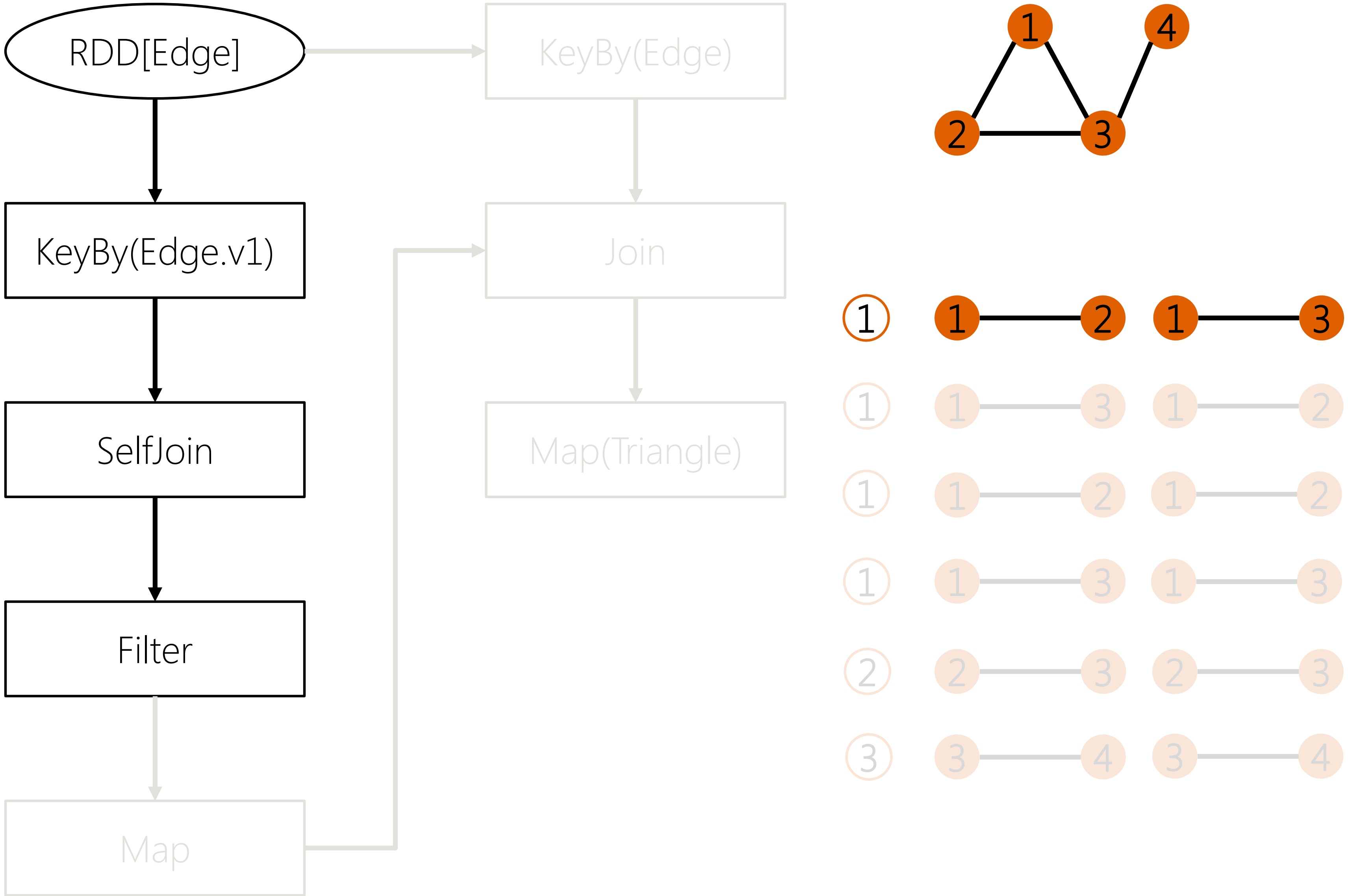

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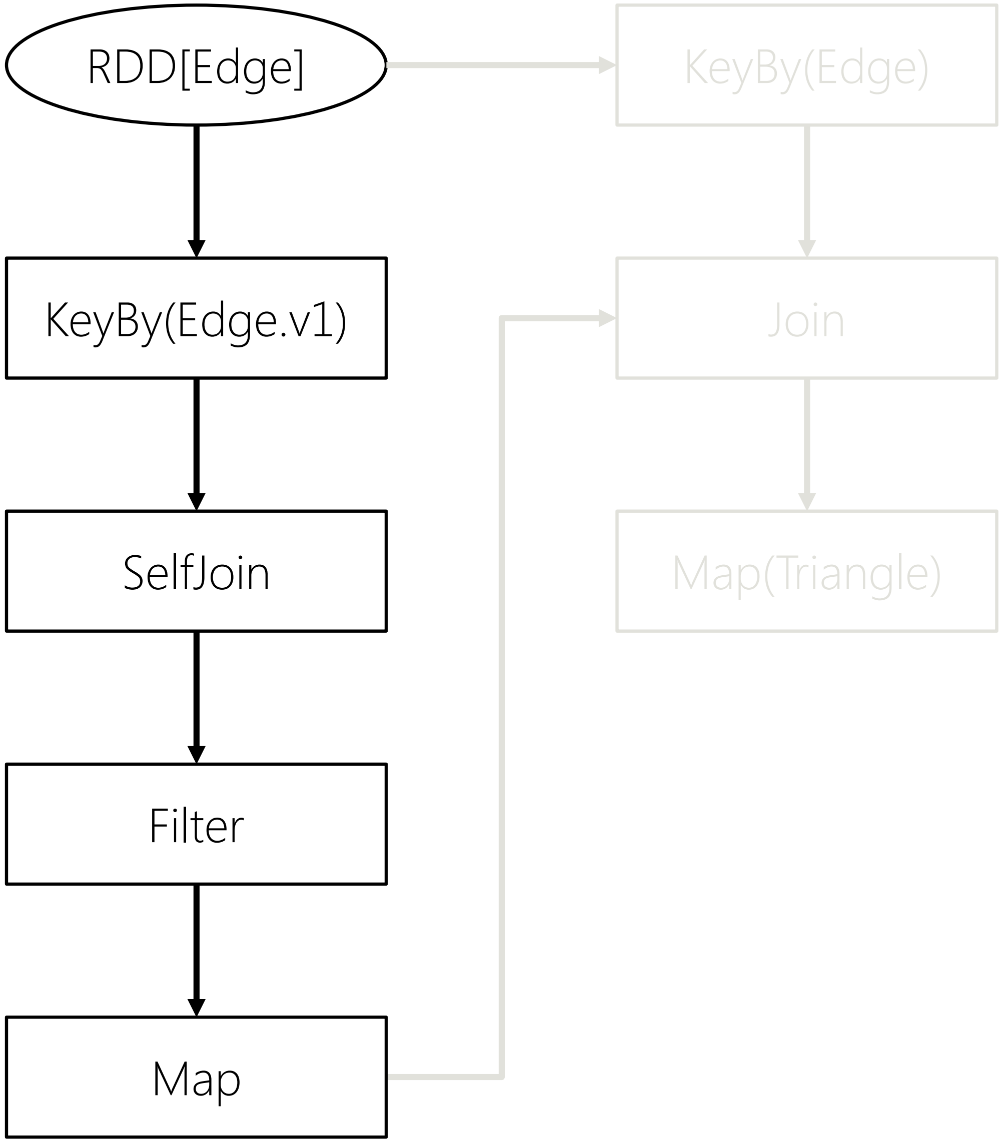

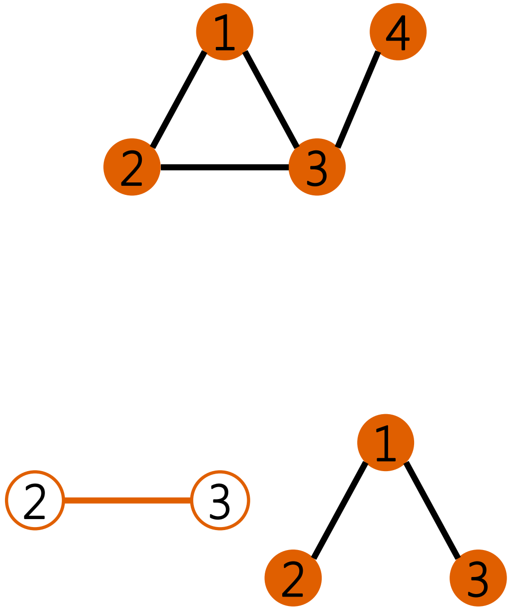

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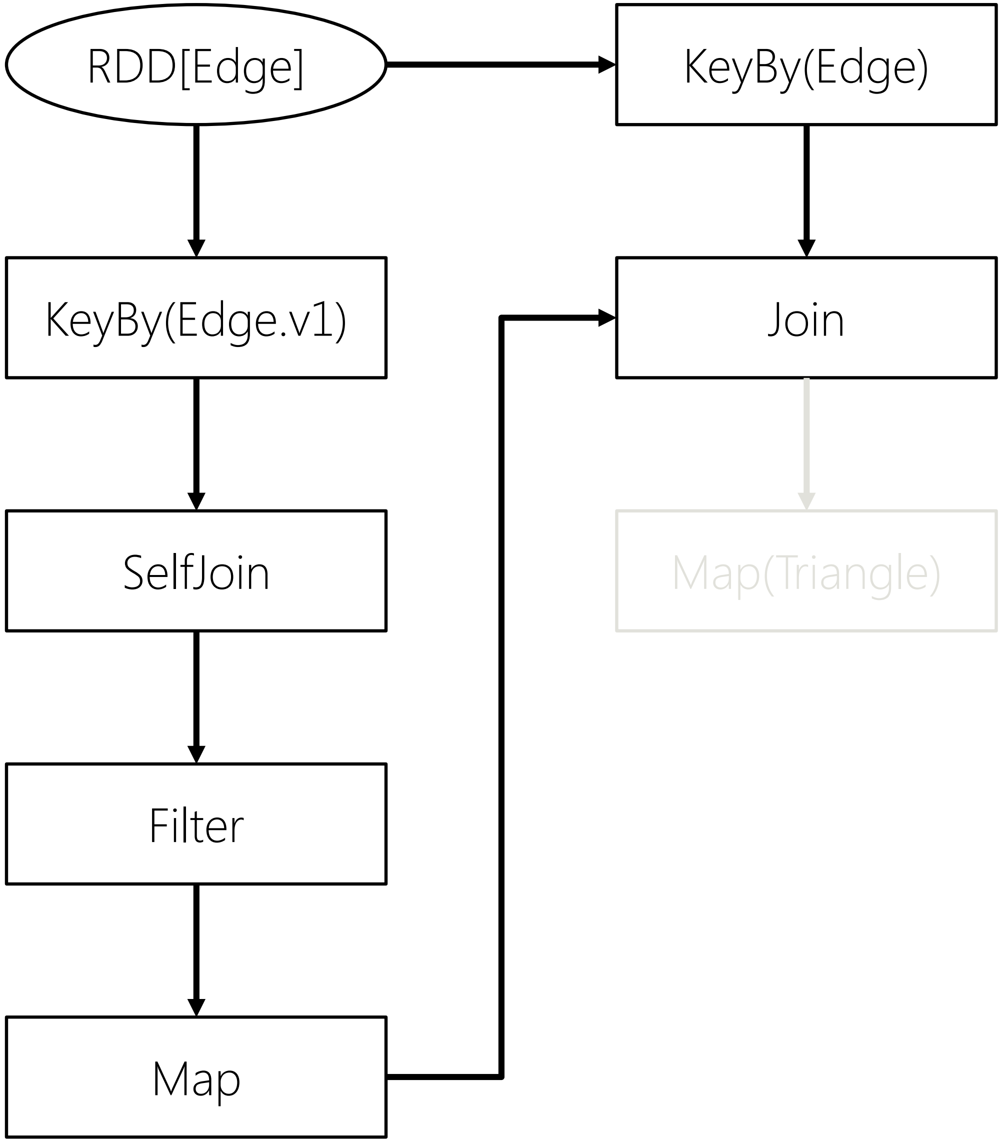

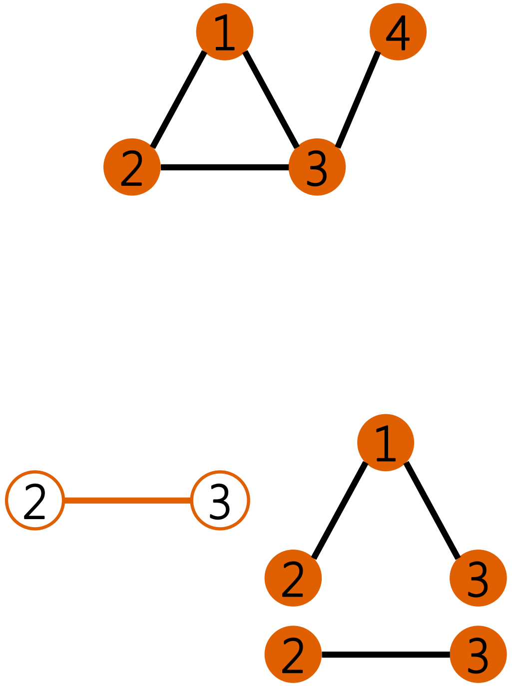

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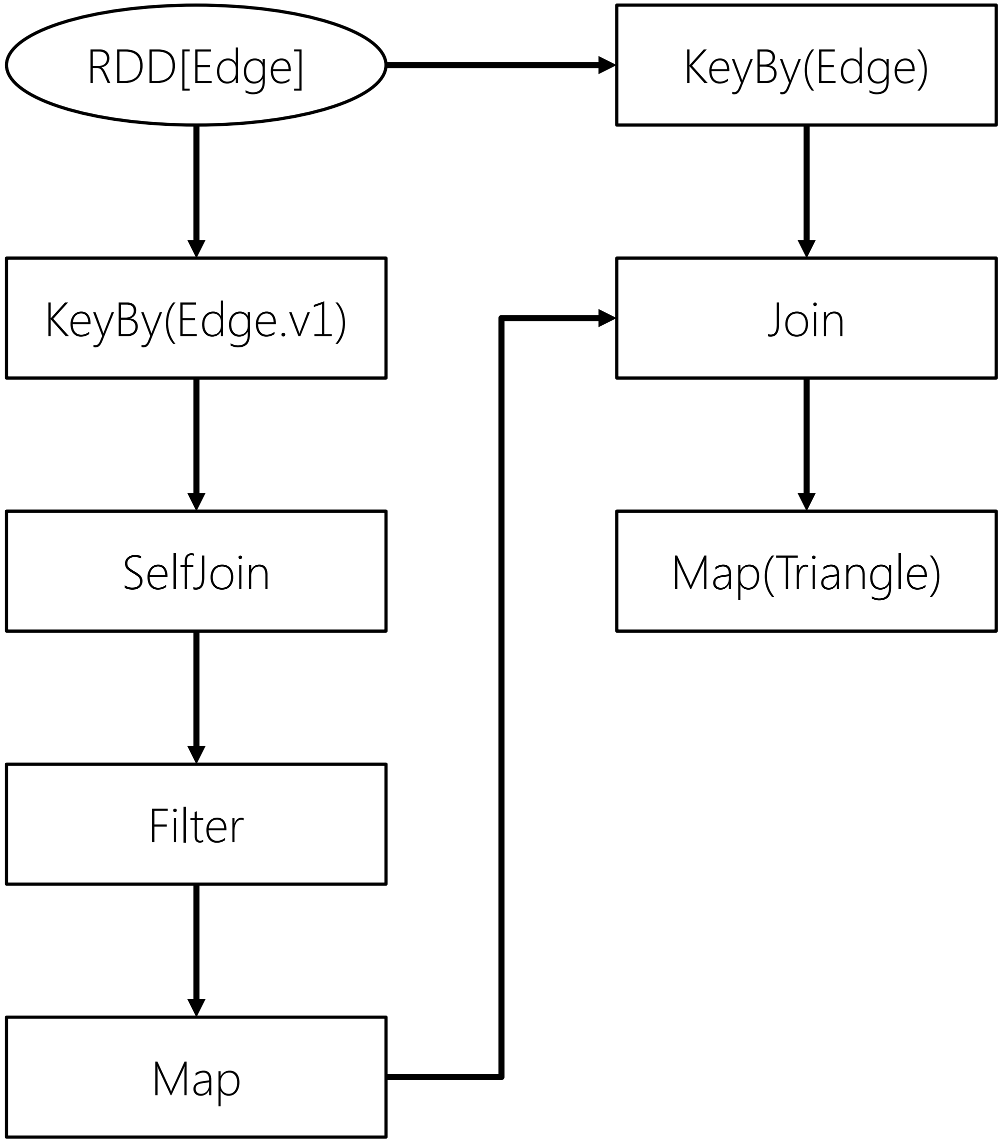
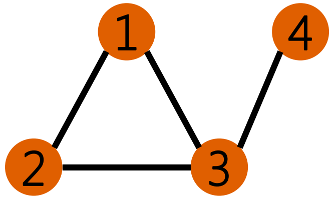
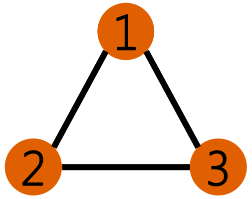
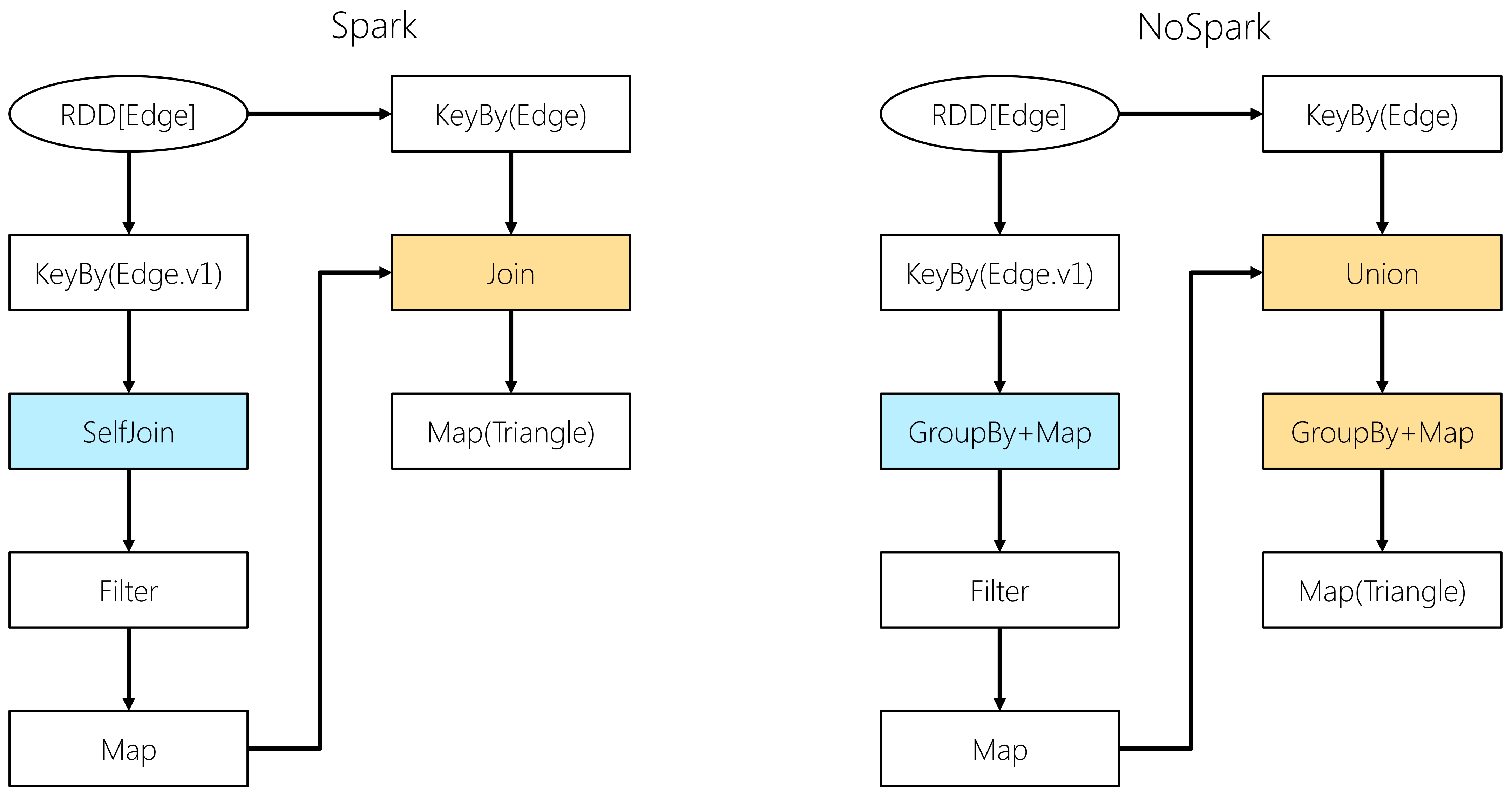






Evaluation – Triangle Generation



Evaluation – Triangle calculation

Number of cores used

- 1 core x 5 machines
  - Spark 14 minutes
  - NoSpark 12 minutes
- 1 core x 10 machines
  - Spark 6.8 minutes
  - NoSpark 5.7 minutes
- 2 cores x 10 machines
  - Spark 6.5 minutes
  - NoSpark 4.1 minutes

Conclusions

- **Distributed Calculation**
  - Choice of starting k is very influencial on run time
  - Great scaling with distribution over multiple machines
  - Current Spark-specific implementation seems limited by reshuffling
- **Future Work**
  - Try larger data sets
  - Distributed clique calculation
  - Usage of directed graphs instead

from [Cohen]

References

Image on title slide: http://polkadotimpressions.com/2013/01/18/facebook-graph-search-3/

[Bron, Kerbosh]: Bron, Coen, and Joep Kerbosch. 'Algorithm 457: finding all cliques of an undirected graph.' *Communications of the ACM* 16, no. 9 (1973): 575-577.

[Cohen]: Jonathan Cohen, 'Graph Twiddling in a MapReduce World'. in *Computing in Science and Engineering* 11(4): 29-41 (2009)