Graph Processing

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Authors:

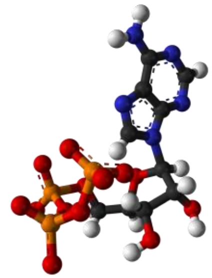
Some slides adapted from Michael Freedman, Joseph Gonzalez

Graphs Encode Relationships

- Between people, ideas, interests, facts, …

Social Media

Science



Advertising

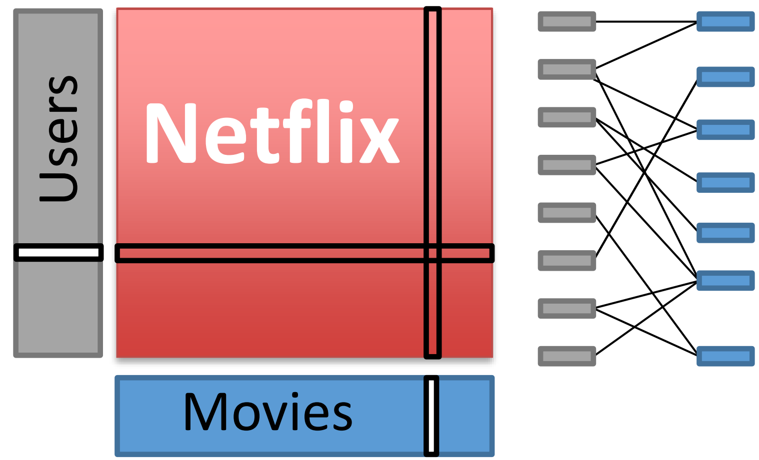
Web

- Graphs are big: billions of vertices, edges, rich metadata

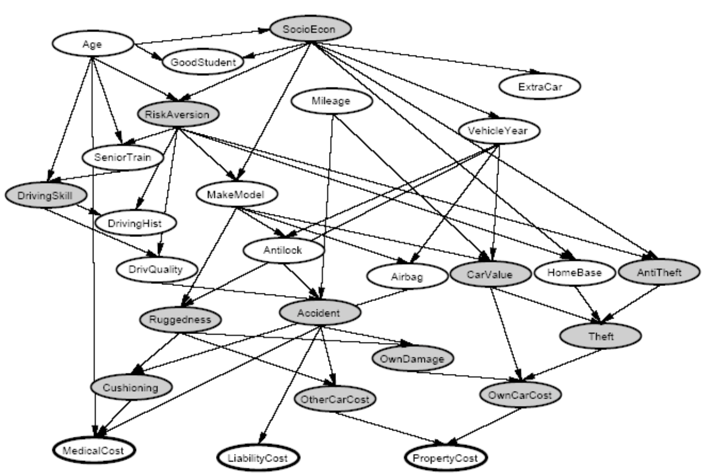
Graphs Are Everywhere

Social Network

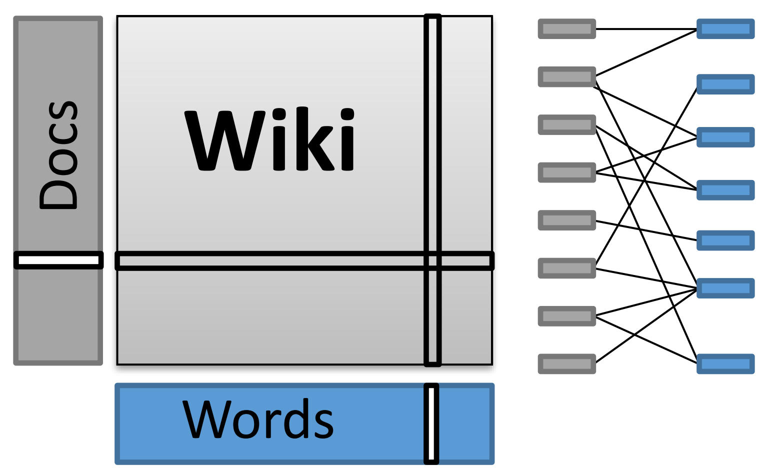
Collaborative Filtering



Probabilistic Analysis



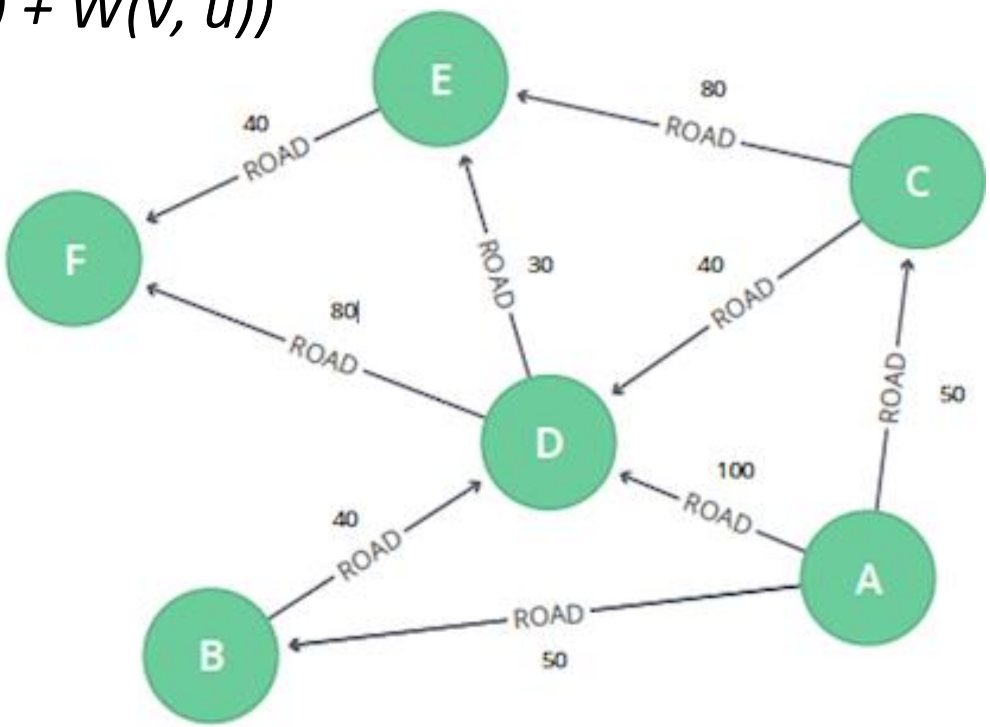
Text Analysis



Graph Algorithm Examples

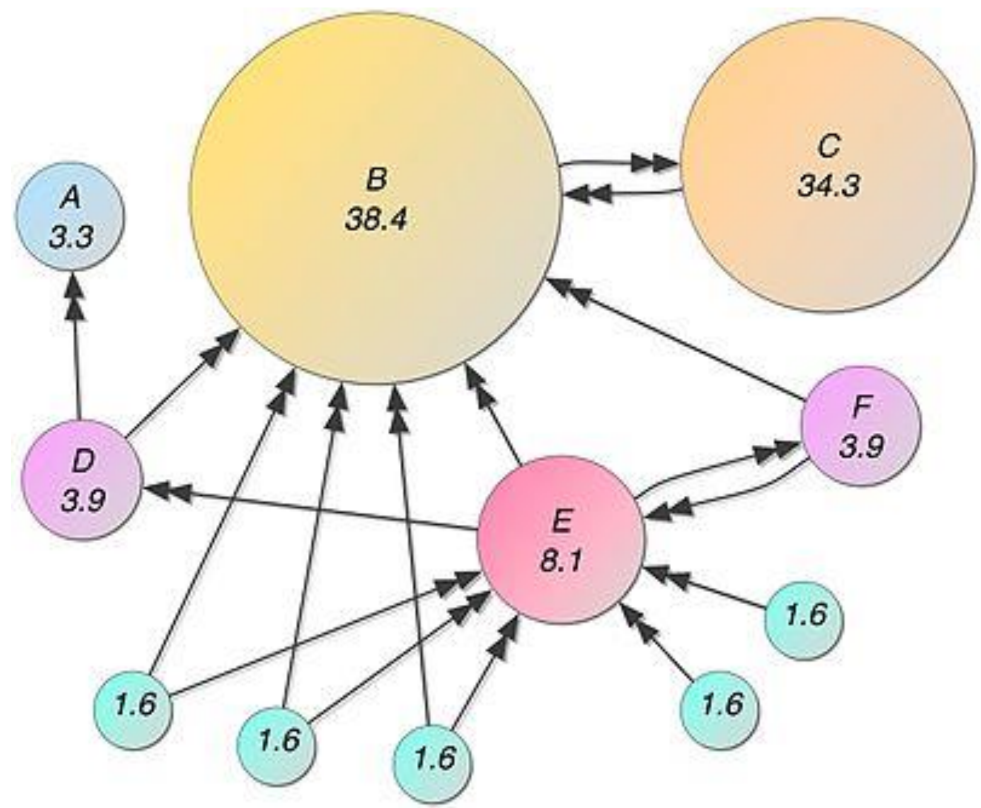
Single-Source Shortest Paths

- Find the shortest path from a node, say A, to all other nodes
- Iterative algorithm:
  - $Dist(A) = 0$
  - $Dist(u) = min_{v \in Neighbor(u)} (Dist(v) + W(v, u))$
  - Iterate until convergence
- Parallelism:
  - Compute all *Dist(u)* in parallel



PageRank Algorithm

- PageRank of u depends on PR of all pages v linking to u, divided by the number of links from each of these pages
- Recurrence Algorithm:
  - $PR[u] = \Sigma_{u \in Links(v)} (PR[v] \,/\, |neighbors(v)|)$
  - Iterate until convergence
- Parallelism:
  - Compute all *PR[u]* in parallel



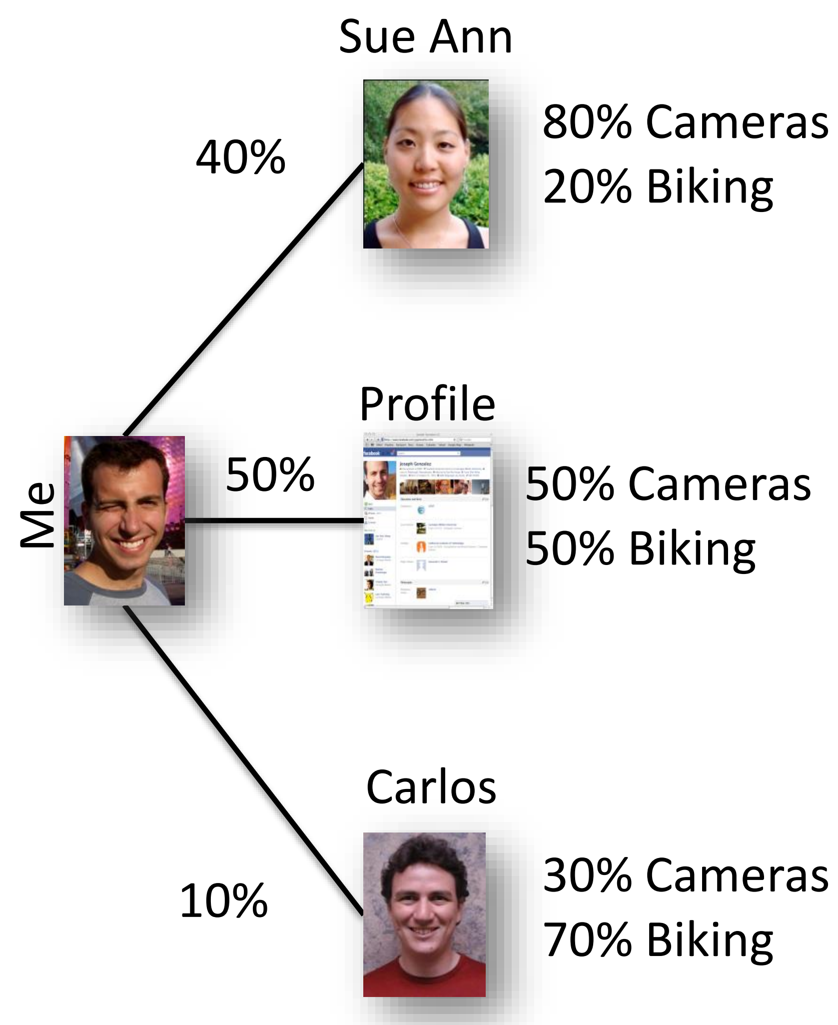
Label Propagation Algorithm

- Social Arithmetic:

  50%: What I list on my profile
  40%: Sue Ann Likes
  \+ 10%: Carlos Like

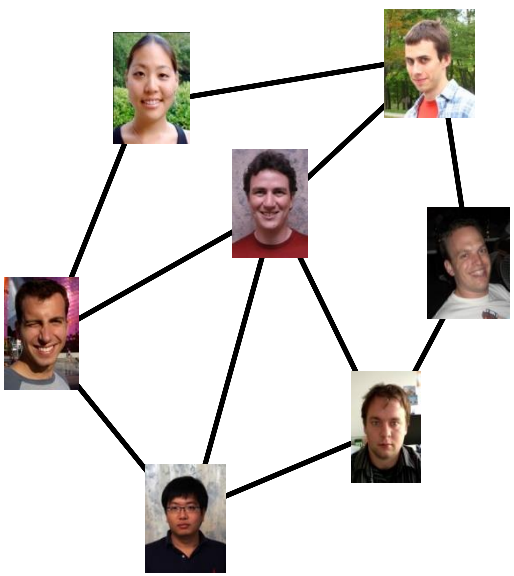
  I Like: 60% Cameras, 40% Biking

- Recurrence Algorithm:
  - $Likes[i] = \Sigma_{j \in Friends(i)} W_{ij} \times Likes[j]$
  - Iterate until convergence
- Parallelism:
  - Compute all *Likes[i]* in parallel

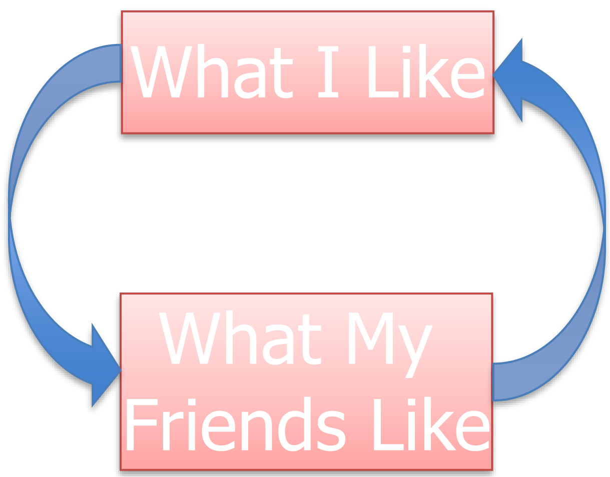


Properties of Graph Algorithms

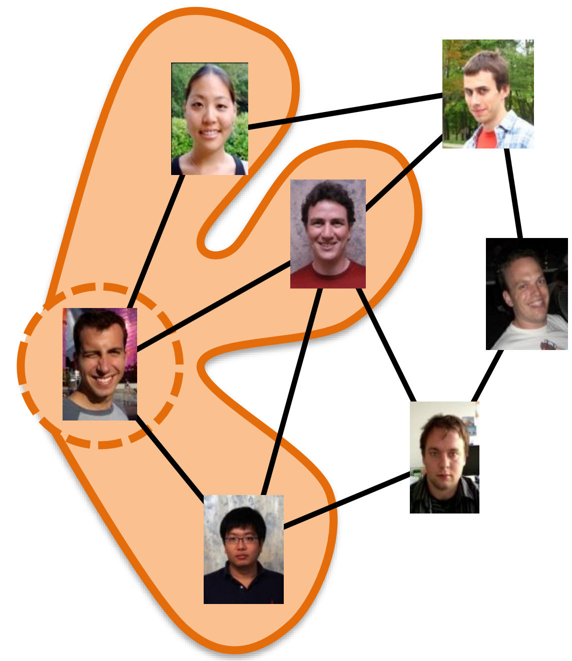
Graph Dependencies



Iterative Computation



Factored Computation



Data Parallel versus Graph Parallel

- We have looked at map-reduce style data parallel frameworks (e.g., Hadoop, Spark)
- Why not use them for graph processing?
- The provide inefficient support for:
  - Graph dependencies
    - Users need to write complex transformations, e.g., reduce, to express dependencies between different vertices
  - Iterative computation
    - The transformations are stateless, so many data copies are required
    - Each iteration is a barrier, so no support for asynchronous operation
  - Factored computation
    - Even when subset of graph changes, require graph-wide computation

Graph Processing Challenges

- How to partition graphs across machines?
  - Need to provide good load balance and locality
- How to support many classes of graph algorithms with a common graph programming model?
  - E.g., algorithms may require exact or approximate outputs
  - E.g.., should we use message passing or shared memory?

More Challenges

- How to scale efficiently?
  - Computation per vertex is small
  - Memory accesses have poor locality
  - Parallelism changes over the course of execution
- How to support factored computation efficiently?
  - E.g., avoid any computation if nothing has changed
- What is the consistency model?
  - Sync or async communication, exactly-once, at-least once …
- How to support fault tolerance?

Today's Papers

- Pregel
  - Partitions graphs using edge cuts (discussed later)
  - Uses message passing based programming model
  - Supports sync communication, with exactly-once semantics
  - Checkpointing for fault tolerance
- Powergraph
  - Partitions graphs using vertex cuts (discussed later)
  - Uses shared-memory based programming model
  - Supports sync communication, with exactly-once semantics
  - Supports async communication, with serializability semantics
  - Checkpointing for fault tolerance